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ELECTRIC LIGHT—A FACTOR IN CIVILIZATION

S. E. Doane, Fel. A. I. E. E., Mem. I. E. S.

Presented November 24, 1914, at a Joint Meeting of the Electrical Section, W. S. E., Chicago Section A. I. E. E., and Illuminating Engineering Society.

INTRODUCTORY REMARKS.

F. J. Postel, M.W.S.E. (chairman Electrical Section): In arranging a program for the year, it was decided to deviate a little from previous plans and instead of having the joint committee prepare the entire program for the year, various sub-committees were appointed and assigned the subjects of "Electric Lighting," "Power Stations," "Transmission," etc. Each sub-committee was assigned a date, the idea being that this sub-committee would be held responsible for a paper and for the entire program for the evening. To the committee on Electric Lighting we gave the November date. They arranged for the Illuminating Engineers to join us in this meeting. This program has therefore been arranged by Mr. Durgin, chairman of the committee on Electric Lighting, and as Mr. Durgin thus represents the three organizations I will now turn the meeting over to him.

W. A. Durgin (chairman, I. E. S.): Some fourteen years ago the most worth-while lectures in the senior year at the Massachusetts Institute of Technology, were given by business men and engineers of eminence in the world of affairs. We have always remembered with especial loyalty one of these lecturers, who, though dealing with apparently dry details of bulb manufacture, squirting cellulose filaments and improvements in mercury vacuum pumps, was so completely master of his subject and so filled with knowledge and appreciation of the skill of man's development and the beauty of nature's working as exemplified in the incandescent lamp, that to his under-graduate audience, lamp manufacture for the time being, at least, became the ideal—indeed, the only—possible life for the electrical engineer.

For several years before that period and during the fourteen years which have intervened, his eminence or rather pre-eminence in all matters relating to lamp manufacture has stood unquestioned.

Some two or three years ago, there developed a need for larger quarters for the concern with which he was connected as chief engineer, and thus he was given opportunity in a new field. No mere enlargement of existing factory space, nor duplication of the current system would do; advancing civilization was asking for a new and better solution of the relation between the workers and the plant. Those of you who have been so fortunate as to visit Nela Park in Cleveland have seen that solution. On a sightly hill, a group of beautiful buildings constructed with the efficiency, convenience, and health of every man and woman in the organization as the primary datum, and administered with such wisdom that each employe is filled with enthusiasm for his employment, constitutes one of the most heartening advances of the civilization of our time.

It seems, therefore, that to Mr. S. E. Doane, chief engineer of the National Lamp Works of the General Electric Company, we must accord not only highly specialized knowledge of electric lighting, but of civilization as well, and that in listening to his paper on "Electric Lighting—A Factor in Civilization," we must all feel that he speaks with authority in both fields.

Mr. Doane: It will not be possible for me to come to the high level set by the chairman of the meeting. I wish all the nice things he said might be true.

As I stand here looking at you, a representative body of American engineers, the title of my paper strikes me in a peculiar and unexpected manner; "Electric Lighting, a Factor in Civilization"; a paper largely prompted by my observations of European conditions in extending lighting service to the smallest homes; a subject which I have discussed for hours with my many engineering friends abroad, who perhaps at this very moment are doing their utmost to take each other's lives in the war which mocks at the very foundation of what we have so proudly called our civilization. Surely we have not advanced very far in these things which make for civilization and co-operative effort for the common good.

Civilization in its final analysis is co-operative effort.

It has been assumed that the first development toward civilization was co-operation for defense by which a number of people, no one strong enough alone to insure safety, by combination had that united strength which did so provide. So it is from that day to this that anything which permanently advanced our civilization has of necessity benefited the community, either as a whole in a collective sense, or the great majority as individuals.

In thinking of the co-operative efforts which have been made for civilization we immediately think of water works, steam railroads, improved highways, mail service, etc.

In the nineteenth century we have seen electricity step into the field giving civilization one of its greatest impulses throughout all time. In speaking of electrical development we might mention the street railway which reaches the humblest. The telegraph is also within fairly universal reach, but we have not yet realized for the telephone nor for the electric lighting industry that most complete development which is essential to their permanent success.

Thirty-six years ago Edison and others were working on the problem of producing an electric light of a size comparable with the ordinary gas jet, and a system of distributing electricity which would permit the electricity to compete successfully with gas as an illuminant. Many declared it to be a problem impossible of solution. Edison succeeded. He subdivided the electric light and gave to the world in the incandescent lamp and the low tension distributing system the foundation of the industry whose value to modern civilization is beyond estimation. This industry is of tremendous importance to the electrical engineering profession, and those of us who have entered it feel the responsibility for seeing that the electric light is maintained in the foremost place among the illuminants, where it was placed by Edison's early efforts.

This has been no easy task, in view of the rapid progress of its most worthy competitor, gas lighting, but taking all in all the electric light has so far maintained not only its initial advantages of convenience and safety, but it has added greatly to them through material and continual reductions in cost.

The incandescent lamp is but one of the two vital elements in the production of electric lighting; electric service, of course, being absolutely essential to the commercial use of electricity as a general illuminant.

The improvements in the incandescent lamp since the beginning of the industry have not only materially increased the efficiency with which electrical energy can be converted into light, but the development in manufacturing processes has served to bring down the cost of the lamps very materially within the same period. This is especially true within the last few years since the tungsten filament lamps have come so rapidly and generally into use. Today practically 70 per cent of the output of incandescent electric lamps is of the tungsten filament class.

Within the last twenty years the total cost of producing electric light has been reduced to less than one-tenth of its former value. The incandescent lamp itself is responsible for a material part of this saving, the economies in production and distribution of electrical energy making up the balance.

The continuous improvements in lamps and systems of distribution have today placed electric lighting in the most enviable position in the field of illumination in spite of the fact that the progress in gas lighting has been most remarkable. We should not feel unduly elated with our wonderful progress, for in spite of all the advantages which favor us there remains at this moment a field for illuminating service which, taken in the aggregate, would compare not unfavorably with the total existing electric lighting business.

The great problem that confronts us today is to "subdivide electric service," so that the electric light may be profitably carried to the smallest tenements in our cities and the safety, convenience and economy of electric service may be extended to the great mass of small consumers which are crowded into the densely populated parts of our cities, often hundreds to the block, and all practically within the heart of our distributing systems. These consumers today regard electric light as an unattainable luxury reserved for the exclusive use of the rich. This obviously should not be,—electricity should be made a universal illuminant available to all classes.

The rapid development of the incandescent lamp, especially that which has occurred within the last few years, has put a new aspect on the entire situation and has made the extension of service to the smallest consumers a possibility. However, the realization of this possibility involves the development of methods for handling the small lighting customer which will reduce that portion of the cost of electric service resulting from capital tied up in individual service, and the handling of individual accounts. Edison's early task was to develop the lamp and the distributing system. The two are so intimately related that the advancement of one cannot produce the greatest economy without corresponding advancement of the other. The lamps have been made cheap and efficient and are at the disposal of the electric lighting industry in connection with the extension of service to everyone within reach of the lines, regardless of size.

The progress that has been made abroad is most encouraging and I cannot believe that we, in this country, will neglect a field which offers so great a return both financially and in terms of the good will of the community, the value of which every large corporation fully realizes today.

As an electrical device the incandescent lamp has almost no standing in the realm of electrical engineering. Considering its aggregate importance, both as an article of electrical manufacture and as a current-consuming device, it at first appears surprising that it has not been accorded more formal attention by our electrical engineering bodies. As a current-consuming device, it must be accorded a high place, for it is probable that there are 150,000,000 in service in this country, which in the course of a year consume more than 5,000,000,000 kw.-hr., or about five times the yearly output of the Commonwealth Edison Company, which I believe has the distinction of having the largest output of any company in the world.

Perhaps the reason why the incandescent lamp receives so little detailed attention on the part of the engineering profession at large may be found in the fact that its production is a highly specialized art involving as much chemical, physical and metallurgical science as electrical engineering. Then, too, the incandescent lamp considered simply as a piece of apparatus had no deep problems of a purely electrical engineering nature concealed within its transparent body. When we have said that the current through the lighted lamp varies directly as the voltage raised to the 0.582 power, and have added the interesting fact that the resistance of the filament at normal operating temperature is about twelve times as great as at ordinary room temperature we have, perhaps, touched upon the most important characteristics of the lamp as an electrical device complete in itself.

We can therefore assume that the greatest interest of the engineering profession lies in the utilization of this particular product to produce electric light at minimum cost to the ultimate consumer. To treat of the economic relations of the incandescent lamp to the rest of the circuit, it is necessary to have certain knowledge of its performance under various imposed conditions, and this subject will therefore be touched upon briefly in connection with a little comment on some of the most important development work which has so vastly improved the incandescent lamp within the last few years.

Before mentioning the striking improvement in efficiency recently attained in heavy-current gas filled tungsten filament lamps, I wish to call your attention to the efficiency improvements in the smaller lamps, which, while amounting to but 20 or 25 per cent, carry great weight in considerations affecting the cost of light to the great mass of users by reason of the large percentage of total light produced through them. The 25, 40 and 60 watt lamps are now operating at 1.05, 1.03 and 1.00 w.p.c. respectively, compared with 1.23 w.p.c. five years ago for the 40 and 60 watt, and 1.31 w.p.c. for the 25 watt, and are giving the same useful life as before. This improvement in efficiency has been made possible principally through the adoption of drawn wire filaments, modifications of the structure supporting the filament, and the introduction of various chemicals within the bulb, which have allowed the filament operating temperature to be increased without increasing the rate of candle-power depreciation. Not only have these lamps become more efficient in utilizing energy, but their mechanical strength has been increased and their prices greatly reduced. I need only point to their extended and successful use in street railway service today to illustrate the second improvement mentioned.

As to prices, these have steadily gone down from $1.10 for the 40 watt lamp in 1908 to 90c in 1909, 80c in 1910, 70c in 1911, 45c in 1912, 35c in 1913, and 30c in 1914. Prices of other wattages have been reduced in somewhat similar proportions. All this has greatly increased the actual operating economy of these lamps, and without considering any reductions in price of electricity, during the past five years has reduced the cost of light to the ultimate consumer about 30 per cent. In passing it is interesting to note that the increase in efficiency of about 20 per cent has done as much to decrease the cost of light to the consumer as the reduction in lamp price from 90c to 30c. In other words, with these lamps the cost of energy consumed is so much more important than the cost of renewals that a saving of 20 per cent in the first item means as great a gain to the consumer in lighting economy as a reduction of lamp price in a 3 to 1 ratio.

The recent improvements in efficiencies of heavy-current tungsten filament lamps are of sufficient importance to warrant some consideration being given to the physical reason for this remarkable advance.

If we take an ordinary vacuum lamp operating under normal conditions with its filament at about 2400 deg. C. absolute and assume that we could fill the bulb with an inert gas, such as nitrogen, to approximately atmospheric pressure, we would find that in order to maintain the filament temperature at its previous value, we would have to put a great deal more power into the filament. This additional power would be required to supply the heat lost through the gas. The increase in the amount of energy necessary to maintain a given temperature in an inert gas depends upon the character of the gas, its pressure, etc., and upon the size and form of the filament. The loss is relatively much greater in the case of a small filament than in the case of a filament of larger diameter or than in the case of a filament coiled in a helix, which gives the same general effect as a straight filament of very large size.

If we assume that the temperature is maintained at the same value, the candlepower emitted by the lamp would be unchanged as it is a function simply of filament temperature. The introduction of the inert gas results primarily in requiring an increase in the amount of electric power put into the filament per c.p. produced, when the filament is operated at a given temperature, but it also has an important effect on the rate of lamp depreciation. When heated above a certain temperature, the filament of an incandescent lamp will evaporate at a rate which increases very rapidly as the temperature is raised. When a filament is heated in vacuum, the particles evaporating from its surface travel freely to the bulb where they form a film of increasing thickness and opacity. The diameter of the filament is reduced as a material is thus vaporized, and this material condensing upon the bulb absorbs a portion of the light emitted by the filament. The life of a lamp depends primarily on the rate at which this evaporation proceeds.

By filling the bulb with an inert gas, most of the particles vaporized from the surface of the filament are reflected back to the filament surface by collision with the gas molecules very near the surface, so that relatively few of the particles evaporated attain their permanent liberty. Under such conditions the net rate of loss of material from the filament is very small compared with what it would have been if the filament were maintained at the same temperature in a vacuum. If the heat losses of the filament have not been too great this increase in temperature made possible through the decreased rate of lamp depreciation may more than compensate for the decrease in efficiency, so that we ultimately find that we have a lamp which when operating at a temperature giving the same rate of filament evaporation as the vacuum lamp actually consumes less w.p.c. The loss of heat from a filament in an inert atmosphere increases more slowly than the size of the filament.

Figure 1 illustrates the result of research work by Dr. Irving Langmuir, and serves to explain the reason for the relatively greater heat loss from small filaments when operated in an inert gas than from heavy ones. He assumes the existence of a stationary film of gas immediately surrounding the filament, which carries heat from the filament by conduction only. The diameter of this conducting film of gas increases, according to his experimental work, at a lower rate than the filament diameter. A filament coiled in helical form has the advantage of a relatively smaller heat loss per unit of length—the amount of reduction depending upon the

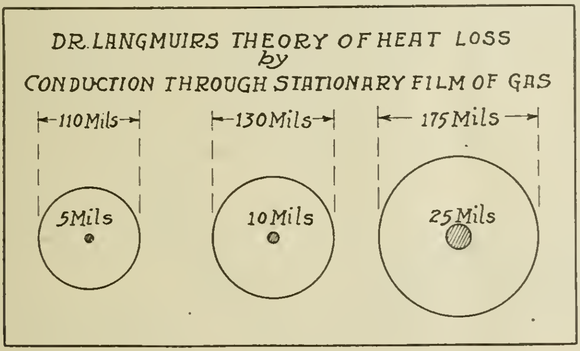

Fig. 1.

size of filament, diameter of coil and pitch, and, of course, on the character of gas pressure and other details of construction.

Some of the most important characteristics of vacuum and gas filled lamps, operating at different filament temperatures, are illustrated in Fig. 2. These relative values have been worked out on the basis of data published by Dr. Langmuir taken in combination with other experimental work, and are intended only to illustrate the general effect of several factors entering into the discussion. The relative rates of lamp depreciation have been assumed to follow the relation between rate of evaporation of tungsten and temperature as determined by Dr. Langmuir, but take into consideration the effect of filament diameter on the actual life of the lamps, for at the same temperature of operation a larger filament will last longer than a small one. The characteristic performance is affected by many other factors, involving details of lamp construction which need not be considered in illustrating the general effects resulting from the use of an inert gas within the bulb. With a very thin filament, the loss of heat through the gas becomes so

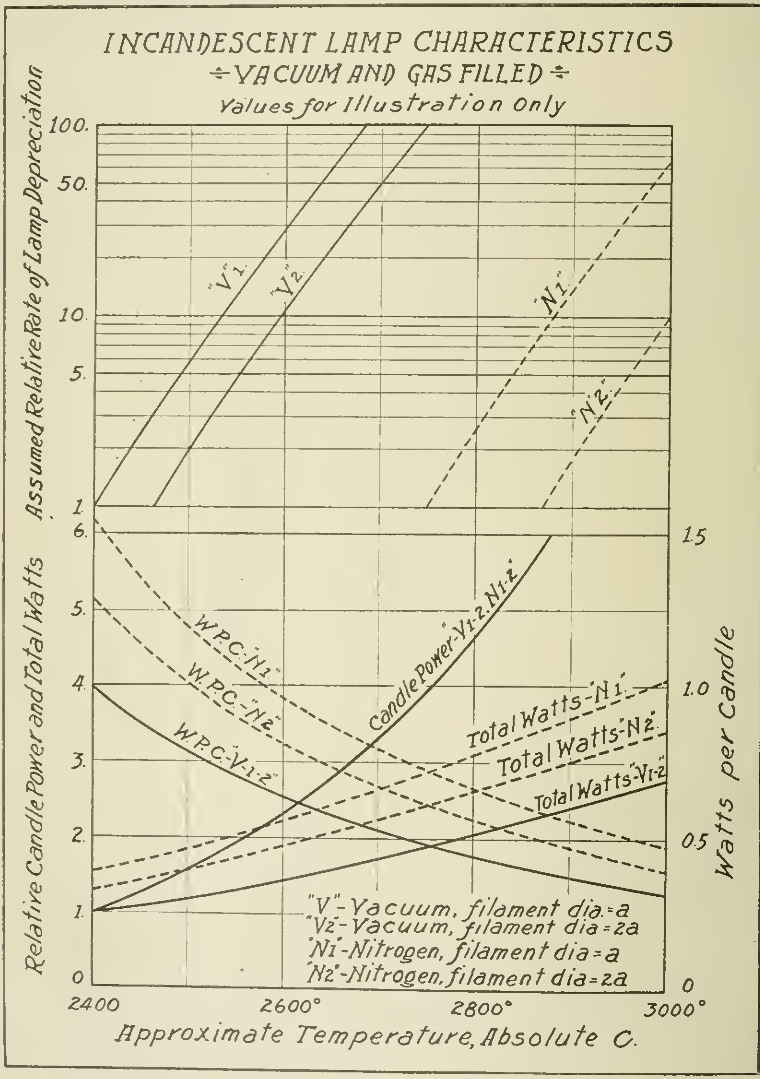

Fig. 2.

great that the increase in temperature possible because of the lower rate of evaporation will not compensate for this loss, and we find that in such cases it is not possible to secure as high an efficiency

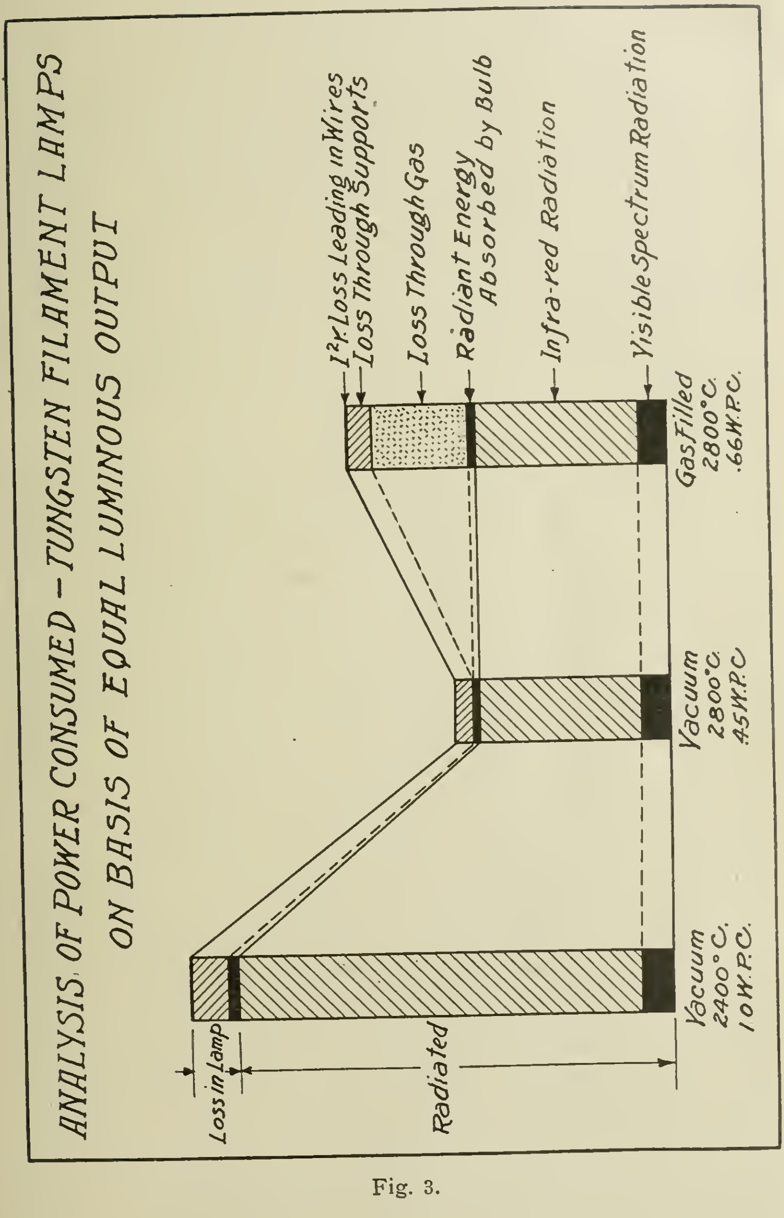
ANALYSIS OF POWER CONSUMED - TUNGSTEN FILAMENT LAMPS
ON BASIS OF EQUAL LUMINOUS OUTPUT
I^2R Loss Leading in Wires
Loss Through Supports
Loss Through Gas
Radiant Energy Absorbed by Bulb
Infra-red Radiation
Visible Spectrum Radiation
Gas Filled 2800°C. .66W.P.C.
Vacuum 2800°C. .45W.P.C.
Vacuum 2400°C. 1.0W.P.C.
Loss in Lamp
Radiated

Fig. 3.

in the gas filled lamp for a given rate of evaporation as in the vacuum lamp. This limiting condition depends, of course, upon the character of the gas used, as well as the form in which the filament can be mounted in the bulb, for, as above mentioned, the winding of a filament in the form of a helix gives us the advantage that would have been secured through a filament of practically the same diameter as the helical coil. There are, of course, practical limits to the size in which filaments can be coiled, for it is essential that the coils should not come into contact one with the other during the life of the lamp. This limits the size of the mandrel upon which the filament can be wound and also affects the pitch of the winding or the distance between turns. The perfecting of the gas-filled lamps required a careful adjustment between these several factors, and naturally much experimental work has been done with reference to the construction of coils which will permit a maximum efficiency to be obtained without increasing too greatly the possibility of mechanical difficulties with coils sagging and touching.

The power put into an incandescent lamp is ultimately dissipated as heat—even that portion of it transformed into radiation in the visible spectrum ultimately appearing in this form. The manner in which the power input is dissipated is materially different in the case of vacuum and gas filled lamps, as Fig. 3 indicates. Here we have a power consumption of one watt per candle for the filament in vacuum at 2400 deg. C.; 0.45 w.p.c. with the filament in vacuum at 2800 deg.; and 0.66 w.p.c. for the filament at 2800 deg. in the gas filled lamp assumed for comparison. A very small part of the input is consumed as I^2R loss in the wires leading from the base contacts to the filament; the remainder is transformed into heat in the filament. This heat is dissipated from the filament through the leading-in wires and hooks supporting it, by conduction and convection of the gas (if any) within the bulb, and by radiation. Dr. E. P. Hyde has published data covering heat losses in incandescent lamps as a result of extended research in this field. The bulb (and in the case of a gas filled lamp, the gas) absorbs a small part of the power radiated from the filament, the remainder passing out into space as radiant heat and light. The difference between the power input and the net power radiated from the lamp appears, of course, as heat at the lamp. The heat losses in the case of the gas filled lamp (as shown in Fig. 3) are relatively greater than in the vacuum lamp, and consequently in using them—especially in the higher wattages—due allowance must be made for this fact. Although Fig. 3 shows that the filament operating in vacuum at the same temperatures as in the gas filled lamp is much more efficient, it would have a materially shorter life. The internal construction of the lamp will affect the distribution of energy so that Fig. 3 should be regarded only as illustrative. The "visible spectrum radiation" shown in Fig. 3 includes wave lengths from

0.76 to 0.38. The ideal distribution of energy within these limits to produce white light would, according to data published by Dr. E. P. Hyde, give us a luminous efficiency of about 300 lumens per watt. On this basis the relative efficiencies of the lamps shown in Fig. 3 would be as follows: filament 2400 deg. C. in vacuum efficiency 3.3 per cent; filament 2800 deg. C. in vacuum 7.3 per cent, and at the same temperature in gas 5.0 per cent. As before mentioned, the rate of depreciation of a filament in vacuum at 2800 deg. C. would not permit the efficiency to be attained commercially.

The heat conducted from the filament of a gas filled lamp by the gas itself is carried by convection currents to the bulb where it must be properly dissipated. Thus far the multiple burning lamps and higher candle-power series lamps have been particularly designed for operation in a vertical position, base uppermost, the bulb surface being particularly arranged to care for the heat carried to it by the gas under such conditions of operation. These large lamps are entering a field of service where there is but little occasion to use them in other than a vertical position, and this limitation should not occasion inconvenience in application. We would not think of requiring any other illuminant of comparative size to be capable of use in any position.

The development of constructions permitting the tungsten filament to be mounted in the form of a helical coil now makes it possible to use incandescent lamps in many cases where a concentrated light source is required, and was a distinct advance in the art of lamp manufacture. For projection lantern or stereopticon work, or where light is utilized in accurately adjusted optical systems, and where the time of use is relatively short, lamps with very highly concentrated filaments intended for operation at higher filament temperatures than usual can be supplied. Lamps for such service may give only a few hundred hours life which, however, is fully justified by the high efficiency of utilization attained. Where lamps are intended for less accurately designed equipment, or where they are to be used for considerable periods of time, the filament need not be concentrated so greatly and its temperature of operation may be somewhat lower. Lamps of this type would be used, to a large extent, in headlight service. The use of coiled filaments is, of course, very important in gas filled lamps, where, as before mentioned, the conduction loss of a given size filament may be materially reduced by winding it in a helical coil.

The fact that materially higher filament temperatures can be reached for a given rate of filament evaporation with the lamps containing inert gas, results in these lamps giving, under normal operation, a much whiter light than the vacuum lamps. This in itself is a distinct advantage in favor of these lamps, for even at the same efficiency of light production, the whiter light produces a better and more brilliant effect, and for most classes of store and commercial lighting it is much to be preferred.

The use of the incandescent lamp in connection with colored screens for the production of "daylight" value of illumination has received a new impetus through the development of the gas filled lamps. The increase in the commercial operating temperature of the filament, made possible through the use of inert gases, has increased the efficiency with which "daylight" illumination may be produced relatively much more than it has increased the efficiency in ordinary lighting service. This is because we are not only dealing with a more efficient means of converting energy into light, but we have at the same time the advantage of having a light source which in itself more nearly approaches the daylight value in illumination we desire to obtain.

Using the large sizes of the gas filled lamps it is now possible to obtain illumination of a true north sky quality at an expenditure of about five w.p.c. If we wish to approximate a light quality equivalent to that obtained from noon sunlight, a much higher efficiency can be obtained—something about one and a quarter watts per candle, or practically the same efficiency of light production which was common to tungsten filament lamps in general but a few years ago.

Another application of the new lamps which depends upon the higher operating temperatures obtained, and which promises to be of commercial importance, is the use of these lamps in photographic work. The high efficiency and high actinic value of the light has given most excellent results in portrait photography, especially where means have been provided for reducing the effective illumination without materially affecting the photographic quality. A special blue glass has been developed which, when used for the bulbs of lamps intended for such service, is particularly successful in accomplishing this purpose.

When Mr. Edison completed his lamp, having made something which was practical, he built his distributing system to supply current to this lamp. It is worthy of notice, that although Mr. Edison devised his system to fit his lamp, it is hardly fair to say that the whole system was made to rotate around the lamp as there were other lamps before Edison, which however were of low resistance and consequently were poorly adapted to any system of distribution which could be devised.

The courts assigned Mr. Edison the credit for recognizing that the successful lamp must be of high resistance in order to adapt itself to a multiple distributing system.

After the system of lighting had been developed it became necessary to devise some system by which a customer could pay for his light. It was immediately recognized that the customer receiving twice as much light should pay twice as much, and consequently the early systems of charging varied with the candle-power. In those days, although the fuel consumption was higher than at present, fixed charges were also very much higher. The whole cost of developing and exploitation, and the high cost of apparatus, with the high depreciation thereon, made an apportionment on the basis of candle-power much more nearly fair than when later years had reduced fixed investment and brought about a very considerable economy in the transformation of energy in coal into electrical energy.

About this time a general increase in sales of current for electrical power made it quite obvious that there must be some other means for paying for electricity and electrical service. In this, as is so often the case, the pendulum swung to the other extreme.

Within recent years there has been recognition that while there is equity in both points of view, neither one entirely covers the ground, neither one is entirely right, and there are other features which must be recognized.

If we accept our duty as a duty laid before us by civilization, we must either ourselves so provide that at least the majority of the ruling class may freely avail themselves of electrical service, or the commonwealth will ultimately enforce this point of view.

If we appreciate that not because of rate systems, but in spite of them, water is served in every home in a big city under conditions of payment which make it possible for that home to obtain that water within its means, if we appreciate that sewage disposal is similarly placed within the reach of all, that street car service must be and is within the reach of all, if we bear in mind that today the name of Edison is better known and more highly appreciated through his contributions to moving pictures and phonographic development, than through his electric lighting and storage battery, I think it will immediately be brought to us that one of the men in this country whom everybody would be glad to see possessed of great wealth and high honor is this man who has reached the common people, and I think that I am safe in predicting that common acclaim would grant him much reward, not because of his storage battery or electric lighting work, but because of his moving picture and phonographic work which has reached everyone.

We honor the name of Gutenberg, not because there was no printing before his time, not because he wrote books, but because he made it possible for everyone to advance to that stage of education which heretofore had only been attained by a few.

While we knew before the advent of the high efficiency lamps that the efficiency of transformation of electricity to light was so low that there was of necessity opportunity for improvement, the sudden increase of this efficiency of transformation to three times its first value dramatically focused the attention of the profession to the fact that even though the efficiency was three times what it had been, it was still only about 5 per cent and that no device which transforms electricity into other forms of useful energy is as inefficient as our best illuminants. This fact makes it very clear, first that if you or I had the problem of lighting all the buildings which our minds can picture as composing this great city, and had no need of considering the business facts of the situation but simply and solely had to engineer our problem so that every room in every building in this vast city could be lighted with the least expenditure of money, we would not for a moment think of lighting it with gas, kerosene, or candles but inevitably every scientific mind would say at once—why, electricity is cheaper.

If any of you were required by the insurance companies merely to see that your work was so done that fire would not result or life be in danger you would not find it difficult.

These postulates being granted, it is a fair question to ask, if you were required to do these things, if you were required to do these things with the least cost, and if you were required to do them in a manner which would give you the highest degree of protection to life and property, would you adopt the methods and rules now prevailing?

It is not difficult to draw analogies. Some of them possibly are far fetched, but I hope that you will agree when I say to you that the problem facing our industry today, as suggested in the introduction to this paper, has passed beyond the stage where the engineers of the Central Station and the engineers of the manufacturing companies have the real basic problem to solve. The problem today is up to the engineers of distribution, who must economically wire the rooms they would serve; and the accountants, who must devise a means for economical transferring adequate compensation for the service from the served to the server.

It is a question of the whole commercial policy which must be influenced greatly by the attitude and effort of the engineers.

I was profoundly impressed, a year or two ago when pursuing some investigations in Europe, by the oft-repeated statement of managers of large properties that they introduced certain policies because of political necessities. They mentioned those political necessities in the broad sense of the obligations and demands of the community and not in the sense that they were catering to demagogy or expediency. They have reached the conclusion that commercial safety to themselves and others lies broadly in the direction of the extension of electrical service to every political unit. The electrical industry in general will sooner or later awaken to this fact and when it does, and only then, will electrical service assume its proper importance as a factor in civilization.

DISCUSSION.

Mr. Durgin: We must not lose sight of the fact that this paper calls up numerous problems. Many of these problems are up to the Central Station Engineer, and it seems particularly proper to have this discussion opened by one of the leading exponents of the industry in Chicago. Mr. Junkersfeld.

P. Junkersfeld, M.W.S.E.: Mr. Doans has given us the kind of a paper he always writes, and many of his papers have become classics. He has given us not only a splendid paper, but a very fine demonstration and exposition of modern lamp manufacture, particularly the very latest gas filled lamp. He has told us a great deal—and very well—of the *why* of all this matter of electric lighting as a factor in civilization. He has told it so well and so completely that it would be impossible for me to amplify on it. The only thing I wish I could do would be to tell you a little of the *how* this might be brought about, but that is impossible, because only the future can tell. So I will attempt to tell you perhaps of a few of the possibilities of bringing about this very desirable feature of electric service for the use of every inhabitant of our country, including every farmer. But the realization of this state of affairs is in the future.

As far as the *why* is concerned, I am in hearty accord with Mr. Doane's statements. As to the possibilities of the future, he has given you one very good clew in his paper, in which he emphasizes the subdividing of electric service and a means of more general distribution. In order to accomplish what he has so well set forth, this problem must be given special study from every angle. I will use a few illustrations from Chicago, as I am most familiar with the conditions here, but most of them will apply, as well, to many cities of our country.

In Chicago we have just passed the quarter million mark in subscribers for electric light. Of that number there are probably 20,000 whose bills per annum are less than $12.00, and probably 40,000 to 50,000 whose bills during the summer time are less than $1.00 per month. I am speaking now only of residential lighting.

Now then, in order to secure these additional customers, it is necessary, of course, to make a considerable investment in preparation for service to those customers, and those additional customers are not profitable customers—at least, not for a considerable length of time—and that brings up great difficulties in the very rapid extension of electric service to everyone.

The first thing necessary in this step is to be able to attract the investors to put their money into the business. Those lines cannot be extended without money. Practically every growing central station has to raise a large amount of new money almost every year. Now then, would you, individually, care to put your money into companies that were taking on very large numbers of unproductive customers? During periods of business depression great care must be used. In periods of prosperity one is more willing to take a chance. This matter was put very well in one of our daily papers recently as follows:

"But if the investor is not convinced that he can safely exchange his savings for securities, or apply them in some other way for the expansion of industry and enterprises, the country cannot flourish.

"We need the investor to finance building operations.

"We need the investor to make possible the establishment of public utility service—trolley lines, electric plants, gas plants, etc."

Now then, we have first of all to be sure to attract that investor, because if we do not we will not get the money to extend these lines. We *must* extend the lines sooner or later. Therefore we must use every ingenuity to reduce the cost of supply to these people who are crying for our service, because otherwise it will not be possible. How are we going to do it? Very great reductions have been made in the past. In the last eighteen years the reduction in cost of electricity for lighting purposes is some 70 per cent. The increase in cost of living on the principal items that enter into the expenses of the household is about as follows:

Rent	40 per cent
Clothing	34 per cent
Food has increased over.........	40 per cent
Servants' wages	55 per cent

A great deal has been done in reducing the cost of electricity, during a period when everything else has been going up, but that record cannot be kept up if we continue the small customers, unless we do a great deal in cutting down the cost of supplying these small customers.

One of the first items we might tackle, one of the first possibilities in reducing the cost of these small customers, is the frequency with which bills are rendered. It costs, approximately, 16½c to render every bill. A large percentage of the summer bills, in the residential district, run up to only about 80c or $1.00. If these bills could be rendered bi-monthly or quarterly, that would bring about a material reduction, but whether that could be brought about is uncertain. If bills were rendered quarterly, naturally there would be great money losses; many bills could never be collected, and the loss would have to be saddled on to the honest customers. In some parts of London bills are rendered once in three months. There it is safeguarded by requiring the customer to make a payment in advance, and then the other part of the bill, for consumption, is paid at the end of three months. That is a pretty good step in reducing the cost to furnish electric light, and even on a bi-monthly basis immediately cuts in half the cost of rendering and collecting bills.

From a mechanical standpoint, it is hard to get a meter for much less than about $6.00; or say $8.00 or $9.00 installed. A $2.00 or $3.00 limiting or demand device would reduce cost materially, but that means some new-residential rate.

As far as distribution is concerned, the cost of wooden poles in alleys cannot be cheapened a great deal, but there is one big factor that has a great influence on the cost of electric light, and that is the density of the number of customers in one block. The same poles will supply every customer in a block that is densely settled just as well as in blocks where the houses are far apart, but because of less revenue from customers in a block where the houses are far apart the expense is greater. The case is different in European cities. There, houses are more often built close together, and there are not the large vacant areas that we have. If this city were built up more compactly, that would be a very great feature in reducing the cost of distribution, and that is a thing which will come about slowly.

The cost of interior wiring might be decreased quite a little. In many cases, in frame buildings, of course, the public, which is the final arbiter, does not want to take too big a fire risk, and the safety precautions add considerably to the cost of wiring. That is another one of the difficulties, but these are all being gradually overcome. Almost every year the fire limits are extended, which means better and better building construction.

There is one other feature that I feel is a factor in civilization, —one, however, that follows electric lighting—the use of electrical appliances in the home. Take an electric fan, for instance; it certainly is an aid to civilization on a hot day. The same is true of the electric flatiron. In a great many cases the use of flatirons and fan motors are as desirable as electric light; they provide an additional service and also an additional income, which makes it possible to extend the lighting further and further. So that, in order to have electric lighting extended as far as possible, and make it as big a factor in civilization as we can, we ought not to forget electric appliances. We are certainly justified in encouraging electric appliances as well as electric light.

Mr. Durgin: One of the first known users of the new lamps is the City of Chicago, and I will call on Mr. Tompkins, of the Department of Gas and Electricity, to tell us a little about their application.

E. W. Tompkins: As one of the initial purchasers of high candle power gas filled tungsten lamps, the Department of Gas and Electricity of the City of Chicago presents the following:

About six months ago, after a thorough investigation, we decided to discontinue installing 465 watt flaming arc lamps and to install in their stead 20 ampere, 300 watt gas-filled tungsten lamps. The favorable results obtained so far from the 1,800 which were installed two months ago lead us to believe that this 300 watt, 600 candle power, gas-filled tungten lamp, which gives an equivalent illumination to that of the 465 watt flaming arc after the flame lamp has been in service a short time, is the most economical high power open street illuminant on the market today. When the slagging of the carbons and the etching of the inner globe of the flaming arc are eliminated the arc should be a strong competitor of the gas-filled lamp.

The gas-filled lamps which are purchased under a guarantee of 1,000 hours' life make a more flexible operating system, give a more uniform light and cost less to install and maintain under our Chicago local conditions. It is planned to replace within the next two years the 6,248 7 ampere 450 watt enclosed lamps (giving only about 250 candle power) with the 300 watt, 600 candle powei gas-filled tungsten lamps, and to extend the system with 8,000 additional lights of this type.

The largest saving in operating the gas-filled lamp under our local labor conditions lies in the trimming and patrolling item.

This saving is brought about by allowing an average of 750 gas-filled lamps to be cleaned and patrolled by one man, who is paid, beside his salary of $100 per month, $3.75 per day for an automobile supplied by him, making a total cost for attendance of $4.00 per year, as against $7.44, the cost for labor to trim flame lamps. This is a saving of over 45%.

Although the cost for four gas-filled tungsten renewals per year (which the manufacturer guarantees not to exceed) is nearly three times the annual cost for flame arc carbons, the relative saving in such items as the cost of power and fixed charges in the gas-filled installation more than offsets this high cost for lamp renewals. It is very probable that the life of these 20 ampere, 300 watt nitrogen lamps will, within a short time, materially exceed the present guaranteed 1,000 hour's life, which would result in a still greater saving over that of the flaming arc.

On November 1st of this year, there were in service 2,500 of these gas-filled lamps. Of this number, 408 located on four circuits have burned a total of 1,003 hours with an outage due to lamp burnouts of 15.4%. This makes the total average life to date 920 hours. We are so well satisfied with this showing that we feel justfied in anticipating a much longer average life than that of the 1,000 hours guaranteed.

These results, coupled with the lowered cost of the lamps, due to improvements in the art of manufacture, and larger discounts based on increased annual purchases, will more than compensate for an increased cost of energy that may occur.

At present, the total annual cost to operate a 465 watt flaming lamp with energy at ½c per kw-hr. delivered at the circuit terminals, is $50.58, including $17.46 fixed charges, while the cost of a 300 watt gas-filled lamp (365 watts including compensator losses) is

$49.43 per year, allowing $13.27 as investment charges. These costs are divided approximately as follows:

	465 Watt Flame Lamp	300 Watt 600 C.P. Gas-Filled Lamp
Energy	22.5%	18.1%
Carbons or renewals	11.6%	32.9%
Globe and lamp repairs	4.9%	1.9%
Trimming and patrolling	14.7%	8.1%
Repairs to circuits	11.8%	12.1%
Fixed charges	34.5%	26.9%
Total	100.0%	100.0%

An inspection of these various percentages will show that while an increase in the energy cost will materially add to the annual maintenance charge on the flame lamp, on the gas-filled lamp it will be not so marked. An increase in the cost of carbons which at present is a very likely event, tends to add to the cost of the flame lamp, while the tendency is toward a reduction in price for the renewals on gas-filled lamps. The other items entering into lamp maintenance are not subject to any material change.

The department will be pleased to answer any questions addressed to the Commissioner, relative to performance of gas-filled tungsten lamps, insofar as the data collected is available.

Mr. Durgin: I will call on Mr. Cravath, who is not only a central station engineer, but an illuminating engineer of particular importance to the Illuminating Engineering Society.

J. R. Cravath., M. W. S. E. Mr. Doane has raised an interesting question in central station economics, and it will be interesting to go into some phases of that topic a little more completely than he has done. He shows that the price of lamps and of electrical energy has now been greatly reduced, and that it is up to the distribution engineer to make cost reductions in order that electricity may be made available to all classes. He explains that he means by the distribution engineer the man who is to get the energy from the street mains to the lamp socket.

We must all admit that one of the largest items in serving these small customers is that of the fixed charge, interest, and depreciation on the investment. To take a specific case, I have done a little figuring on the basis of a small consumer having, say, four outlets, divided as follows: Two 45 watt lamps and two 40 watt lamps. Rather small, you may say, but we have got to handle that size if we truly popularize the service. This would make a total connected load of 130 watts for that consumer. The maximum demand on the power station, according to Mr. Gear's figures on

"Diversity Factors"* taken from Chicago consumers of larger size than the one we are considering would be 18.1% of 130 watts, or 23 watts. The diversity factor percentage might be double 18% for a group of such small consumers as we are considering, but for the present we will take 18%.

Mr. Gear's figures on investment, in a densely settled district, showed that the investment in central station equipment, including everything down to consumers service, including meters—was about $500 per kw. of peak station load, of which about $160 was in the meters. If we deduct that $160 for meters it leaves $340 per kw. of maximum power station demand to serve that class of consumer, and 18.1% of that demand will exist at the consumer's terminal for each kilowatt of station peak load. So we can take 18.1% of $340, or $61.20, as investment for the apparatus to bring 1 kw. to the consumer's door, not including meters. Or, in the case of the small consumer just considered, with a demand of 130 watts, it will take $8.00 worth of station investment to bring the service to his door, not including meters. If we allow 18% for depreciation, profit, and taxes, that will be $1.44 per year, or 12c per month. Even with double the station investment and double the assumed 18.1% diversity factor, the investment to this point is small compared to that on the consumer's premises. The trouble comes the moment we get to the meter. A meter costs, installed, not less than $8.00; in other words, from 50% to 100% as much as it costs to bring the service to the consumer's door and build the station.

When we come to the wiring, we strike some more snags. And right here is probably where there is big room for improvement in the future. In Chicago our requirements are high; the standards for wiring are high; the cost of labor is high. It would cost not less than $25.00 to $30.00 to wire a house for such a consumer. In small towns in central Illinois things can be done much cheaper, where within my knowledge many four-room cottages have been wired in the past for $10.00 to $12.00. This was for drop cords or ceiling sockets with a reflector on each lamp, but no switches and simple knob and tube work. It was good work but was done without much red tape formality. It was quite a common thing, in one small town, for a wireman to go after noon to a four-room house that was not equipped with electric light, and say to the housewife, "Wouldn't you like to have your house wired today for electric light? I could have the service installed complete before night, so as to surprise your husband when he comes home." And he would make good his promise, too.

So we can see that the cost of wiring, meter, and service in a large city like Chicago is likely to run up, in the case of the small consumer, to $40.00. At the present time, the tendency is to increase rather than decrease our costs of wiring. There have been

*Journal W. S. E., October, 1910.

some reductions lately in the cost of meters, but the cost of wiring is going up instead of down. We must get away from the old lines in order to make progress; we must use something new that will not cost so much—either in labor or material.

As far as handling small consumers is concerned, Chicago is one of the best developed of the large cities. Large cities are as a rule undeveloped. In Chicago there is a consumer for every ten population. In some small country towns there is a consumer for every five in population, which approaches close to the saturation point.

Mr. Junkersfeld: One point I would call attention to: Mr. Cravath used a diversity factor of 18%, which he had taken from Mr. Gear's paper of 1910. Those figures were based on a block in which the homes were wired for 20 or 30 lights each, and the diversity factor which would be correct for such a block would not be anywhere near correct for a block of cottages with only 4 lights each. It does not change Mr. Cravath's conclusion in his case, but whenever diversity factor is used, great care must be exercised to avoid large and serious errors.

I referred in my previous remarks to conditions in Europe, but did not wish to give the impression that the lighting per capita in Europe is greater than in America. The lighting per capita in America is greater than in any European country, with the possible exception of Switzerland.

Mr. Durgin: After all, the man who has to make the expansion in civilization of electric light is he who sells the power. He also is the one who is going to reap the great benefit from such expansion. Mr. Lloyd, of the Commonwealth Edison Co., will talk to us along this line.

E. W. Lloyd: The thing that impressed me, in listening to Mr. Doane's paper tonight, was the fact that this tremendous development in incandescent lamps has been brought about by men we all know and have friendly feelings for. And right in this connection, it seems to me that those men are not receiving the proper share of praise for the tremendous development within the last five years. As we grow older and look back to the five years ending in 1914, we will doubtless give these men much more credit then than now for their great work in advancing civilization.

Several of the speakers brought out some of the problems in connection with distributing cheaper lighting. Both Mr. Doane and Mr. Cravath have spoken along lines I have thought a great deal about—namely, the question of the cost to the consumer of light. Today we have developed, especially in our large cities, wiring systems that cost a great deal per outlet. We must, as Mr. Cravath pointed out, develop—and very soon—cheaper wiring systems; and, gentlemen, it can be done. But we must have coöperation. We must have aid from all interested in order to be able to furnish electric light to the homes of our poorer people. And further, the work of the National Electric Light Association in this connection deserves your serious consideration. There is a committee of that Association giving very close attention and working along the lines of trying to recommend something in the way of cheaper wiring that will be satisfactory and safe.

After all, the cost of electricity itself in its delivery to the small consumer is not the greatest element of cost. The service cost is very high. It is not necessary to go into the cost of meters, but we all know that the cost of electricity itself is a very small item. In fact, today the central station company is not selling electricity particularly, it is selling service. The cost of electricity itself has been reduced rapidly, and it is hoped that it will be reduced still more. But when we talk about the customers paying a few cents for electric light we must stop to think very seriously about the capital side of the question—how serious it becomes when, even in the winter time, there are thousands of bills amounting to less than $1.00 per month.

The cost of metering has been mentioned, and it is my firm conviction that the electric meter will be entirely changed in form in order to meet this particular demand. I am inclined to believe that we must come to the European method of handling this class of customer. From the present data available I am not quite sure we have the best method or that it will be based entirely on the European method. I believe there is going to be a development in this country in small business that will surprise all of us, and with the reduced cost of interior wiring we can develop systems of charging for electricity which will enable the small customer to get light at a satisfactory price, no matter what his salary may be.

Mr. Durgin: The question of cheaper wiring is one in which the Municipal Bureau of Inspection is interested, and Mr. Tousley, of the Inspection Department, will tell us what the attitude of the people of Chicago is going to be on this question of cheaper wiring.

V. H. Tousley (Chief Electrical Inspector, City of Chicago): I want to say first that I have listened with a great deal of interest to Mr. Doane's analysis of the whole electric light situation, and am glad of an opportunity to discuss, in a brief way, one particular feature he has brought out,—that of the present wiring methods. As you probably all know, the present wiring construction is governed by the National Electrical Code.

Some two or three weeks ago a celebration was observed of the thirty-third birthday of the incandescent lamp. In 1881 there was a number of codes, or rather a number of compilations of rules that had been passed by various states throughout the country, regulating electrical construction. In 1883 this city passed an ordinance regulating electrical construction, and since that time rules have been gradually developed and have kept very close to the development in electrical construction. At the present time I think the rules of the National Electrical Code are the highest developed of the rules in any country in the world.

I want to say just a word as to the rules of this city. They are primarily based on the National Electrical Code, and each year a committee is called together to discuss the various changes in the National Code, and decide what changes shall be adopted in the Chicago rules. This committee generally consists of a representative from the Chicago Electrical Contractors' Association, a representative from the Chicago Board of Fire Underwriters, two representatives of the insurance companies, representatives from the lighting companies, a representative of the wiremen, a representative of the electrical fixtures association, and a representative of the city.

It has been observed, and I think I have made the remark on several occasions, that when the committee get together the general public is not specifically represented. I have personally recognized this fact, and have tried to act as the representative of the public in going over these rules, and have always felt that the question of cost was to be given serious consideration. I want to say, also, that I think, while that is true of Chicago, it is also true of electrical inspection departments throughout the country in general.

The Electrical Committee having in charge the revision of the Electrical Code has, during the past four or five years, shown very great liberality in the construction of rules. By liberality I mean they have taken the cost to the public more into consideration. As an illustration of this, if a man built an apartment building last year, he was permitted to put 12 lights on a circuit. The present rules allow him to put 16 lights on a circuit—an increase of 33% in capacity. They allow him, also, to attach to that circuit a heater outfit. In other words, he is allowed 133% excess capacity over what he was allowed a year ago.

The electrical department of this city has under consideration at the present time the question of mains. It has been the policy in this city to require mains feeding an apartment building to have a capacity for the total connected load. The department has recognized that the current furnished over such mains was not 100% of the connected load and that a certain load factor could be applied and smaller size mains permitted. The department now has this subject under discussion, and undoubtedly there will be results soon.

As far as cheaper methods of wiring are concerned, the Municipal Inspection Bureau has but one purpose,—that of safeguarding the public from electrical accidents and from electrical fires. Primarily, it cares nothing about the cost of electrical construction—whether it is excessive or low; it has one important thing in view, the safety of the public. If safe methods of wiring can be devised at less cost than at present, I have no doubt that the Electrical Committee of the National Fire Protection Association, which has in charge the matter of making rules, will be willing and glad to consider them. It will be necessary to show, however, that this cheaper wiring is absolutely safe, because that is the purpose of the Underwriters' Association, and is the purpose of every Municipal Inspection Bureau. Logically this matter should come from either the lighting companies or from the manufacturers of electrical material. If they have material which is safe and cheaper, they have but to submit it to the Electrical Committee, and I have no doubt I voice the sentiment of every member of that committee in saying that they will be glad to consider it. When you take into consideration that on the one side the electrical companies are striving for cheap wiring, and on the other side the Municipality and the Underwriters are looking for safety, I feel sure that the public can rest its case safely in these two hands.

Mr. Durgin: There is one point that we have, in the past, heard very little about,—namely, the very beautiful scientific achievements in the lamp, in the way of photography, etc. Dr. Lloyd, of the *Electrical Review,* will talk to us from the standpoint of the pure scientist.

M. G. Lloyd (Technical Editor, *Electrical Review and Western Electrician*): I think every scientist must admire the achievement which is represented in the most modern type of incandescent lamp. It represents a research, as Mr. Doane has pointed out, which is a combination of engineering, physics, chemistry, and metallurgy. I think Mr. Doane has put the characteristics of those lamps in a way to be very readily understood this evening. When we first consider the way in which these results have been obtained, it seems simple enough, but after looking a little further into it, a question is likely to arise in one's mind as to just how those results are obtained. In considering the lighted bulb we do not have a case of equilibrium. If we did, that is to say, if we had a state of things where a certain amount of the metal vaporized until its vapor tension is in equilibrium with the hot metal, we should not have the condition actually existent and we should not have the same effect from the gas. Now, what is really going on in the bulb is the distillation of the filament. The hot vapor of the metal comes in contact with the cold bulb and is condensed against the glass, so there is really a process of distillation and the filament is gradually and continuously eaten away. When at one point it gets unduly thin, that point gets overheated, and the breakage of the filament eventually occurs there. The action of the inert gas present in slowing down that process has been very well put by Mr. Doane.

In considering the higher efficiency of this type of lamp, one thing should be mentioned and kept in mind. The high intrinsic brilliancy which accompanies this high efficiency makes it undesirable, if not really unsafe, to use such filaments without some kind of screen. The light should be diffused before coming to the eye.

The necessity of using screens cuts down, somewhat, the commercial efficiency, which can never be, in practice, as high as for a bare lamp. Even with the vacuum tungsten lamp we have that effect to a lesser extent, and yet to an extent which I personally think requires shielding from direct radiation into the eye. That is a thing which does not seem to be very generally recognized, however, and in the use of even the vacuum type of lamp we find many cases in practice where it is placed in position without any diffusing medium, making it actually hard to see the things people are really trying to illuminate with the lamp. This is a barbarous practice, and not in line with civilized ideas.

I should like to ask Mr. Doane a question in connection with those lamps, and that is with regard to the use of other gases than nitrogen in the bulb. I have understood from the researches that have been made that somewhat better results have been obtained by using argon and mercury vapor.

If Mr. Doane feels like saying what progress has been made along those lines, and what we may expect will be forthcoming in that way, we shall be glad to hear from him.

Albert Scheible, M.W.S.E.: While Mr. Doane has so ably shown us the wherewithal for some of the coming developments, and while other speakers have touched on the economies to be effected in the future, we must not overlook the many ways in which electric lighting has already been a factor in civilization. One of these has been its influence in reducing fire losses. The greater safety of properly installed electric lighting as against any of the gaseous illuminants has long been demonstrated, and electric developments have recently added another important item, viz., the portable lantern made possible by the perfection of low-voltage, low-candle tungsten lamps.

Another influence has been that of effectively controlled street lighting for replacing (or at least supplementing) moonlight in the three important purposes of lighting our paths, preventing crime and prolonging the effective day.

Still another influence of electric lighting on civilization was in indoor lighting, in connection with which the use of intense and non-smoking lamps has made it feasible to light rooms by indirect or semi-indirect methods, thereby enabling us to secure ample illumination without undue eye-strains.

A fourth factor has been that toward industrial concentration and efficiency. We have been enabled, by using the electric light, to apply the illumination where we most need it, and with effectiveness. Our manufacturing plants, whenever necessary, can be run for 16 or 24 hours, and we have gotten lately so we can vary the color values and apply the artificial lighting also where formerly we were confined to daylight.

In the fifth factor there is perhaps less of the commercial element, it being the effect on artistic development. We have all noticed the effects which would not be possible with the older illuminants, and one of Mr. Doane's colleagues (Mr. Luckiesh) has recently shown us how the modern lighting enables the artist to emphasize a particular color to best convey the artistic effect. In short, while it has been interesting to note the prospects for further advancement, I believe the five influences above mentioned are far greater than what the future has in store, and these are already to the credit of electricity as a factor in civilization.

W. C. Bauer: I would like to ask what is the factor of safety allowed; in other words, how near the melting point is this filament? Let us say the lamp is running on 110 volt circuit.

CLOSURE.

Mr. Doane: Answering first the specific questions that have been raised in the discussion, Dr. Lloyd is correct in his understanding that inert atmospheres other than nitrogen, such as argon and mercury vapor, have been experimented with in connection with the gas filled lamps and have, under certain conditions, shown interesting possibilities.

There is no question but that the advent of the new lamps of higher intrinsic brilliancies makes the question of exposed light sources a matter of even greater importance than heretofore. I am sure that everyone interested in good lighting will agree with Dr. Lloyd, and I believe that eventually the practice to which he objects will be changed so as to correspond more nearly with the theory we all accept. We must expect that movements of this nature will be slow in showing results, involving, as they do, such a large mass of users.

In connection with Mr. Bauer's question regarding "factor of safety" in operation of the filament, it may be pointed out that we cannot apply a factor of safety to a filament in the same way as to a steel girder. The mere fact that filaments are operated to destruction would preclude the application of such a factor in its ordinary sense. When a lamp gets old enough we expect it to fail —even when operating under normal conditions.

In the new gas filled lamps the filament operates roughly at from 2,400 deg. to 2,500 deg. C., compared with temperatures in the vacuum lamps of about 2,100 deg. C. The melting point of tungsten is about 3,100 deg. C. (these temperatures are not absolute). A new gas filled lamp would probably stand a momentary increase of current of 50%.

As to the general trend of the discussion I wish to express my pleasure in seeing the problems with which I have been particularly concerned discussed in such a broad minded way. I feel that the facts I have endeavored to impress upon you in my paper have been so augmented by the comments of those participating in the discussion through their different points of view that I have really secured more from you than you have from me. I can only add that I hope that you may all feel as well repaid as I do for having been here tonight.

MODERN USES OF WOOD

Hermann von Schrenk.

Presented December 14, 1914, before the Bridge and Structural Section.

In modern building construction, many forms of raw material are available, such as wood, stone, cement, brick, etc., all of which have certain specific attributes to recommend them to the prospective builder. The form and number of these various materials have become so large that it is frequently a problem to determine which of the materials should be used. It is my object this evening to indicate some phases of the uses of wood, in particular to discuss the relation between the attributes and qualities of wood and its application as a building material.

The modern American attitude towards building materials, meaning by this such materials as stone, brick, wood, steel, etc., is unfortunately still one which might be characterized as a disregard for intrinsic value. Most materials are handled and used much as they were many years ago, without much consideration for the material itself. This is a part that I will call, for want of a better term, our national economic sense, or, rather, the absence of economic sense. The disrespect in which most of us hold materials leads to waste, not only as to quantity, but waste as to the manner in which we use the materials. This disrespect has probably grown as a result of the cheapness and the quantities of the raw materials which could be obtained with ease all over the country. I am fond of telling a story illustrating this point. Some years ago, while waiting for a train at a Texas railway junction, in the middle of a summer day, I met an old German who was waiting for his train. He had come to spend his remaining days with his son in southeast Texas, and had been in the United States only a few months. When he found that I was interested in wood and timber, he told me he felt that America was a more or less scandalous country. On inquiring for his reasons for this viewpoint, he told me the following tale: "In my father's home," he said, "we had chairs, tables, bedsteads, etc., which had belonged to my great grandfather. When any member of the family broke any part of one of these pieces of furniture, it was taken to a cabinet maker and carefully repaired, and it then served for another generation or two. In my son's family, in Texas, this is by no means the policy. If any member of the family breaks anything, the whole family rises up and exclaims 'out to the wood pile with it and buy a new one.' This is a scandalous country." The sentiment expressed by the old gentleman is readily applicable to our whole sense of the value of most things which we deal with. In the case of furniture, it is undoubtedly easier and probably cheaper to throw away a broken piece of furniture and buy a new piece, because one would probably have great difficulty in most of our cities in finding a cabinet maker who could, or would, for a reasonable sum, repair such a piece of furniture. The point I wish to make is that this fundamental disregard for the intrinsic value of the material has prevented our recognizing that there are ways and means for so using the material that a very much better, as well as longer service therefrom, can be obtained.

These are days in which we hear much about conservation. By this I mean conservation in its best sense as applied not only to the deposits of iron, oil, timber, stone, etc., but also to the finished product derived from these raw materials. I am thoroughly convinced that we will never have actual conservation until the general

Fig. 1. Timber Yard, A., T. & S. F. Ry., Somerville, Texas,

respect for the finished material will have risen among the public at large. If, in the mind of the average man, a chair is not worth handling with care and repairing when broken, how much practical interest will he have in the conservation of the tree from which the chair is made? If we use pieces of wood so that they will last only three years, where they might last fifteen years if properly handled, it is but natural that our opinion of such a piece of wood should be correspondingly low. I claim that we must first obtain an increasing respect for the material before we can hope to make any progress in conserving the same. Other countries have learned this lesson largely because of the scarcity of the raw material and the increased cost which follows such scarcity. I sometimes think that we may have to go through the same process. The only alternative that I can see is to so present the intrinsic value of any material for the purpose for which man uses it, that there may be a better understanding of what that material is good for and how its maximum value may be realized. This involves a careful study of each class of structural material, with a complete understanding of its good qualities and its bad qualities, with a complete understanding of what constitutes proper use and what constitutes improper use.

I have spoken of the disrespect for wood because of the failure of a piece of wood to last. This is frequently held as a censure on the material as a whole rather than a censure on the individual who uses the material improperly. While improper use is very general with most of our materials, it is nowhere so striking as in the use of timber. I am struck every day with the curious fact that to many people it seems to be a new thing (judging by the opinions they express) that wood decays, that it may break under excessive loads, or that it burns. As a result of this apparent discovery they turn automatically to the use of other materials, which in their turn may have defects of another type, but these people turn to these materials without due consideration of the circumstances under which the failure of the wood to serve occurred, or, for that matter, without proper consideration for any specific reason for using any other material.

Wood is the oldest and most universally used structural material. From time immemorial it was readily obtainable without long haul; it was relatively cheap; it could be easily adapted to a thousand and one things. It is a striking fact that in the early days, and even as late as the middle of the last century, architects and engineers were thoroughly familiar with timber from every possible viewpoint. They knew about the different kinds, their strength, lasting power, what loads they were capable of bearing, the different forms of decay and methods for prevention. Only last week I had occasion to look at an old book written by an architect about 1850, and I was surprised to find that the first chapter in this book was devoted entirely to timber and methods for obtaining long life from it. On the other hand, I am just as much surprised at the apparent disregard for some of the fundamental characteristics of wood manifested in this country by those who are responsible for structures of various kinds. I fail to understand why so many houses are being built in which the joists are being placed in the foundation walls without any precautions to preserve the timber or to prevent the attack of wood-boring insects. I also fail to understand why so many structures like grand-stands, bridges, and other structures are being built of wood with no attempts to protect the parts which come in contact with the soil, or where two pieces closely touch each other. The wood in these cases is a perfectly fit structural material, but it is being maltreated, and it will not give its maximum service because of the neglect to observe certain fundamental precautions.

The use of wood has naturally decreased somewhat of late, due to the substitutions of other materials. In many cases this has no doubt had abundant justification, notably where increased strength required the use of steel. There have been other cases, however, where the elimination of wood has been due not to specific physical or chemical causes, but to a misunderstanding of the various characteristics of the wood and the lack of knowledge as to how its good qualities could best be realized. It is my purpose this evening not so much to enumerate the various uses of wood as to consider the basis on which it can and should be used. This brings me to the question as to what it is that usually determines the use of any material. For the sake of simplicity, I will divide the factors which determine such use into three classes: fitness, availability and cost, and consider each one separately, and, in so doing, reverse the order in which I have just mentioned them.

Cost: Wood is still the cheapest building material, that is, considered as a raw material. This usually refers to the first cost, but the first cost need not necessarily be wholly the determining factor, it must be considered in conection with other factors. So, for instance, the first cost may be very much higher than other materials, but in the long run it will be cheapest. This is particularly true in such instances as in the use of wood for paving block purposes. Another notable instance was described by A. F. Robinson some years ago (Proceedings, A. R. E. A. 9:280; 1908) in discussing the construction of open vs. ballast deck bridges, in which he concluded that his comparison showed "that roads using open deck bridges are having to pay more per lineal foot per annum for them than for ballast deck structures, even though the first cost of the open decks may be the lower of the two types."

A man putting up a building will consider cost as a very important factor. Wooden beams and posts are still cheaper than any other type of building material. An engineer associated with my work kindly prepared a number of diagrams for me, illustrating this point. I asked him to take typical floor loads using beams of yellow pine, concrete, and steel, and to show the size and cost for these three materials at present day prices. It will be noted that in all cases the timber beams or posts are cheaper than any of the other materials. In presenting these diagrams it should be distinctly understood that the prices refer entirely to the cost of the raw material, and do not in any way include cost of installation. It should furthermore be stated that the ratios for cost will probably vary somewhat in different parts of the country and at different times. It will be generally found true, however, that the timber beams, particularly for the smaller sizes, such as are used in the building of dwelling houses or small buildings, are still the cheapest.

Another point which enters into the consideration of cost is the permanence of the building. Many people will build a house with the idea of living in it for a few years, provided they can build it at a small cost, but these people would not erect such a building provided they would have to spend half as much again for their house. Our people are still more or less of a roving disposition, and it has been a matter of general observation that we have not yet reached the permanence in the United States attained in Europe, where families build houses and settle down in them with the expectation of occupying them for generations.

The discussion as to cost might be considerably extended. My main point in connection therewith, however, is that wooden structural materials are still cheapest from the standpoint of first cost, and also that it costs less to install them than it does the other materials like concrete and steel.

Availability: We have heard much about the decreasing timber supply, and I am not going to tire you with a tedious lot of statistics.

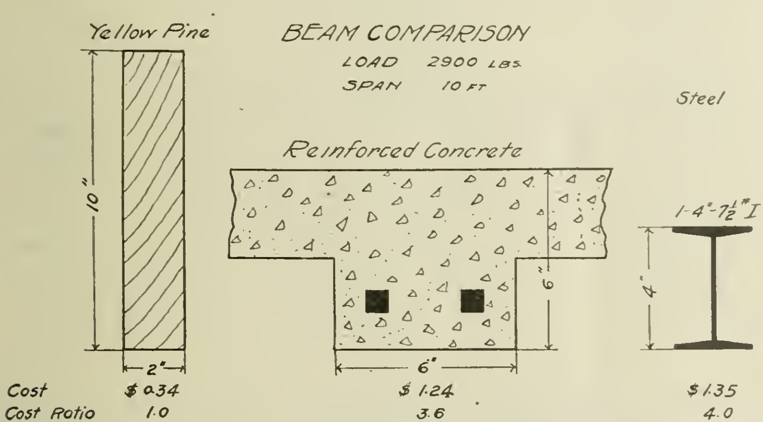

Fig. 2.

A few figures may, however, be of interest, particularly in view of the frequent opinions still held that the timber is practically gone and that its use for building purposes may, therefore, be done away with. Using the figures compiled by the Bureau of Corporations of the Department of Commerce and Labor (in their report on the lumber industry, issued January 13, 1913, quoting these figures in round numbers), it appears that in 1913 the total sawed timber standing in the United States amounted to 2826 billion feet, of which 2197 billion feet were privately owned. Of this total, the distribution of three of the more important timber regions was as follows:

In the Pacific Northwest....	1013	billion ft.
" " southern states	634	" "
" " lake states	100	" "

Dividing these figures according to timbers I find:

In the Pacific Northwest:

Douglas fir	521.9	billion ft.
White pine	19.6	" "
Western pine	153.4	" "
Redwood	101.9	" "

In the South:

Yellow pine	384.4	billion ft.
Cypress	40.4	" "
Hardwoods	209.2	" "

The actual cut of timber the year before amounted to a total of 44.5 billion feet, of which 33.9 billion feet were soft woods, and

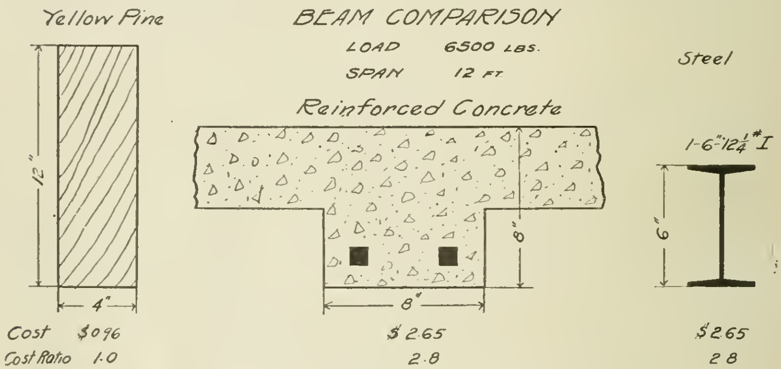

Fig. 2-a.

10.6 billion feet hardwoods. Classified according to timber, there were cut 16 billion feet of yellow pine; 4 billion feet of Douglas fir, and 4 billion feet of oak. It will be noted from these figures that even at the rate of cutting 44.5 billion feet per year—a figure which will probably not be realized again—there is still left more than 60 years' supply, without considering a single foot of regrowth, or increased growth on the part of younger trees now growing.

With your indulgence I wish to present one or two additional figures. The statement was made last year in Chicago that there was no longer any yellow pine left tributary to Chicago. According to the report quoted from above, there is at present in the southern pine region a total of 384 billion feet of pine, of which 232 billion feet are longleaf and 152 billion feet shortleaf. Of the longleaf, 52.5 billion feet grow in Louisiana, 47.6 billion feet in Mississippi, and 22.4 billion feet in Texas. In other words, approximately 53% of the available longleaf pine in 1913 grew in three of the states immediately south of Chicago.

I believe that it will be evident to all of you that these figures indicate a very considerable supply of timber available to anyone who may wish to purchase it.

Fitness: We come now to the most important of the three factors. Any discussion of fitness involves an enumeration of the qualities, both good and bad. One of our failings in advancing any structural material is that we pay attention only to the good qualities. I consider it just as important to discuss the defects, so that we may have a proper appreciation of how to overcome them. Among the good qualities of timber one may enumerate strength, resilience, toughness, ease of working, weight, and in some cases lasting power. Timber is also a poor heat conductor and a poor conductor of electricity. Among the defects, one may mention decay, inflammability and weakness.

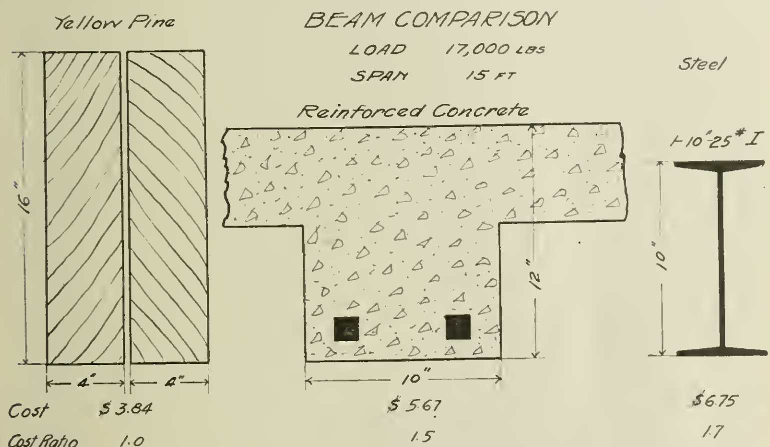

Fig. 2-b.

The good qualities of wood are more or less well known, but there is more need for discussing the defects, and particularly for discussing methods for correcting these defects. Timber can usually not be strengthened, and where high strength requirements obtain, it will be necessary to use some other form of structural material. Timber can be rendered practically decay-proof, however, and it can also be more or less effectively made fire resistant. We will not have time this evening to discuss in detail the methods used for preventing decay. Suffice it to say that it is practicable today to obtain properly preserved wood, either creosoted timber or zinc-treated timber, both of which will give very efficient service. It is absolutely essential, however, that in the purchase of treated timber or lumber, the same be purchased only under the most rigid specifications. Poorly treated timber is worse than untreated timber. It will be necessary to frequently plan ahead in order to get properly treated timber, but there should be no reason why, with properly protected timber available, untreated wood should be used under conditions and circumstances where it is almost positive that the timber will fail after a short exposure. I do not mean that treated timber should be used under all conditions. There are frequently cases where a short term of service is all that is anticipated. I simply wish to insist that where long-term service is anticipated, only naturally-resistant timbers or artificially-preserved timbers should be used.

The protection of wood against fire is a comparatively new industry in the United States, as we have heard very little as to

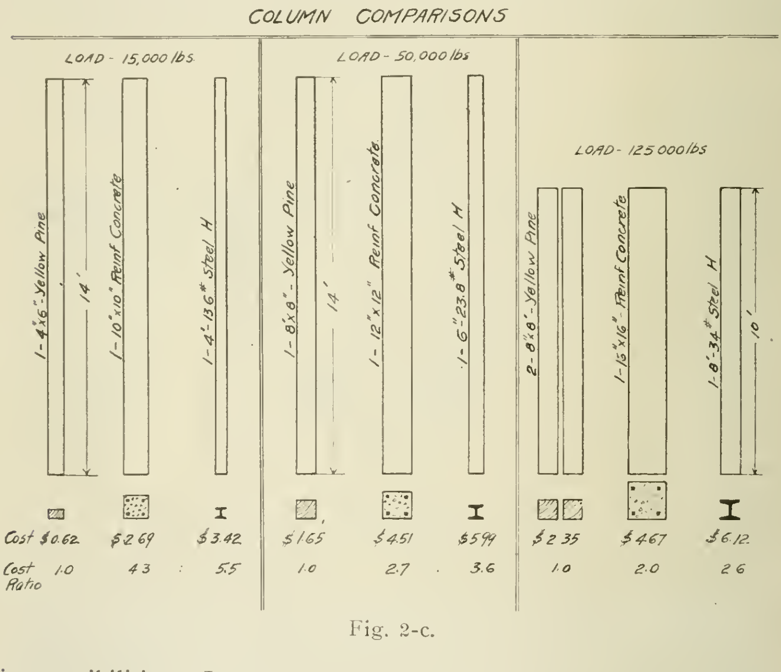

Fig. 2-c.

its possibilities. It may not be known to all of you that efficient protection of wood, not to make it absolutely non-inflammable, but to make it fire-resistive, has been practiced abroad for many years. The rules of the British Board of Trade require, for instance, that all woodwork in British trains be made fire-resistive. With increasing demand, I have no doubt but that works similar to those abroad will start here. In fact, there is no reason why most of the timber-preserving plants should not at the same time prepare fire-resistive wood. Some extremely interesting results in connection with rendering wood fire-resistive have recently been made by the Forest Products Laboratory of the U. S. Forest Service at Madison, Wis.

A committee of the National Fire Protection Association is also studying this problem.

Having enumerated some of the good qualities and some of the poorer qualities of wood, together with methods for overcoming them, I wish to use a few examples of what I conisder proper adaptation. Our present attitude should be to avail ourselves of the good qualities as far as possible, incidentally overcoming the poorer qualities. One of the principal uses of wood is in connection with railroad ties. Wood has so far proved to be the best material, largely because of its high resilience. The trouble with railroad ties, however, is that they decay, and that they wear out mechanically. We have here a case of where absolute necessity requires that some-

Fig. 3.

thing be done to reduce the numerous annual outlays, not only for raw material but for labor. In Europe railroad ties have been treated for many years in such a manner that they give an average service of from 28 to 35 years, or more. This means that they have not only been protected against decay, but also against mechanical wear.

The chief difficulty with preserved ties lies in the fact that they wear out mechanically before the full length of life has been realized. There is an increased tendency to use larger and heavier tie plates, and much experimenting is going on with different types of rail fastenings, especially with screwspikes and dowels. The writer

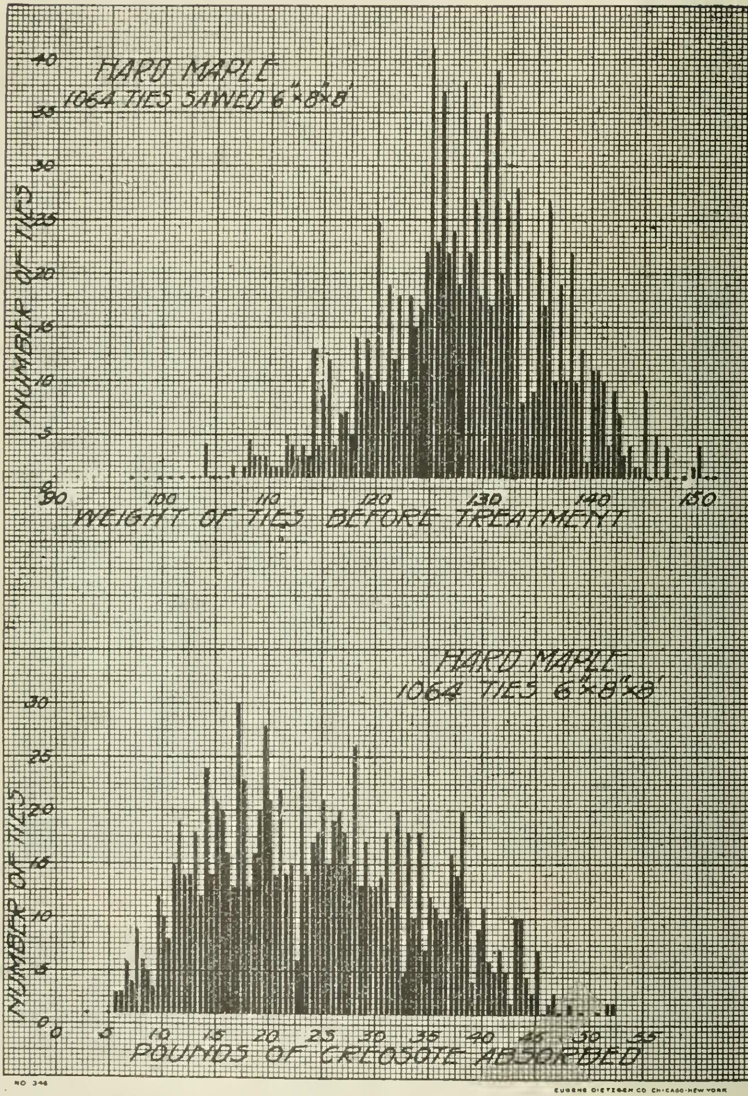

Fig. 4. Diagram Showing Variation in Weight Before Treatment and Creosote Absorption of 6x8x8 Hard Maple Ties.

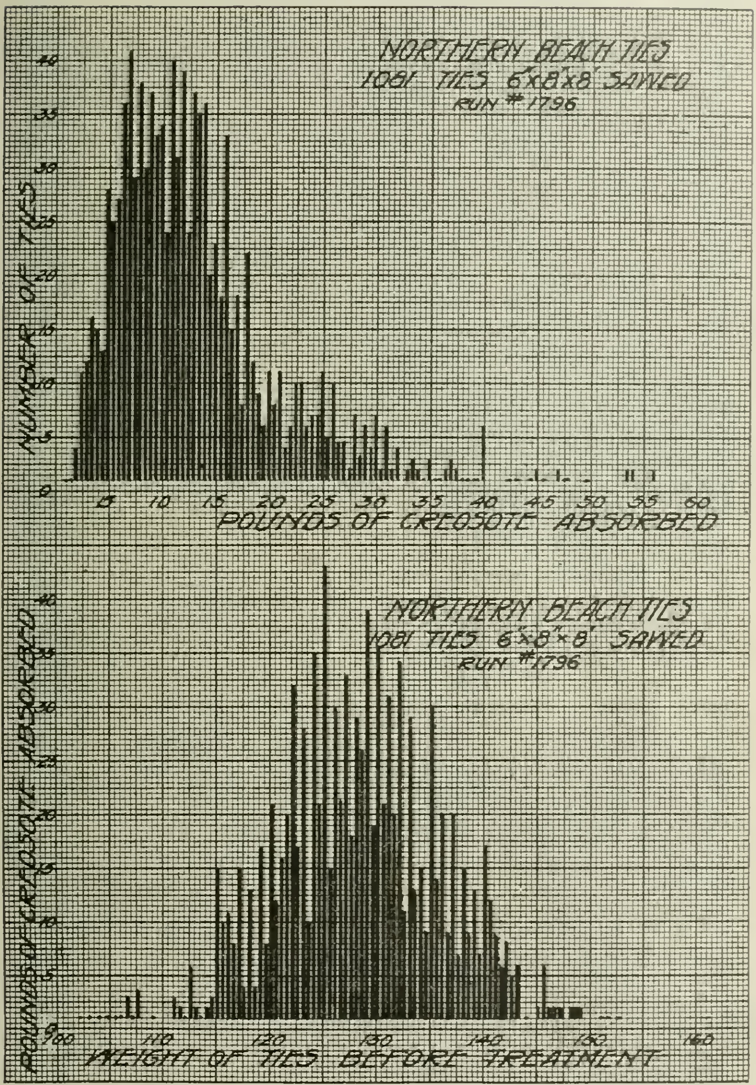

Fig. 5. Diagram Showing Variation in Absorption of Creosote by Weight and Numbers. Northern Beach Ties, 6x8x8.

Fig. 6. D., L. & W. R. R., Showing Use of Screw Spikes. Showing Careful Piling and Clean Yard.

Fig. 7. P. & L. E. R. R., Showing Combination of Screw Spike and Cut Spike Fastening.

feels somewhat proud of the fact that he was the first one to actually bring about the importation from abroad of any large number of screwspikes. Screwspikes are now used as the standard rail fastening on the D. L. & W. R. R., and in conjunction with cut spikes on the P. & L. E. R. R.

Another instance illustrating a specific adaptation is in the use of various types of gum for paving purposes and for flooring, in particular tupelo. This is one of the woods which has only recently come into general use because of the common impression that the

Fig. 8. Tupelo Gum Runway on Wharf, New Orleans.

wood was of inferior quality, but which has already demonstrated singular qualities from the standpoint of resistance to such wear and abrasion as occurs on floors. It is not a longlived wood and requires treatment, but when properly treated chemically, it will far outlast many of the woods so universally used for flooring at the present time. This example is interesting also as indicating how a shortlived wood can be made serviceable for purposes where in its untreated state it could not have been used. This is strikingly shown in some recent tests with sapling maple, sycamore, red oak, etc., creosoted at the butt, for use as fence posts. Figure 9 shows an untreated cedar post in southeast Texas, burnt off at the ground line by grass fires. Figure 10 shows creosoted butt treated elm and maple perfectly sound after eight years of service in southeast Texas.

Another example of strict adaptation is the use of such a wood as cypress where resistance to decay is of importance. There is probably no wood better adapted for outside work on houses, for porches and purposes where the weathering influences are severe than is southern cypress.

Another specific illustration of adaptation, because of peculiar qualities, is our modern practice of using various kinds of wood for street pavements. In the early days the round cedar block was used without proper foundations, and it was natural that the results obtained from these blocks were only partially satisfactory. Nevertheless, it has taken many years to overcome the general feeling that wood block paving meant round cedar blocks. The magnificent examples available to you here in Chicago of what can be obtained with properly selected, properly treated and properly laid wooden paving blocks speak for themselves.

Another instance of adaptation in connection with the use of wood is for boxing material. There has been a considerable amount of agitation lately in favor of substituting other materials for wooden boxes. No attention was paid to the relation between the material shipped and the container, and, as a result, everything from lamp chimneys to boots and shoes, ninepins, and even ship anchors, have been shipped in fragile containers, bringing a loss not only to the carrier, but also destruction of valuable property. I cite this case as one of the startling instances of how people will frequently turn to something new without regard to the qualities of the material thus selected.

In the foregoing I have selected a few instances of adaptation. To these many others might be added. Yellow pine and Douglas fir should be mentioned as structural woods, with western hemlock and western pine close seconds. Red gum, birch, maple and others are specifically valuable for ornamental purposes, furniture, etc. This list might be indefinitely extended. I believe these will suffice, however, to illustrate the point which I started out with, namely, that a careful selection of qualities and an adaptation of fitness to use are all essential.

Proper description and specifications are essential to proper use. This has become increasingly evident in such cases as involve distinctions between the various grades of southern yellow pine. The same applies to the classification of Douglas fir. Investigations such as are being conducted by the Forest Products Laboratory of the U. S. Forest Service and others to determine fundamental facts as to the qualities of various woods are of the highest importance. The charts showing variation in Douglas fir recently published by the Forest Service are typical of the type of investigation with which

Fig. 9. Untreated Cedar Post, Southeast Texas.

Fig .10. Sap Maple Butt Creosoted Fence Post, in Service in Southeast Texas Since 1904.

every user of wood should be familiar. We have recently been making similar investigations with regard to hardwood ties. It has been known for a long time that there is considerable variability in the absorption of creosote, not only for various species of wood, but also for individual pieces of the same species.

The work of committees of the American Railway Engineering Association, the American Wood Preservers' Association, the American Society for Testing Materials, deserves a word of comment. These committees, working in co-operation and in co-operation with producers, are formulating specifications for grades of timber and lumber preservatives, methods to be used in preservation, etc. Not only do they devote attention to these subjects, but they are formulating specifications for various grades of uses, the object of which will be to indicate to the consumer where and how various kinds of timber may properly be used. I bespeak your hearty co-operation for this work.

In conclusion I might say a few words about the comparison of the use of wood with steel, concrete, stone, etc. It is true that all such comparisons are more or less without value, because individual circumstances will in every case determine which material shall be used. There has been so much indiscriminate criticism of wood of late, however, that a few words in connection with this subject may not be out of place. More or less enthusiastic claims are made for various classes of materials to be used as substitutes for wood, some of which are true, but many of which are misleading, to say the least. Exorbitant claims usually defeat their own ends.

One of the principal points of attack of late has been from the standpoint of fire protection. There can be no question among all good citizens that everyone should do everything he can to reduce the loss of life and property due to fire. There is such a thing, however, as balancing the fire risk against the other considerations involved in building. In some cities, the undoubtedly well-meant efforts of those interested in fire protection have been interpreted to mean absolute prohibition of wood in any form for building purposes. In such cases, there has been no regard paid to the significance of such a prohibition. The basis on which such prohibitive laws are formulated is that the elimination of wood will eliminate fires. That is not so. We all know this, and yet such arguments prevail before city councils and appear with increasing frequency. The recent fire in West Orange, New Jersey, is perhaps as good an instance as any that even the best fireproof construction will sometimes give rise to great conflagrations. Absolute prohibition results in reducing building operations, and, after all, does not protect. The logical corollary to the absolute prohibition of wood as a building material would be to require everybody to live in caves. It is easy enough to specify a fireproof building, particularly for the men who can spend fifteen to twenty thousand dollars; it, however, cuts out the five-thousand-dollar man, who, after all, is of more importance in most of our communities than the former; and just to the extent that the five-thousand-dollar man is prevented from putting up a home, just to that extent it would reduce the thrift of our citizens and the development of our communities.

A very notable instance of this sort occurred last year in Texas, where the enactment of an anti-wood shingle ordinance resulted in such building stagnation that the commissioners had to repeal such ordinance after a very few months.

I am the last one to argue for the universal use of wood irrespective of the fire risk, and am personally very much in favor of any scheme for reducing the fire risk, where there is such a risk, particularly in the congested parts of our cities. I thoroughly believe that the use of wooden shingles in congested parts of our cities ought not to be allowed. I do maintain, however, that restrictions in the use of wood, if they are not to act as a hardship on the individual citizen, must be based on the evidence of scientific underwriting, and that the balance must be struck between fire risk and civic development.

That which I have said about the fire risk applies equally to such controversies as the wooden box versus the fibre box; of the wooden bridge versus the steel bridge, and of hosts of other so-called antagonisms. I hold that the greatest good for the greatest number will come with sensible use, and this applies equally well to steel, brick, and iron, as well as it does to wood.

The determination as to which one of these materials should be used will in the last analysis depend upon careful study of the individual characteristics of each, and the final selection will be based essentially on fitness, using this term in its broadest meaning. Wood has held a prominent place for many years, and probably always will. The only difference between the methods of utilization of the past and those of the future is that closer attention will be paid to the proper utilization, and this, I hold, is essentially the modern attitude.

DISCUSSION.

W. E. Williams, M.W.S.E.: What effect has the treatment of timber, with reference to shrinkage?

Dr. Von Schrenk: Some wood will shrink and some will not. The wood most liable to shrink is that treated green. The shrinkage factor depends almost entirely on the percentage of water in the wood to start with. The subsequent shrinkage in creosoted timber is practically nothing. In zinc chloride treated wood, if it is used fresh, the shrinkage may amount to as high as 5 to 8%.

Mr. Williams: Take timbers used in car construction, 1½, 1¾ to 4 in. thick, which are dry before treatment; how about shrinkage?

Dr. Von Schrenk: There is no shrinkage at all if dry wood is treated with creosote. If treated under the kyanizing process, you would get shrinkage according to the climate in which the timber is located, i. e., the amount of evaporation which takes place. It should never be used green.

Mr. Williams: The use of the timber I had in mind was inside of the car, bolted on to an iron framework. If that timber was treated properly, would there be any occasion to expect shrinkage sufficient to allow the bolts to get loosened?

Dr. Von Schrenk: The shrinkage would be rather less than with the untreated timber.

H. C. Lothholz, M.W.S.E.: I would ask if any use has been found for wood in Texas called bois d'arc. I remember that in testing that wood we used to put it in the testing machine and watch it shoot. It would fly about 15 ft. with a loud report.

Dr. Von Schrenk: For posts, that wood is unsurpassed. The next use is for pins for crossarms. The users of telegraph and telephone poles and crossarms would like to know of a large available supply of that timber.

F. E. Davidson, M.W.S.E.: I would like to emphasize what the speaker said about the proper uses of structural timber, particularly in building work. I had occasion not long ago to make an examination of a timber-constructed building completed less than two years ago. I found that the basement columns rested directly upon concrete piers, and had not been protected, with steel or cast iron plates, from direct contact with the moist concrete. Dry rot had attacked a number of these basement columns. It seems to be the exception in building work when the ends of heavy wooden girders resting in brick walls are protected. My own practice is to provide steel wall plates around the ends of the wooden girders, to prevent the wood coming in direct contact with the masonry.

It might be well at this time to call attention to a very customary improper use of structural material in building work. About two years ago my attention was called to a building then under construction, where the floors were of the well-known laminated type. There was some question about the theoretical strength of this floor. The matter was gone over very carefully by a number of engineers and architects, as to the relative strength of laminated floors, where different methods of splicing the laminations were used, and the result of this examination disclosed the fact that there is usually considerable waste in the floor construction when this particular type of floor design is adopted. In other words, the average laminated floor has not been laid to secure the maximum strength. For example, assume 16 ft. as the center to center distance of the floor girders: In laying a laminated floor, if one piece of flooring in each 2 ft. extends a distance of about 2 ft. over the center of the girder in order to secure a proper tie, the floor will have a certain theoretical strength. Again, using another method of splicing, which is quite a common one, if we splice every fourth lamination on the quarter point of the span, the floor will have a different carrying capacity. Another method, and the one followed in the building examined, is to splice every alternate lamination at the center. Why engineers and architects, when using a laminated floor construction, have not designed the floors to secure the maximum strength is one of the unsolved problems of our profession. A most casual examination of the problem will show that the maximum strength will be secured when each piece of flooring is spliced or joined over the center of the girder, and insofar as the laminations are spliced elsewhere will the theoretical strength of the floor be reduced.

I also know of an instance where a 6 in. laminated floor was laid of lumber dressed on both sides. This floor was replaced in about two years on account of dry rot. Here again is the problem of the proper use of material. No material dressed on both sides should ever be used in laminated construction. I personally prefer to use material as it comes from the band saw, as in this condition it is impossible to lay the different members of the floor so close to each other as to interfere with the proper drying out and the proper ventilation of its various members. I maintain that it is just as criminal to improperly design in timber as it is for an engineer to design in concrete or steel, unless he knows how to properly use materials.

Mr. Lindstrom has had a good deal of experience along this line, and perhaps will offer some discussion.

R. S. Lindstrom: Mr. Davidson has brought up a problem which is really an engineering problem. The question has arisen on several occasions at the City Hall, Building Department, where we obtain our final loadings for floors.

The types which Mr. Davidson has outlined have been attempted by various architects in Chicago. In my first practice I used 3 x 6 lamination, dressed four sides, beveled, breaking joints every other lamination. I found in doing that, it was expensive in laying, for the reason that the alternate lamination overhangs the girder until the next lamination is in place, and it requires several men to hold it in place for spiking. Then there is another reason for changing the method of laying. I found after the building was erected, and also during construction, that considerable vibration was caused longitudinally with the lamination from one panel to the other, which finally transmits itself to the wall.

In a mill-constructed building having a lot of line shafting I changed the method of breaking joints from every other lamination to every fourth, and discovered some vibration over the entire floor area. On the next building I broke joints every sixth,—a similar building to the one just described,—and found less vibration. In the buildings erected during the last four years I broke joints every eighth lamination. This method has been approved by the Building Department, and in my opinion it is the best method of laying laminated flooring. I leave one inch space between ends on griders, thereby giving an air space between every eighth lamination connected with air space between the girders. Where there are double girders, separate those girders by maple strips, giving a continuous air-circulation space.

Breaking every eighth lamination is more for the continuous tie of building than for transmitting loadings. Take the quarter spans; this is the method used in a building recently erected on Michigan Avenue, and the advantage claimed by the architect is that a floor constructed in that way transmits the loadings from one panel to another, making the entire floor panel act as one panel equally distributed, which I fail to see, unless the entire floor area is equally loaded. I have never made a laminated flooring over 8 in. in height.

There are some other features, in connection with laminated floors, also with yellow pine timbers in mill-constructed buildings. I had an experience last winter with a six-story mill-constructed building, using yellow pine posts bored through the center. During construction in winter, at times we had bad weather—there was alternate freezing and thawing. After the roof was on and the heat turned on, there was practically 4 ft. of space on the floor around each column which was very wet. On investigation we found that the columns were bored 1½ in. the length of the column, with ½ in. air space holes at the top and bottom for ventilation, which holes during the winter had filled with ice and melted when heat was turned on. The question is, should a hole be bored in the column, such that at the bottom of the basement column the adhesion of the wood column to the base plate is sufficient to hold that water for some time, which simply seeps out as the ice melts. To overcome mildew, we bored another hole in the top of the columns and poured paint into the hole in the column, and then painted the columns 3 ft. up from the floor, and had no further trouble. I think the ends of all timber should be protected with damp proof paint. In a recent visit to the above mentioned building, I found no more evidence of wetness around the column nor any more mildew on post.

Mr. Davidson: The author brought up an important point, and that is that due regard should be paid to the records of the National Board of Underwriters, that is, statistics of the records of fire losses of the contents of buildings contained in the different types of building construction.

Based upon these records, there is no way for an engineer or architect to prove to a prospective client that as a business proposition it will pay him to construct a fireproof building if the floor loads are less than 150 lb. per sq. ft.

I challenge any engineer or architect to prove by figures that there is any economy in the construction of a fireproof building, when first cost, maintenance, depreciation and insurance charges are all considered, for a building designed to support less than 150 lb. per sq. ft. loadings. I maintain that it cannot be done.

There is also a new problem confronting architects and engineers, in the proper use of materials. In factory work there is today less reinforced concrete and fireproof construction being done than two or three years ago, due in part to the fact that skilled workmen will not work if they are compelled to stand on a reinforced concrete floor, if they can secure similar employment in a factory building having wooden floors. The tendency is to avoid the use of finished concrete floors, particularly in factory construction.

As I view it, it will be many years before timber construction will be replaced by reinforced concrete. We all know that in a certain class of concrete buildings, after a building has been erected for two or three years, serious cracking of the floors occurs, due in large part to the increased use of the various flat slab types of floor construction. This is caused by a false assumption on the part of the designer, who has assumed that there will be a uniform settlement throughout the entire structure. Every engineer knows that the theory of the flat slab is the theory of the continuous beam, supported on unyielding supports, and if there is any unequal settlement, no matter how small, this settlement causes stresses not assumed when the building was designed, resulting in the cracking of the floors I have referred to.

Ernest McCullough, M. W. S. E.: In regard to the construction of reinforced concrete buildings, my experience has been rather good and in a number of cases I have been called in to investigate cracks in such structures. In no case have cracks appeared where, in designing, the principle of continuity has been followed as it should be followed. Levels have been taken on a number of buildings under my direction and in very few cases has any settlement been found sufficient in amount to do any damage. The reason for dissatisfaction existing in the case of reinforced concrete buildings is that many were improperly designed. When reinforced concrete buildings are properly designed by competent men, and properly constructed under competent supervision, there will be no trouble. So long as architects and owners accept so-called free designs from steel salesmen there will be trouble.

Mr. Davidson is right about buildings for light loads. With short spans and floor loads of not more than 150 lb. per sq. ft. wood, in the majority of cases, will be the most economical material to use. The present tendency is towards long spans and here wood is ruled out. Wood is cheaper in first cost and also cheaper in the long run than either steel or reinforced concrete when complex secondary stresses are of no great importance.

E. N. Layfield, M. W. S. E.: These various types of construction have their advocates, and the paper by Dr. Von Schrenk was intended to show the uses of wood, not so much as a rival of these other forms of construction, but to show that the tendency in dropping the use of wood on the theory that there is no more of it, or on the theory that it is not valuable, is wrong. He is not advocating the use of wood on the basis that he objects to reinforced concrete, but he does object to having wood maligned when it is not guilty. Wood has its proper uses and very important ones they are, and the conservation of the supply by the means indicated in the paper is greatly to be desired.

I think the paper is very valuable and useful to us. Many things are desirable and not obtainable; it is desirable that a building shall be non-inflammable, but not desirable to the extent that we shall rule out the home of the $5,000.00 man, who was referred to. The same thing exists in many other phases of engineering work. We would like to see many things done in railroad construction. We would like to have it absolutely impossible for an accident to happen; that is probably not possible. It is not feasible to insure every man against any possible accident, which may be fatal or otherwise. The only way for him to be absolutely safe would be to stay at home or in a cave.

H. E. Goldberg, M. W. S. E.: Dr. Von Schrenk has mentioned some of the compounds used for treating wood for waterproofing purposes, namely, mercury chloride, creosote, etc. He also said that wood had been treated so as to resist fire, but I did not hear him mention any of the compounds for that purpose. I would like to know the composition of some of those compounds.

Dr. Von Schrenk: In reply to Mr. Goldberg I would say that ammonium sulphate is one of the compounds most extensively used for fire-resisting purposes. Borax comes next. Most of the compounds are not commercially practicable. In England and Germany, where the processes of manufacture of most materials are radically different from ours, the use of these processes is confined to smaller amounts of timber. If the American manufacturer does not have an output of 5,000 ft. per day, he does not think he has any kind of a plant. Abroad they spend a lot of time on the details of the manufacture of their product, and that is why they get such a high efficiency.

In regard to the hole-boring in columns, that is a much mooted problem, among architects particularly. I personally think that is a relic of an old, old practice, started years ago, and people seem not to be able to get away from it. However, it does little harm to bore a hole in a column, but it does not do a lot of good.

With our laxity in the handling of columns, the boring of holes in columns forms an ideal path for the dry rot fungus to travel upward in the columns, without detecting it on the outside. I know of a case in which the dry rot infection started in the basement and went up to the sixth story. There was a startling case of that sort in one of the Canadian mills; the same thing happened recently in a large building in this city. The better system is to protect the timbers. The same objection might be offered to a farmer who left his machinery in an open field exposed to wind and weather, and was surprised not to find it in good condition when he was ready to use it. Timber does not grow any better by being exposed, any more than any other material. The proper procedure is to protect it and put only air-dry timber in buildings.

The suggestion was made to protect timber with paint on the butts. I think I would disregard all weatherproof paint, for this reason: The infection is usually on the timber when it comes from the woods. The destroying bodies are in the woods and practically every stick of wood is liable to be infected to some extent. If you put weatherproofing compounds on the wood, you produce a moist atmosphere, which permits the development rather than the prevention of infection. What I would do instead of using a weatherproofing compound would be to use some kind of an antiseptic like Barrett "A" creosote oil, which is much cheaper than any paint you can buy, and at the same time it is a good disinfectant. We are rapidly finding out that poor results in painting are invariably due to painting wood when too moist. The thing we have learned is to constantly endeavor to so arrange timber that the moisture will have an opportunity to escape. The use of air chambers around beams is an ideal way for protecting them. I feel very strongly about that at the present time, because all through the South we have an epidemic of white ants extending to some of our most beautiful residence distdicts. These have made their way up into the timbers, and usually walk right through the stone walls into the ends of these timbers.

Mr. Davidson: In regard to the boring of timbers, is it not a fact that the boring of timbers lengthwise has a good deal to do with the proper drying out of the timber, and that it would be less apt to check than a timber not bored? That is the reason why I specify that timber should be bored. I find there is less tendency to check.

I would ask Dr. Von Schrenk if he will not tell us a little about the rule of the National Board of Fire Underwriters, which gives the owner credit if he will whitewash his timbers.

Dr. Von Schrenk: Mr. Davidson is absolutely correct, that you must be perfectly sure that the hole is bored when the timber is green. There is no question that it will reduce the checking, because it will bring about more equal shrinkage as the timber dries out.

In regard to the ruling of the Board of Underwriters, much as I would like to answer that question, I cannot do so. The National Fire Protection Association has appointed a committee to consider the proper uses of lumber in buildings and its relation to fire resistance. We are trying to find out what fire protection means. There is one curious condition—namely, that we have no standards. We speak of making a thing fire-resistive or fire-protective. What we are doing now is carrying on tests to establish a definite standard of fire resistance. All forms of impregnation or paints may be more or less fire-resisting, but there are no means of determining their relative value.

In co-operation with the U. S. Forest Service, we are using a series of electric furnaces in which we are testing pieces of wood, putting them through different processes, etc. Until some sort of standard has been established, there is hardly any use of talking about these things. It is undoubtedly true that whitewashing will act more or less as a fire-resistive element, but to what extent, I do not know.

Mr. Lindstrom: I got rid of mildew by using a very thin liquid tar product, and feel assured that it did the work.

The question was raised about preserving timber. I have had considerable experience in that line. I find that after yellow pine has been lying around on the ground and before the timber is put in the building it has gone through a certain process of natural seasoning. The worst abuse of the timber after being built into the building is generally given it by the occupants in overheating the building. I have been advising my clients to keep water pans on radiators for giving natural moisture to rooms, and have been informed that when this is done the amount of checking of timber, also shrinkage, has been greatly reduced, due to the moisture evaporated from the water pans on the radiators. After the first year one can apply whitewash or whatever paint one may desire to the timber without any evidence of hurting the strength or life of the timber.

Dr. Von Schrenk: I agree entirely with the last speaker's statements. We made a number of tests during the past year on painting different types of cypress wood. Some of the panels received a second coat several days after the first coat had dried. Others were not painted until a considerable period after the first coat had dried. The second series showed up very much better at the end of a year. In other words, the preliminary exposure seemed to have a good deal to do with the subsequent adherence of the paint film.

Summing up what I have been trying to say, the underlying idea as to the consumption of wood ought to be on the basis of fitness and adaptability. I believe we are rapidly coming to the realization of this fact. Architects and engineers are beginning to appreciate this fundamental notion, not only with regard to wood, but with regard to all materials of construction. Wood is, of course, only one of these. Where other materials are better fitted for specific purposes than wood, they will, of course, be used and should be used. The main thing is to avoid superficial judgment and to follow constructive ideas.

THE GOETHALS' LUNCHEON

On Friday, January 22, 1915, Colonel George W. Goethals, Governor of the Canal Zone, was the honored guest of the Western Society of Engineers and the Chicago Engineers' Club, jointly, at a luncheon served in the ball room of the Hotel La Salle, Chicago.

Over seven hundred attended the luncheon, including the members of the two organizations and their invited guests. Among the most prominent of the invited guests were a number of the federal jurists, United States Army officers and engineers.

Our honored guest, Colonel Goethals, made a short speech telling of the valuable services rendered by the civil engineers in the designing and establishing of the original organization which started the construction of the Canal work. Among the names specially mentioned were those of Messrs. Wallace, Stevens and Goldmark. He referred to the difficulties caused by the slides, which naturally seriously interfered with the operation of the Canal and at the same time made it difficult to remove the obstructions in the Canal caused by the slides.

Colonel Goethals was introduced by Mr. W. H. Finley, past president of both the Western Society of Engineers and the Chicago Engineers' Club.

President Jackson, after making a few brief remarks, presented Colonel Goethals with an Honorary Membership of the Western Society of Engineers, and President Edward Haupt of the Chicago Engineers' Club presented Col. Goethals with an Honorary Membership of that organization.

The arrangements for the luncheon were made by a special committee consisting of Mr. B. F. Affleck, Vice-President of the Chicago Engineers' Club, and Mr. Albert Reichmann, past president of the Western Society of Engineers.

Albert Reichmann,
Committee.

COL. GEO. W. GOETHALS

THE ANNUAL MEETING.

The events of January 13th and 14th, this year, may well be taken as the last word in engineering events, the success of which was due largely to the enthusiasm and untiring efforts of the Boosters Committee, and which we think have so far surpassed all previous Annual Meetings as to demand an outline of the work which made it possible.

In the beginning, an attendance of four hundred at the Annual Dinner was adopted as a slogan by the committee in charge. This meant a fifty percent increase over all other records. It looked big, but the enthusiasm and determination of the Boosters Committee was greater.

The first announcement sent to the members early in December asked for the names of engineers not members to whom invitations might be sent. A return of twenty-five percent (three hundred names) was realized. In addition, the names of the alumni of the technical schools were placed on the mailing list, giving eight hundred additional prospects.

The next problem was to reach the membership as individuals instead of as a unit. This meant personal attention by letter, telephone, or interview, and represented an enormous amount of work if carried to completion. It was necessary, therefore, that this work be divided among a number of men who could be depended upon to do their parts thoroughly and on time. To this end each member of the Boosters Committee and each officer of the Society chose from the membership the men he would try to reach personally. Accordingly, on the third of January, or thereabouts, at the time the second announcements were mailed, these Boosters and officers sent out over seven hundred letters urging their fellow members to attend the events of the meeting.

As the time for the dinner drew near, careful record was kept of the results brought in by these letters, and three days before the dinner each man who had taken part in the work was notified of his percentage of acceptances and the names of those who had not responded as a result of his personal attention. This called for a second letter to the tardy ones, which doubled each man's percentage and in some cases increased it many times over in the short space of twenty-four hours. Again, on the eve of the dinner certain members of the committee worked far into the night sending notices to each Booster with a last appeal for a special effort to make every member feel the necessity of his attendance. During the daylight hours the wires were hot carrying urgent telephone calls that would not take "no" as an answer. This ended the campaign of the Booster Committee and when the final count was taken in the banquet room of the

Auditorium Hotel, three hundred and ninety engineers were glad that they had heeded the call and were attending the Forty-fifth Annual Dinner of the W. S. E.

THE DINNER.

Tables were reserved for the alumni of several technical schools, for groups from the railroad offices, and the telephone company, and at one long table sat all the attending past-presidents.

The festivities started with a series of college yells and a few songs, in which each sang his part. From that moment good fellowship reigned supreme. Songs, music, a good-natured exchange of the rarest wit, and even a pink sheet "War Extra" announcing the results of the annual election in scare-head type, and parodied lyrics by James N. Hatch, relegated logarithms and blue prints to the evening's scrap heap and brought forth that spirit of fellowship found only when big-thinking men drop the worries of the business world and smile upon the lighter side of life.

Mr. Douglas Malloch, as toastmaster, was at his best. A series of clever telegrams good-naturedly exposing characteristics of some of the prominent members brought forth laughing applause at regular intervals. His stories and introductions were unusually clever and original, never failing to catch some one unawares for a good laugh.

Mr. Malloch introduced the retiring president, Mr. Lee; President-elect Jackson, Rev. Dr. R. A. White, Mr. Harry Wheeler and Hon. Harry Olson.

THE EXCURSION.

Bright and early the next morning (Thursday, the 14th) the waiting rooms of the Dearborn Street Station held many engineers all eager to purchase tickets, and board the seven-coach W. S. E. Special for an all-day trip through the industrial district of Chicago.

Immediately upon leaving the station a count was taken and given as five hundred members and guests, including parties from the American Bridge Company and Armour Institute.

The excursion arrived at the new Corwith Plant of the Crane Company and the inspection was begun on time. This was greatly simplified by the advance folders printed and distributed to the party by the committee. The folders described in detail and with illustrations the various industries to be visited on the trip.

The excursion train was then routed through the new clearing yard southwest of Chicago, where the greater part of all freight entering and leaving the city is classified and routed to its destination.

About noon the train was started for a long run to the Sears-Roebuck Company mail order house. Here the party received the kindest attention and was most delightfully entertained with a splendid luncheon. Here was remarkable evidence of big organization. Sears-Roebuck expected only two hundred at lunch, but the full five hundred reported. Yet there was not the slightest hitch or delay in their handling of that increased number. Guides escorted parties of twenty and thirty through the more interesting departments until about four-thirty, when the train left for the city.

It had been intended that the party should stop to inspect the new Soo Freight Terminal, but it was not thought advisable owing to the late hour.

Party Leaving Train at Sears, Roebuck & Co. Plant.

THE SMOKER.

In the evening of the same day three hundred and twenty-five members and guests assembled in the Society rooms for the final event of the Annual Meeting. The committee made good its promise that the smoker should be a strictly informal good time. There was a can of tobacco, some corn-cob and briar pipes, and plenty of stogies to make it a real smoker. At one side stood a good sized keg of cider and along side of it a table loaded with eight big pans of old-fashioned wholesome ginger bread.

After each one had secured a big piece of ginger bread and something to smoke, the meeting was called to the lecture room where the Armour Musical Club entertained with college songs and orchestra selections. George Frederick Wheeler gave an excellent illustrated travel talk on the California Expositions, the Grand Canyon, Yellowstone Park, and the scenery enroute.

After a reel of comic movies the smoker adjourned at eleven-thirty with the one regret that the 1915 Annual Meeting was over and that three hundred and sixty-five days must elapse before there could be another.

PROCEEDINGS OF ANNUAL DINNER.

DOUGLAS MALLOCH, TOASTMASTER.

At 6:45 p. m., the assembly was called to order by Retiring-President E. H. Lee, who called upon the Reverend Dr. R. A. White to lead in the invocation.

Retiring-President Lee: Gentlemen, I refuse to be responsible for this bunch, and I will now turn them over to the toastmaster, Mr. Douglas Malloch.

A Voice: What's the matter with Malloch?

Voices: He's all right. He's all right.

The Toastmaster: Gentlemen, we thought this evening we would reverse the ordinary custom and have all the speeches first. Now, I was introduced at this time, gentlemen, to make an announcement of the greatest importance to the engineers of all the world. At this moment, gentlemen, your picture will be taken by the photographer in the corner.

(A flashlight photograph was taken.)

(During the course of the dinner, from time to time pages appeared announcing telegrams for various members as follows:)

The Toastmaster: A telegram for H. S. Baker.

(Mr. Baker arose and proceeded toward the speaker's table.)

The Toastmaster: Never mind, Mr. Baker. I will read it. This is for Lieutenant H. S. Baker, from Woodrow Wilson:

"You will proceed at once to Mexico in heavy marching order, including six-shooter and dress suit and put down the revolution.

(Signed) Woodrow Wilson."

The Toastmaster: Telegram for Mr. John Ericson. We are going to censor this stuff tonight. Telegram for Mr. John Ericson.

Voices: Read it. Read it.

The Toastmaster: (Reading):

"Proceed at once to the seventeenth ward and report on the condition of the municipal fences.

(Signed) Carter H. Harrison and the Missus."

The Toastmaster: A telegram for Mr. J. J. Reynolds.

A Voice: Read it.

The Toastmaster: Be quiet, gentlemen. This is serious.

"J. J. Reynolds, Chicago Harbor Commission.

"Come at once. A four-pound white fish has just collided with the north pier and seven hundred feet of it have collapsed.
(Signed) Murphy, Foreman."

The Toastmaster: A telegram for Mr. F. E. Davidson. Is Mr. Davidson here?

A Voice: Read it.

(Mr. Davidson arose.)

The Toastmaster: Where is Mr. Davidson? There he is.

This is from General Pumpernickel, to F. E. Davidson:

"We are looking for brush behind which to conceal our siege guns. What will you take for yours?"

The Toastmaster: Telegram for Mr. W. C. Armstrong. Is Mr. Armstrong in the house? Will you stand up, Mr. Armstrong?

(Mr. Armstrong arose.)

A Voice: Read it.

The Toastmaster: We want you to hear this, gentlemen. A telegram to W. C. Strongarm—W. C. Armstrong from the Mayor of Elmhurst:

"Have seen the Northwestern Terminal and like it. What will you charge to build a new depot at Elmhurst?"

The Toastmaster: Telegram for Mr. W. L. Abbott. Is Mr. Abbott here? Mr. Abbott is not here, so I will open it and read it anyway, it may be something private.

From the editor of Harper's Magazine to W. L. Abbott, care Commonwealth Edison Company:

"Isham Randolph has just sent us another poem. Please send repair crew to his house at once. There is something the matter with his meter."

The Toastmaster: A telegram for Mr. Andrews Allen. Is Mr. Andrews Allen here? Will Mr. Andrews Allen stand up?

(Mr. Allen arose.)

The Toastmaster: This is from Rudyard Kipling to Mr. Andrews Allen:

"Please don't read any more of my poetry to the Western Society of Engineers. After hearing you read it they refuse to buy it.
(Signed) Rudyard Kipling."

The Toastmaster: Telegram for Mr. Onward Bates. Gentlemen, we will read it. This is a telegram from Doubleday, Page & Company to Onward, Christian Soldiers, Bates:

"Are you the author of a book entitled 'The Story of My Life, by Me'? and if so, what will you charge to write another like it? Also, what will you charge not to write another like it?"

The Toastmaster: Mr. O. P. Chamberlain.

A Voice: Stand up, Paul, and take your medicine.

(Mr. Chamberlain arose.)

The Toastmaster: Where is Mr. O. P. Chamberlain? A telegram for Mr. O. P. Chamberlain of the Dolese & Shepard Company. Aha, it is from Kaiser Wilhelm.

"O. P. Chamberlain,
"Dolese & Shepard Company,
"Chicago.

"The French have just captured one of our stone quarries in Alsace. What can we do to make them keep it?"

The Toastmaster: A telegram for Mr. Bion J. Arnold. I will read it:

"If you cannot take care of the traffic any other way, why not try the subway?"

The Toastmaster: Mr. Arnold has referred the telegram to Mr. Carter H. Harrison.

The Toastmaster: A telegram for Mr. John W. Alvord. I will read it, anyhow. Telegram for John W. Alvord from the Mayor of Dayton:

"Come at once. Ohio has gone wet again."

The Toastmaster: Is Mr. Robert W. Hunt here? Telegram for Mr. Robert W. Hunt, from Mrs. Netcher:

"Want to add seven new stories to the Boston Store. Understand you are just the man to add seven new stories to the Boston Store."

The Toastmaster: Telegrams for Mr. Ambrose Vincent Powell and Mr. Albert Reichmann. This is to Ambrose Vincent Powell from Anthony Comstock:

"Understand you are purely a consulting engineer. If you know any other pure engineers please wire."

The Toastmaster: And here is a telegram to Mr. Albert Reichmann: Is he here?

(Mr. Reichmann arose.)

This is a telegram from Isham Randolph—

(Voices were heard in the rear of the hall.)

The Toastmaster: I am not interrupting you, gentlemen, am I? Here is the telegram:

"Is the American Bridge Company built of concrete or is it steel trussed?"

The Toastmaster: Telegram for Mr. H. B. Herr. Is Mr. Herr here?

(Mr. Herr arose.)

From the Western Society of Engineers:

"Understand you have retired. Please explain how an engineer can do it on the money."

The Toastmaster: Telegram for Mr. John F. Wallace.

(Mr. Wallace arose.)

To John F. Wallace, from The Public:

"Please tell us if the new railway terminal will ever be built, and if so why not."

The Toastmaster: Telegram for Mr. W. H. Finley. To W. H. Finley, from the Chicago & Northwestern Railway:

"Understand that a man who does not work for the Chicago & Northwestern Railway has been elected President. How about this? Report at once."

The Toastmaster: Telegram for Mr. Lyman E. Cooley.

(Mr. Cooley arose.)

To Lyman E. Cooley, from General Kitchener:

"Come at once. You are a big man and we need you. Understand that you made a report for the Sanitary District that was so loud that twenty-seven Chicago politicians fell dead."

The Toastmaster: Gentlemen, I have a telegram for the Czar of Russia. Is he present? If he is not present, we will read it. Gentlemen, this is a state secret, you understand. It is a state secret, and it is entirely confidential. It is from Colonel Judson to the Czar of Russia. Is Colonel Judson here?

(Colonel Judson arose.)

Colonel Judson, you are about to send a telegram or a cablegram or something, to the Czar of Russia. Colonel Judson cables the Czar of Russia:

"Would be glad to represent the Engineering Department of the United States Government at the front and make observations as you suggest, but it is impossible. I understand you have shut off the supply of vodka. I suggest that you get John F. Hayford.

(Signed) Colonel Judson."

The Toastmaster: I have been asked to make an announcement in regard to this exertion—excursion—tomorrow. I think you gentlemen understand that there is to be an excursion tomorrow, and I want to say that over five hundred of the considerably more than four hundred gentlemen present have already signified their intention of going and there is plenty of room for you and your friends. And you are invited anyhow; you are invited to show up there tomorrow and see Chicago.

(At the conclusion of the dinner, the following took place:)

The Toastmaster: I believe the formal part of the evening is to be preceded by something somewhat of a business nature. The gentleman to whom I am to surrender the gavel needs no introduction from me to his friends. I refer, of course, to your retiring president, and I use "retiring" in the sense of modest. He has been some president, I understand. I understand, in fact I have heard something about his boosters' committee and entertainment committee, and smokers, and ladies' nights—a beautiful confession from a bachelor, it seems to me, and his students' nights, and moving pictures—and, yes, even the North Side Irrigation Congress.

I understand that since he has been president, your attendance has trebled. I said trebled, not trembled. I am not a member of your organization, but it seems to me that it would be a nice thing for you people to give him a vote of thanks, or three cheers—or something else inexpensive. But if you do want to get reckless with the Society's money, I suggest a box of Cremos.

I have the honor, gentlemen, at this time, to introduce myself to your president, Mr. Lee. (Three cheers were given for Retiring-President Lee.)

Retiring-President Lee: Gentlemen, we have a few brief formalities with which to begin this session of our Annual Meeting, and I will call on our Secretary for the annual reports. (Report elsewhere in Journal.)

Retiring-President Lee: Gentlemen, it is the usual custom that your retiring president shall render some account of his stewardship at the Annual Meeting, together with such other remarks, pertinent and impertinent, as he sees fit to make. (Address of Retiring President elsewhere in this Journal).

The Toastmaster: Mr. President, Mr. ex-President, and Gentlemen of the Western Society of Engineers:

At every banquet there comes a time when we excuse the waiters and begin the speeches, and many is the time I have wished to heaven I were a waiter. Tonight, of course, it is different. Tonight we have as speakers men who are known as after-dinner speakers wherever men who are known as after-dinner speakers wherever they are known as after-dinner speakers; men, I might say, whose names are household words wherever there is a household that has words.

I was much interested in the remarks of this president who is just coming in and this railroad train that is just backing out. I was interested in Mr. Lee's tribute to Mr. Grant as a man and an engineer. I never knew before there was any distinction between the two, and I was mighty glad to hear that this Society is preparing an Act for the Illinois Legislature.

I feel tonight that in opening the festivities of this evening, an occasion, I may say, that marks an epoch in the engineering history of the world, I should also say a few words about another gentleman who is present here tonight, to whom a great deal of credit is due for the success of this evening. If Mr. DeBerard will stop blushing I shall explain that in these few entirely inadequate and feeble words I am referring to your Toastmaster, but Mr. DeBerard also deserves some credit as chairman of the banquet committee, and I am going to see that he gets it, because credit is a hard thing for a newspaper man to get.

It is always customary to have the Toastmaster make a few and appropriate remarks, and the fewer the appropriater. I may say that it is customary to have the Toastmaster make some opening remarks, so that there will be at least one good speech during the evening. His speech is supposed to be sort of a monologue, and I suppose you know what a monologue is. It has been defined as a conversation between husband and wife, but your Toastmaster is at a loss to know what to say in this monologue.

I hate to stand up here in the presence of my friend Mr. Finley and talk about engineering, and expose my ignorance. And I hate to talk about anything else and expose his. Mr. Finley has forgotten more about engineering than I will ever know, and he has forgotten more about engineering than anybody will ever know, if he can help it.

It is difficult for a layman to stand up before an audience of scientific or technical men and talk about anything that he understands—that is, so they will understand it.

I thought I might say something about engineering, and that I ought to read up on the subject. And so I went out and got a book by my friend Ernest McCullough, at a second-hand book store. I knew it was McCullough's book, because I recognized his handwriting. In the front of the book was written: "Presented with the compliments of the author to C. F. Loweth." This is a very well printed book, and can be had at any book store, and I am glad to advertise it. I hope that McCullough will do as much some time for some of mine, because I never mention them myself. You will find a lot of McCullough's books over at Frank Morris' book store. Frank laid in quite a stock of them, and within a short time he applied for a receiver. The title of Mr. McCullough's book is "Engineering as a Vacation." As I say, it is a very fine book, but it did not do me any good, because it hasn't anything in it about engineering.

Then I thought I might read Warder's Journal of the Western Society of Engineers, but I didn't do that because I didn't want to appear eccentric.

Then again I thought I might call on Norman Stineman for some help. I thought I might say a few words about reactions in a three-legged stiff arm with hinged column bases. Of course, I know you gentlemen all understand what that is. At least, you did until Stineman explained it. This is not intended as a slam at the engineer or the scientific man. Science has done great things for mankind. It has, for example, discovered a lot of diseases that are incurable. Then it has discovered a cure for them. And then it has discovered that the cure is unnecessary.

Some scientist proved the other day that we still have stone age brains. I don't know anything about that, but I have attended enough banquets to know that we still have stone age stories. A scientist, a professor in an eastern university, proved a short time ago that an angle worm can think. Now, that is very important, gentlemen. It was very interesting to me. It demonstrated that a contractor is no angle worm.

Right in here, to square myself, I want to read a few lines in which I have tried to express my idea of the engineer and of other men who do and build things:

The band is on the quarter deck, the starry flag unfurled,
  The air is mad with music and with cheers;
The ship is bringing home to us the homage of the world,
  And writing new our name upon the years.
Her officer is on the bridge, we greet him with hurrahs,
  But some one says, "Not he the glory won,
Not he alone who wears the braid deserves the loud applause,
  But don't forget the man behind the gun."

'Tis said that to embattled seas our ship sailed forth at dawn,
  Unheeding shot, unheeding hidden mine,
And through the thunders of the fight went steaming bravely on,
  The nation's floating fortress on the brine.
And never throbbing engines stopped nor yielded flow of steam
  In all that bloody day from sun to sun;
The good ship sang her battle cry in hissing clouds of steam,
  To cheer anew the man behind the gun.

I look upon her shining bore, her engine's pulsing heart,
  I look upon her bulwark shaped of steel.
I know there is no other skill as great as gunner's art
  That makes the world in homage kneel.
This mighty ship, resisting shell, defying winds and seas,
  Is fruit of honest labor rightly done.
The man who built the ship, my lads, remember him,
  For he's the man behind the man behind the gun.

Now, it does not take very much to make an after-dinner speaker. All it requires is a good digestion. A man does not have to have the brains of an Ingersoll; all he has to have are the works of an Ingersoll.

But we must be getting on to the subject. I have tried to put it off as long as I can, gentlemen. It is here on the program, and, of course, you understand the committee paid good money to have this program printed, and these gentlemen have been promised.

We have two speakers here tonight named Harry. In all its forty-five years, at a banquet this Society has never been so Harryed before. Each of these two gentlemen has come to me and said that he wants to speak first because he wants to get away as soon as he is through. Apparently these two gentlemen have heard each other before. But I have told them that they will both have to stick if we do. Of course, I have not promised them that we will. In view of the fact that Mr. Wheeler and Judge Olson have each and both asked me to call on them first, the only thing for me to do, apparently, is to call on Dr. White.

Dr. White is pastor of the People's Church on the South Side. He is such a good speaker that men even go to church to hear him. Dr. White is somewhat of an engineer himself. He has taken the Christian religion and squared it to the needs of men.

Dr. White will speak to you upon "The Philippines." And I now have great pleasure and the honor of introducing to you Dr. R. A. White.

(Address of Dr. White elsewhere in the pages of this Journal.)

Toastmaster: The Toastmaster is quite willing to excuse Dr. White for that reference to the mule, although I hate to hear a man talk about his own ancestry.

I am astonished that no speaker tonight has paid any tribute to this intelligent audience. And I want to do that, and I want to tell you that I like the audience. You remind me of a certain—well, I will give you the story:

A New York man and a Chicago man were talking about dance halls, and the New York man claimed that down in New York City they had the toughest dance halls in the world. And the Chicago man said, "Why, say, we have got a dance hall out here on the South Side in Chicago that is so tough that when the fellows come in, they search them to see if they have any concealed weapons, and if they haven't they give them some."

Now, I rather think that this audience likes this program, as far as it has gone, and I am sure that I am quite willing, as your accidental Toastmaster, to introduce these other gentlemen. I am as willing, you know, as that colored man who went with a hunting party down in Tennessee. He was sort of a cook for the party, and they never could get him out of the camp. He was mortally afraid he would see a bear. They told him a bear hadn't been seen down in that country for twenty years. But the first time Sam went up in the woods he came tearing back into the camp and somebody said, "Sam, what is the matter?" He said, "You see that little bresh up there on de mountingside?" They said, "Yes." "Well, Boss, I went up there with a little Flobert rifle, and while I was lookin' round up there I looked down and heah wuz a great big black b'ar followin' me, and he was asmellin' my tracks, and he would smell one track, and then he would come a little closer and he would smell another track, and then he would come a little closer and smell anudder one of my tracks. And I looked down at him, and I says, 'Misto B'ar, if it is de tracks you is lookin' fo' I'll just dash off a few fresh ones.' "

The next speaker that I am going to dash off is the Honorable Harry A. Wheeler, and he will talk to you on Business Conditions, if I know anything about the law of probabilities, and I don't.

Perhaps in introducing him it would be appropriate for me to briefly review—briefly to review, I beg your pardon—briefly to review the business year just closed. In a business way the year 1914 came in like a lamb and went out like a Mexican hairless dog. If a man wanted to make any money, he had to show some speed. He had to be like O. P. Chamberlain. I don't know whether you know it or not, but O. P. Chamberlain used to be an athlete in college. He could do a hundred yards in ten seconds flat. The other day a man offered him an order, and he made it in nine.

I don't want to make all the speeches, but I do want to say personally I am not inclined to attribute business conditions to the administration or to the war in Europe. Whenever we have a little business depression we are too much inclined to look abroad for the cause, when it may be very close at home.

In the building in which I have my office, there is a doctor on the seventh floor and a barber on the ninth floor. The other day I went into the barber shop. The doctor was getting a shave, and they were talking about business conditions, and they agreed that business was bad, but they could not agree as to the cause. The barber thought it was the trusts. The doctor thought it was anti-trust legislation. Well, as a matter of fact, gentlemen, they were both wrong. I could have told them what was the matter with business as far as the doctor and the barber were concerned—Christian Science and safety razors.

Talking about business has been about as pleasant as an icicle down your neck, but Mr. Wheeler I know brings us a message of optimism. Here in Chicago I believe that Harry Wheeler has been more in the eyes of the public than anybody I know, unless it is the cinders from the Illinois Central. He has been President of the Chicago Association of Commerce, and President of the Chamber of Commerce of the United States, and has held other positions of honor and trust—and no salary.

I had a great many more pleasant things about Mr. Wheeler, but I don't want to make the introduction better than the speech.

I now have the honor to introduce the Honorable Harry A. Wheeler, whose every idea is an inspiration and every gesture a picture.

Mr. H. A. Wheeler: Mr. Toastmaster:

God knows it is a hard life for a banker to be dragged out by such a toastmaster, to follow a preacher, and to be followed by an eminent jurist. What chance have I?

Well, not being versed even in the remotest borderlands of your profession, I am not likely to talk shop. But I am related to your profession, because the only boy I have was induced, because of my great respect for the engineering profession, to try to become one, and he is on the way. Only, I am using him in a rather different field of action than that which the majority of engineers are trained for. That is, so great was my respect for the training accorded to an engineer, not only in those things which pertain immediately to his profession, but to the substance which is gained in that training in integrity and honesty and accuracy and sincerity, that when I wanted the boy to follow into the banking business, I gave him an engineer's training as the best preliminary training that a boy could have.

(Address of Mr. Wheeler elsewhere in this issue.)

The Toastmaster: Didn't I tell you?

In referring to these two Harrys tonight, I have been in doubt which is the real Harry. And the speech which we have just heard, and the one I know we are about to hear, still leaves me in doubt, because I know that the deriviation of the word "Harry"—and this is authentic, probably the only authentic thing I have said tonight. "Harry" comes from an old Scandinavian word, "Haar," meaning the devil himself.

The next Mayor of Chicago, whoever that may be, is going to have his hands full. During the next twelve months the subway will be built, Michigan Avenue widened, Twelfth Street Viaduct constructed, the new Union Station built, taxes reduced, and the Chicago River straightened. I know this because the candidates have said so.

I don't know that Judge Olson is a candidate, but on the other hand I don't think we will have to use any forcible feeding to get him to take it. There are a great many people who think that Harry Olson is just the man to do these things. There are two of them at this table tonight—and I am one of them.

Judge Olson has made his home in Chicago for a great many years, if an after-dinner speaker may be said to have a home. Judge Olson is a good citizen, a constructive official, clean, able and honest. There are a great many other pleasant, complimentary things that could be said about Judge Olson and I would be glad to say them, but the hour is getting late—and I am not much of a liar anyway.

I have the honor to introduce to you—I should say, present my good friend Harry Olson, Chief Justice of the Municipal Court, and the next Mayor of Chicago.

(Address elsewhere in this issue.)

The Toastmaster: Gentlemen, I want to say that this concludes the festivities of the evening, and the speakers have had a lovely time. I thank you.

Address of Retiring President, E. H. Lee.

Toastmaster: I have the honor, gentlemen, to introduce myself to your retiring president, Mr. Lee, and although I am not a member of your organization, it seems to me it would be a nice thing for you to give him a vote of thanks, or three cheers, or something else inexpensive. (Three cheers were given retiring President Lee.)

E. H. Lee: Gentlemen, it is the usual custom that your retiring president shall render some account of his stewardship at the Annual Meeting, together with such other remarks, pertinent and impertinent, as he sees fit to make.

"Hard Times" might perhaps be considered a fit subject for these remarks in view of present conditions. Last July, the period of depression that for upward of two years had existed in this country, was suddenly intensified by the shock of the appalling war, now being waged. Engineering as a profession is peculiarly susceptible to times of financial stringency, and it is to be feared that many of our members are suffering severely on account of existing conditions.

"Hard Times," however, is not the selected topic, but rather "A consideration among other things of some encouraging factors in the present situation," and if you ask me, "Watchman, what of the Western Society for 1914?" the answer must be "All's well."

Our society has had a period of inactivity, insofar as growth of membership is concerned. But, as in western dry farming, a year's harvest must be followed by a year's rest, during which the fields lying fallow are plowed and harrowed in order to store up the elements of fertility for the succeeding year. So this year of apparent rest for our society has not been an idle one. Our effort has been to cultivate our field intensively with a view to future harvests.

One of the factors we have felt to be the enrichment of the Society is in the friendliness and good fellowship resulting from human contact, and toward that end our chief efforts have been directed.

The amount of hard conscientious work done by the committees of the Society is little appreciated by some of its members. Your Legislative Committee is preparing an Act for submission to the Illinois Legislature, designed to remove some of the unjust disabilities laid upon engineers by existing law. Another committee has negotiations under way, which we trust will result in securing more adequate and permanent quarters for the Society. Some of the younger members have been given an opportunity to serve the Society in committee work, which they have done most effectively, and this cannot fail to bind them more firmly to the Society.

The great engineering event of the past year, one of the greatest of history, was the opening of the Panama Canal, that joins the waters of the Atlantic and Pacific. This great work will loom ever larger as the years recede, although its magnitude is now obscured by the clouds of war. Lying outside of our immediate boundaries, but due to American genius, it must greatly influence the commerce and life of the entire world.

Within our country the granting to the railroads of a partial advance in freight rates offers the hope that we are soon to see a return of general prosperity.

The principle of the regulation of railroads by the Government is accepted by all as just and right. Therefore obedience is to be expected. But equity requires that obedience by the railroads shall be accompanied by adequate protection. Even the old Mosaic law stipulated that obedience and protection should be conditions reciprocal to each other.

The railroads in the past have been charged with many errors of omission and commission. These charges fall into three general classifications: that the railroads are over-capitalized; that railroad men are dishonest and that railroad administration is inefficient.

Thoughtful men observe that all new enterprises in the commercial and business world are started on credit; that they involve large elements of risk; and that the rewards of any enterprise should be in proportion to the risk.

Railroad companies were formerly considered private enterprises, and their status as such has only recently been changed by the decision of the courts. Therefore until recent years, in common with all business, their owners have expected profits in proportion to the risks assumed. Even so, the fact remains that most of the capital subscribed by the men who originally financed the railroads has been entirely lost to them. Further, that railroad capitalization today is represented by actual value is accepted as a fact by very many of the best informed men of the country.

Some railroad men have been dishonest, but thoughtful men observe that rascality is not peculiar to the railroads, and that rogues are found in all the various walks of life.

The iteration and reiteration of charges of over-capitalization, dishonesty, and inefficiency is diminishing, and the chief purveyors of these charges at present are men from that noble band of patriots, who are public spirited "for revenue only."

Before saying a further word as to the efficiency of railroad administration it may be well to recall that reciprocity can be stated in the Algebraic Symbolism of Life as an equation, in which the right to exact obedience equals the obligation to give protection. Likewise other equations there are, some of which may be stated as follows:

Wisdom equals learning or knowledge, plus experience, plus good judgment. Here it is to be observed that mere knowledge never has and never can equal wisdom. Efficiency equals wisdom, plus the will and the power to act. So here again it may be emphasized that mere knowledge is not equal to efficiency, which may be paraphrased thus: Efficiency equals knowledge, plus experience and good judgment, plus the will and the power to act.

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Inefficiency therefore may result from the absence of any of the terms in this equation; and the resulting loss is a variable, which under certain conditions may be equivalent to disaster or to utter ruin.

Our country in its government, our business in its modes and methods of procedure, even our system of education, are characterized by inefficiency. Perhaps this is the price we pay for liberty as we know it.

Through inefficiency in agriculture, a foundation of national well-being, our farms, a few short years ago virgin soil the most fertile on the globe, now produce an average yield of less than 15 bushels of wheat per acre, while elsewhere tillage areas cultivated for hundreds of years, treble our average production.

The military and naval officers who are charged with the defense of our Great and Beloved Country, have for years been making urgent recommendations and appeals for adequate preparation to that end. Their efficiency, once given the power to act, is demonstrated by the magnificent results achieved at Panama. Their sincerity is proven by the pathetic fact that in case of emergency their lives must be the first to be laid down in defense of their country. What thoughtful man, who observes the continuous and even contemptuous indifference of the Government at Washington to these appeals can doubt the grave inefficiency thus demonstrated.

No thoughtful man can question the honesty or sincerity of our Interstate Commerce Commission, nor the ability and efficiency of certain of its members. He observes, however, that most of its members lack practical experience in the actual problems of railroad administration. He notes that the Commission is overwhelmed with a prodigious burden of detail, most of it self-imposed, the remainder imposed by Congress but the sum total of which is entirely beyond the capacity of any such body, as a mere question of physical endurance. He also notes that the Commission has in great part failed to generalize its great and pressing problems, largely occupying its time with fussy detail. He remembers that the efficiency of the Commission has been called in question in an official way by at least one of its own members. Can the thoughtful man be criticized therefore, if he detects the irony of a situation in which the Commission attempts to assume the role of instructor in efficiency? The thought to be emphasized is not that the railroads are perfect or even approximately so, but that relatively the efficiency of our railroad administration is probably far greater than the average efficiency of either Government or of most other business activities.

During recent years the railroads have enormously reduced the cost of handling freight per ton mile, a unit that faithfully discloses actual efficiency; although the saving thus made has been entirely absorbed by the increase in cost of labor, material and taxes.

In considering the handling of a shipment of less than carload freight, as a typical example, the mind of the average man immediately runs to that element of the transaction which it is the duty of the railroad to perform. As a matter of fact, every such shipment may be separated into a sequence of elements. The shipment from the farm, warehouse, or factory is first handled by hand there, at a cost of from $4.00 to $10.00 per ton mile. It is then transported to the railroad by team or dray at a cost of from 40c to 80c per ton mile. It is then delivered to the railroad, whose average total revenue for the handling of the shipment is probably from 3c to 6c per ton mile, although it is to be noted that the average revenue per ton mile to the railroads, for handling both carload and less than carload freight the country over is only ¾c per ton mile. When the shipment reaches its destination on the railroad it again is handled to its final destination by dray and by hand at the costs per ton mile already given. In other words this shipment in completing its entire transportation trip is handled by the railroads at a cost per ton mile of from only 1/10th to 1/100th the cost per ton mile as compared with the cost when handled by dray or by hand.

True, the average trip on the railroad is so much longer than the average trip by team or by hand, that the total cost for each element is not in the ratio of ton mile cost. Yet where the elements of cost for transportation vary so widely in these different phases, it is a subject of wonder that efficiency is not insisted upon first where its fruits are entirely gathered by those who entirely control the factors involved.

A simple illustration is to be observed everywhere, in the condition of public highways throughout the country.

Artemus Ward was perfectly willing to have his wife's relatives drafted for the war. Many business men apparently hold the same view relative to the efficiency of their own work as compared with that of railroads.

One of the most hopeful signs of the time is the fact that judging from current indications not only the Interstate Commerce Commission, but also the business man and the man in the street are beginning to realize that the prosperity of the railroads, while of importance to their security holders, and to the men who work upon them, is of far larger importance to the general well-being of the country.

They are beginning to realize that the railroads starved will be in the case of the old horse which was taught to eat shavings, but which died just as his education was completed, thereby effectually removing his master's only agent of transportation. They are coming to see that only at peril to the general well-being can our equation be disregarded; namely, that the right to regulate and to require obedience is equal to and reciprocal with the obligation to equitably protect. They are coming to see that it is neither fair nor reasonable to seek to enforce upon the railroads standards of honesty and efficiency, vastly higher and more rigid than those applied to either business of other kinds or to Government itself.

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Gentlemen, the Engineering Profession is intrinsically a Profession of Efficiency, and insofar as any of its members fail of true efficiency, in that degree do they fail as engineers. With the abounding opportunities lying on every hand for our work, as thus defined, how can we as engineers be other than sanguine as to the future?

And shall we not also bear our part in helping to create conditions which shall make for the return of general prosperity, by calling attention to the fact that the prosperity of the railroad, equally with the prosperity of the farm, spells general prosperity, and by demonstrating to our friends and neighbors as opportunity may offer the truth of the equation, that the obligation to protect equals the right to regulate?

Gentlemen, a year ago I assumed office as president of this Society with a very deep sense of indebtedness for the honor conferred upon me. In passing the office to my successor I feel a still deeper and heavier sense of indebtedness for all the kindliness and friendliness and co-operation of the officers and members of this Society manifested to me during the past year. And I wish to take this opportunity to thank the members of this Society most sincerely and heartily.

And, gentlemen, I want to add a word of appreciation for our retiring vice-president, Mr. Grant. He has endeared himself to the Society by many years of conscientious, faithful work for its benefit, and we admire him both as a man and as an engineer.

And now, gentlemen, it becomes my pleasant duty to introduce to you as our new president one of the three strong men who struggled so valiantly a year ago. Gentlemen, our new president, Mr. William B. Jackson.

ADDRESS OF PRESIDENT-ELECT WILLIAM B. JACKSON.

I greatly appreciate the honor that the members of our Society have conferred upon me in selecting me as president of the most important engineering society in the West. And this appreciation is necessarily increased as one looks over the list of our past presidents, a list of which we may well be proud, in which are counted the names of such men as Octave Chanute and Alfred Noble, who gave of their best to the Society. I must not mention any of our living past presidents, else my enumeration would necessarily become too long.

This honor is particularly gratifying, for I have a very high regard for the importance of well-established and effectively-managed engineering societies to the engineering profession. I believe that the lack of membership in the Western Society of Engineers by any of our older and well-established fellow engineers of Chicago tends to indicate a lack of full appreciation of the broad principles of engineering and of the importance and possibilities of the engineering profession. I believe that in no profession can its broad and underlying principles be beneficially applied with greater universality to the affairs of life than in ours.

How is it, therefore, that so many of us have failed to see their direct application except in matters having to do with physical structures, or in the working out of the most effective methods of handling materials in our shops and in its fabrication? The engineering profession primarily stands for honesty, economy, efficiency, charity, brevity, and the ability to visualize those things not yet accomplished, but which should be accomplished.

There is and has been, I expect, since the beginning of man, much controversy as to whether the world has been improving in the past, and whether it is on the upgrade at the present time. There seems to be fair grounds for such controversy. But in the case of the engineering profession there can be no question on this score, since a hundred years ago there was no such profession. Today there can be no question as to whether the engineering profession is on the upward part of the curve, but we must necessarily agree that it has not yet progressed very far along the curve. I believe it is largely through the agency of such combinations of engineers as the Western Society that this much to be desired progress is being made. In fact, if our profession is to become of the greatest possible benefit to humanity we must look largely to our engineering societies for the inspiration and the broadening of view to enable us to do our part in making it so.

We not infrequently hear the thought expressed that engineers as a class have not taken the place in the bodies politic, economic, social, that they should, and that they have not been given the recognition to which they are entitled. I am inclined to agree with the first part of this thought, but I am not in agreement with the latter part, for I believe that engineers and the engineering profession have received due credit for what they have accomplished, so that it behooves us to see to it, as we make engineering principles better understood by the people at large, that they also are given an appreciation of the fact that the engineering profession is one having as great, if not the greatest, beneficial influence on the development of the best civilization of the world.

A few days ago I received a beautifully executed monograph descriptive of one of our important comprehensive electric lighting and power properties. The first page was given over to the names of the officers of the company, including the president, the board of directors, the vice-president, the secretary, the treasurer and the general counsel, but the name of no engineering officer was among them; this notwithstanding that after the splendid organizing, financing and general engineering ability of the president, the most important factor in the successful creation and operation has been the engineer. We can see a reason for such omissions when we come to think of how many of us forget our possibilities for usefulness along lines other than the mere application of our engineering knowledge to physical structures.

You may ask, what has all this to do with the Western Society of Engineers? Simply this, that the great object of a well-organized and effectively-managed engineering society such as ours should be the inspiration and broadening of the point of view of engineers. I believe that every meeting of such a society should have very definitely in it some element of this character. During my administration it will be my earnest endeavor to limit, so far as the conditions will warrant, the presentation in our meetings of pure mathematics and dry facts, and to encourage to the greatest possible extent those features of our papers and discussions and meetings that will stimulate us all to an appreciation of the big things in engineering. In this I do not wish it to be thought that I view the technical features of engineering societies lightly, but rather that I wish to eliminate from presentation in our open meetings all material that is not helpful in making our meetings most useful and enjoyable.

In what I have above set forth, I believe I have the hearty sympathy of our retiring president, and as I look over the work done by the Society during the past year it seems to me that his administration has crystallized much of it into actual practice. I shall hope to have Mr. Lee stand shoulder to shoulder with me during this coming year in helping me to carry forward the splendid work that he and his helpers have so ably started during the past year.

ADDRESS OF DR. R. A. WHITE.

Toastmaster: Dr. White, pastor of the Peoples Church on the South Side, will speak to you upon "The Philippines." He is such a good speaker that men even go to church to hear him. Dr. White is somewhat of an engineer himself. He has taken the Christian religion and squared it to the needs of man.

Dr. R. A. White: Mr. Toastmaster, Mr. President and Gentlemen of the Western Society of Engineers:

I submit to you that it is a perfectly unfair handicap to an ordinary after-dinner speaker to have to follow an introduction of that kind, and especially a toastmaster of such renown and undoubted wit as my friend the toastmaster of the evening. And thus handicapped I think I can appreciate the feelings of the young farmer's kid who had been sent home with a mule which his father had borrowed for the day. It was getting toward the close of the afternoon, and the boy started to take the mule home. He got down the road a ways, and this mule, according to the habit of some mules, absolutely refused to go any farther. This mule stopped. The boy coaxed him, whipped him, pulled him and pushed him. But the mule would not budge. In the midst of this predicament a physician came driving by and said: "Sonny, what is the difficulty here?" The boy, now half in tears in his ineffectual efforts, said to the doctor: "I am trying to get this mule home and I can't budge him." The doctor said: "Well, sonny, perhaps I can help you out a little." So the doctor pulled out a bottle of carbolic acid and poured it on the mule's back, and the effect was certainly astonishing to the boy, and possibly to the mule himself, for he started down the road at a clip that it was mighty hard to beat. As he disappeared around the curve in the road, the boy, looking after him in perfect wonder, turned to the doctor and said: "Doctor, have you got any more of that stuff?" The doctor said, "Yes, plenty of it." "Well," said the boy, "Doctor, pour a lot of that on me. I have got to catch that mule."

I assure the toastmaster that the use of this particular animal in this illustration is entirely impersonal, but I wish somebody would pour something on me so that I might even hope to keep in sight of this toastmaster. The only satisfaction I have in the situation is that Mr. Wheeler and Judge Olson have got to make the same race, and I hope they will do a great deal better than I expect to.

I consider it a great honor, gentlemen, to be the guest of this splendid Society, men who are graduates of our great institutions, men of intelligence, of effectiveness and efficiency. My only regret tonight, as I share your joyous fellowship, is that when I was in college I did not study engineering instead of theology. Then I should have been boring mountains, instead of boring, as I have done for the last twenty-three years, one perfectly delightful but helpless congregation in this city, a congregation that has absolutely now lost all hope of ever getting rid of me.

In speaking to you tonight I am congratulating myself upon the fact that I am first on the program. I am usually placed at the tail end, and then if the other fellows are considerate and generous, I am permitted to have whatever time is left, and to speak to whatever number of gentlemen have staying powers enough to hang on until the end of a series of after-dinner speeches. Now the tables are reversed, Mr. Wheeler and Judge Olson take the tail end of this tonight, and I shall feel perfectly comfortable and consume all the time that I want.

I don't know whether or not it is an old story to you gentlemen, but I was feeling that probably I had as much time on my hands as the Bishop of London who was met on the street one day in London by a little freckled-faced street boy. And if you have seen those chaps over there you would appreciate the humor of the story all the more. The street boy said to the Bishop: "Bishop, what time of day is it?" and the Bishop, who was a generous-hearted sort of fellow, dug around in his pockets, finally fished out his watch and said: "Sonny, it is half past four." And the little fellow looked up into the Bishop's face and with a twinkle in his eye said: "Bishop, at half past five you go to hell." The Bishop was very angry at this, and started after the boy to chastise him. You know something about some of those crooked streets in London, and they hit up a pace down one street and up another, and they doubled this corner and then another, until the old Bishop, who was a little corpulent, was simply out of breath, very nearly "all in." Just as he turned a certain street corner, he ran plump into the arms of the Bishop of Oxford. And the Bishop of Oxford said: "My good

Bishop of London, what is the matter with you? I never saw you so all-in and done-up in my life." "Well," panted the Bishop, "do you see that little rascal running down the street there? Well, he came to me a few moments ago and he said, 'Bishop, what time of day is it?' and I got my watch out at a great deal of trouble and I said, 'Sonny, it is half past four.' And the rascal looked up in my face and he said, 'Bishop, at half past five you go to hell.' " "Well," said the Bishop of Oxford, "that is all right. What's your hurry? You have an hour yet."

The toastmaster sent over a card to me a few moments ago and said: "How much time do you want?" I wrote on the card and sent it back by parcel post, "How much can I have?" What do you suppose he said? He send it back again and said: "You can have fifteen minutes." Fifteen minutes, for a speech on the Philippines! Now, I don't want to be unkind, you know, or ungenerous toward my friend the toastmaster. I have trained with him before and I know him. I have an awful suspicion—I can't quite get rid of it—that the curtailment of my time to fifteen minutes was not an entirely unselfish proposition on his part. He is some talker himself and needs time.

I rather suspect, gentlemen, that so far as my speech is concerned, I am in wrong tonight. I can't say that I was commanded to say anything about the Philippines, and yet in a way I was. I was something in the situation of the Irishman who had just joined a new cavalry regiment, and the boys, thinking they would have some fun with him, the first time they put him on a horse they put him on the ugliest horse in the whole outfit. The sergeant came and said: "Now, Pat, after you get on that horse you are not to dismount, you understand, without orders." "Sure," said Pat. They started the horse, he made about three jumps, his heels went up in the air, and Pat went off on the ground. The sergeant came up, looked at him sternly, and said: "Pat, you dismounted." "I did," said Pat. "Did you have orders?" "I did," said Pat. "From headquarters?" "No, begorrah," said Pat, "from hindquarters."

Now, I didn't have orders from headquarters to speak on the Philippines, but I did have permission from headquarters. I appreciate that no one in the world except a preacher would dare to stand up before a jolly lot of good fellows after a fine banquet like this, and attempt to say anything very serious. Not because you are not thinking men, but because once in a while, I suppose, you like to be relieved of thinking, and of things serious. I felt very highly complimented, as I am sure Mr. Wheeler and Judge Olson did, by the assurance given you by the toastmaster of the evening that it did not require very much intelligence to make an after-dinner speech anyhow. It takes about as much intelligence to make an after-dinner speech as it does perhaps to make a certain automobile. A little doggerel is running through my mind that I heard the other day for the first time, which is something like this:

There was a man and he broke his leg;
He could not work, and he would not beg.
So he bought a string and a little tin can,
And he made a Ford, and the darn thing ran.

Now, your toastmaster seems to think you can get up an after-dinner speech on a very small intellectual capital. That it is as easy to make a speech as it is to make a Ford.

The only justification for my speaking briefly upon the question of our duty towards the Philippines, lies first in the fact that it is one of the most important questions before the American people at the present time. It is a national question and ought not to be a merely political party question, and it must be settled, if it is ever settled properly, by the enlightened judgment of all the people and not any particular section of the people. The second justification possibly lies in the fact that I have recently returned from the Philippines, where through the courtesy of Governor Harrison, a man whom I very highly respect and to whom I owe many courtesies, I had the opportunity of studying the Philippine question somewhat at first hand.

The Philippine problem presents itself under two aspects. First, ought the United States to give up the Philippines entirely? Will it be the best thing for our country to do that? And, secondly, from the standpoint of the Filipinos, will it be the best thing for the Filipino people if we do give them up?

I am perfectly free to say that from the standpoint of our own country I do not believe that those islands are valuable to us from any point of view, or ever will prove to be of sufficient value to us to compensate for the responsibility involved, the more than probable political—and perhaps worse—complications that their continued possession will lead us into in the future of the great oriental world. For, gentlemen, the great battle ground of the future, the next great battle ground of the world, whether merely commercial, or whether, as is more than probable, it will be military, will be in the orient. The possession of the Philippines on the edge of the storm center of the future revolutions that are bound to take place in China and Japan, will almost inevitably draw the United States into the maelstrom of that future struggle.

We, of course, may say, "We have spent much money in the Philippines. We have got to hold them and get our money back." Yes, the Philippines Islands have cost us something. They cost us $170,000,000 to take. We sent 123,000 soldiers across the Pacific before we conquered the little men of the Philippines and subjected them to our political will. But if there is no greater reason for America's staying in the Philippines than to stay until we have exacted a return for our investment and gotten our money back, then in my judgment we should pack up and get out bag and baggage. For if there is an un-American proposition, in my opinion, it is, that, having taken these islands against the will of those people—

at a great expense incurred, however, by our own voluntary purpose —we now insist that we will hold them on the cold ground of commercial expediency until the Filipino people themselves have returned what the venture cost us.

Or, some may urge, with great show of reason, that we want the Philippines because of their future commercial value to the United States. They point to the fact with pride that under the Spanish régime our trade with the Philippines was about $500,000 a year, and that in the 1913 we sent to the Philippines $25,000,000 worth of American products, and brought back $21,000,000 worth, leaving a balance of trade in our favor of over $4,000,000. They assure us still further that in that year we bought $751,000,000 worth of raw material of one kind and another that we need in this country, from the various tropical and sub-tropical countries of the world, and that every dollar's worth of that can be produced in the Philippines. Furthermore, they point to the fact that in that enormous trade with tropical and sub-tropical countries, the balance of trade is very largely against us. Out of $640,000,000 worth of imports on the part of the United States in 1913, we shipped to the same countries $277,000,000 worth of American products, leaving for those tropical countries a balance of trade against us of over $363,000,000.

If the prosperity of a country is to be measured, as I doubt not it must be, in spite of certain political economists, by the balance of trade in its favor, then our trade with the tropical or semi-tropical countries of the world has been a commercial failure. And the argument is,—and it is a seductive one, from the standpoint of industry and commerce,—why not keep these islands, develop their enormous resources, buy of them what we are now buying of a dozen different countries of the world, and have the profits and the trade wholly within our own possession?

I must confess, gentlemen, that so far as I am concerned, I cannot quite feel that it is American to hold those islands against the will of these little brown people, simply because American business and industry may profit at the expense of what those people consider their political rights. Therefore I am frank to say that from my standpoint there is no sufficient argument that justifies the United States, from its own point of view, from the standpoint of its own profit and value, to maintain the flag in the Philippine Islands.

But now let us turn for a moment to the other side of the question. I have only a moment in which to say this to you. But let us ask ourselves whether the Filipino people would really be better under absolute independence than they are under the present American régime. And to appreciate and to form conclusions on this matter, gentlemen, you must go there. And if you go through those islands, as I did, you will come back, I am sure, feeling an increased pride in our American control of the Philippines. For it is nothing less than a marvel, gentlemen, what American initiative and control have done and are doing for the people of the Philippine Islands. If our officials here in America were half as considerate of public interests, the conservation of our great national resources for the future of this nation, as American officials are in the Philippines today for the commercial, industrial, moral and educational interests of the Philippines, America would have less cause to breed reformers and less reason to complain of official action.

I suggest, gentlemen, that in groups of twenty-five or thirty, you take the controlling politicians and officials of our American life, give them a vacation of six months, send them to the Philippines to school, and let them learn how to govern a people in the interests of the whole people and for all the people, and not for any section of the people or for any political party.

I haven't time to tell you in detail what they are doing in the Philippines. But you gentlemen will be interested in knowing that one of the great things that is being done in the Philippines today is being done under the leadership of men of your profession. I met some of those men, possibly some of them are members of your organization. These men today are flinging out great lines of railways and roadways, and building the finest bridges in the world. Nearly 6,000 miles of the most excellent roads that you ever motored over have been constructed, and all within the last twelve or thirteen years. The progress in education is marvelous. The islands are being dotted with beautiful school houses, and modern methods of elementary and higher education are everywhere prevailing. Sanitary science, with its modern system of bacteriology, sanitation and health is transforming the life of the islands. Great hospitals are in evidence. There is safety, peace, quietness, so that you can go, even back among the savage hill tribes of the mountains, and feel safer than you will feel tonight on your way home on the streets of this magnificent city of Chicago. All that and more America has done, in some twelve or thirteen years. America has done more for the Philippines in the fifteen years of its occupation than proud Spain did for them in three hundred and thirty years of Spanish occupation.

Now, the question is just this, if we get out of there bag and baggage—and it must be said in all fairness that neither one of the great political parties are really proposing immediate independence for these people—but if we do get out of there and give them the freedom that the Filipinos themselves are demanding—or at least the politicians of the Philippines are demanding—will this splendid work of civilization go on? My answer, based upon observation and investigation, and for which, had I time, I could give you convincing illustrations, is that this work would not go on.

Take the American initiative and the American administration out of the islands today, and they would simply fall the victim and the prey of exploiting Filipino politicians, and the face of the Philippines, now turned toward the sunrise of a civilization that they have never before dreamed of, would be turned back again toward the darkness of the old Spanish régime.

And, finally, my judgment is that if America gets out of the Philippine Islands, if the flag and the khaki go out, at the very first opportunity that offers, Japan will go in. And judging by what Japan is doing in Korea today, and in Formosa, the Filipinos were infinitely better off even under Spain than they could ever hope to be under Japanese rule.

For these reasons, too briefly indicated, my feeling is that the Filipino people themselves will act most wisely if they decide of their own accord that the American flag, symbol of a new civilization, new opportunity, and international safety, shall fly above them for many and many a long year yet to come.

I am not ready to say, gentlemen, that if, in view of all these facts—and the Filipinos are waking up to these facts—if in view of all these facts the Filipinos still shall insist upon independence, of trying the game of managing their own fortunes in the future, I confess that I am too much of an American to say that we should, or that we would be justified in holding them under the flag by force of arms. But on this thing I am absolutely convinced, gentlemen, that if we can convince the Filipinos that they ought to accept a territorial form of government, become practically what Hawaii is today, a territory of the United States, a situation that is very largely accorded them in the present Jones bill, their fairest future, their largest opportunity, their certainty of safety will be under the American flag. A flag which I sometimes describe as the flag whose stars we caught from midnight heavens, whose blue we stole from summer's skies, whose white we painted with an unbroken ray of the sunlight, whose red we caught from blazing Mars, the flag that never knew a shame or bowed to a foe, the stars and the stripes.

Adderss of Harry A. Wheeler, Vice-President, Union Trust Company.

Toastmaster: I now have the honor of introducing Mr. Harry A. Wheeler, whose every idea is an inspiration and every gesture a picture. Here in Chicago I believe Harry Wheeler has been more in the eyes of the public than anybody I know, unless it is the cinders from the Illinois Central Railroad.

Harry A. Wheeler: While I esteem it a distinct honor to be one of your speakers, I must nevertheless confess to a feeling of some embarrassment as I consider the task which I have this night undertaken to perform.

Not being trained even in the remotest borderland of your profession, you are safe from shop talk; however, in my study of our national development I have reached some rather positive conclusions with regard to the part which has been played by the great engineering corps of the nation, and these conclusions have led to a profound respect for the profession.

In my judgment, engineering in its accomplishments borders the omnipotent. Look where you will in this modern day, whether in the development of the physical or the artificial, and it is the engineer who has pioneered the path and has aided if not actually produced some of the processes of which we are pleased to call evolution.

Engineering is a profession of sincerity and integrity as compared with other recognized professions.

Journalism uncovers, betrays and exposes human faults and weaknesses; its influence upon the character is apt to result in a hardening of the milk of human kindness, as in the performance of duty the journalist ruthlessly pursues those who have given offense to society.

Medicine develops the philanthropic spirit and in no profession is so much given for immediate human relief, yet because the study of this science relates only to the human organism, there comes with the years, except in rare cases, a narrowing of interests, a loss of business acumen, and a cynicism born of dealing with human frailties and weaknesses.

The law develops powers of research and analysis, but not always for purposes of ascertaining the truth. To avoid the penalty; to come as close as possible to transgression without an actual violation of the law; to discover technicalities by which to escape what the statutes clearly intend,—this is an unavoidable part of the legal profession, and leads to a blunting of the finest sense of honor so that it must be a strong character, indeed, that will entirely escape the taint.

Engineering deals with nature and nature's laws. No trickery will develop these; no technicalities are to be found which will permit escape from the penalty of their violation. Someone many years ago gave this definition of engineering: "The art of directing the great sources of power in nature for the use and convenience of man." If the author of this definition had lived in this day of engineering accomplishment, I am quite sure he would have added the word "discovery," for to me it is the discovery and the direction of the great sources of power in nature which cause the profession to stand out so clearly in its relation to natural development.

Engineering is an exact science and its training tends to develop honesty. Scientific research is conducted to discover truth, never to escape from it. Honesty, truth and accuracy should be synonyms of engineering as they are of character, and I am optimist enough to believe they are also coming to be basic to business success.

I did not come here tonight to pay you pleasant compliments, no matter how much they may be deserved, but rather, since your profession is inextricably interwoven with business stability and business administration, to urge upon your consideration an obligation to be more alert in dealing with those influences which directly affect our progress.

It is not necessary that I should go back over a few decades to point out to you the progress of events as business has evolved in this country, how, through all of our business and political conditions, we have come to the present place where there has been question as to the co-operation between business and the people, and between business and the federal government. You know the story as well as I. It may be read, and read with interest, in the messages of our Presidents as they have succeeded one another, or it may be read even in the daily press as the illustrations come from day to day, indicating the changes in policy and in thought and in the theory that govern both our federal authorities and our business authorities.

We have reached a day when the control and regulation of our business affairs are being lodged in commissions. The day of commission regulation is with us and is going to remain for some time to come. If I read aright the future of this great country and the part which business men must have in its development, I read that we must accept the conditions upon which we have fallen, and by some form of practical co-operation must bring sober sense and business judgment to bear upon the problems that are being considered by these commissions in order that they may not go far afield in their determinations and do infinite damage to our business interests.

Let me give you an illustration: The Interstate Commerce Commission has been spoken of by your retiring President. That is the first of the commissions for regulatory purposes. The increase in the rate has also been spoken of as possibly leading up to a more prosperous condition. Gentlemen, that increase in rate is not sufficient, either in itself or in the sentiment which may follow it or that may have preceded it, to bring prosperity to this country, or even to the interest that was favored with that increase.

I shall tell you what I see wrong with the Interstate Commerce Commission: It is largely the fault of the railroads that that wrong exists, and the wrong is possible of being remedied by the railroads if they will even now take a more conciliatory position.

I want to suppose that immediately after the appointment of the Interstate Commerce Commission in 1887, the railroads, instead of contending against the proposed regulation, had recognized the right of the government to intervene and had, through a well-intentioned and broad-minded committee, given co-operation to the Interstate Commerce Commission from the beginning of its deliberations. Such co-operation would, I contend, have smoothed out many of the rough places, have saved the commission from many errors, the railroads from infinite loss and the nation from a sorry exhibition of dishonest flotations and inefficient operation.

And if a mistake was made in 1887, is there any reason under the sun why that mistake should persist through 1915? Or shall the past be buried and a new spirit of co-operation be exhibited toward the commission by which we may level some, at least, of the barriers, and make the way less difficult to travel, not only for the roads themselves, but also for the public and the shipper?

I believe in regulation, but not in strangulation. But I believe that regulation will become strangulation unless the interests that are to be regulated establish cordial and co-operative relations with the regulatory body, and as reasonable men work upon their problems until they shall find a common ground upon which to operate without loss to the interests affected and with great benefit to the public at large.

I give you that because in the Federal Reserve Act we have accomplished just the thing that has been here proposed. It was not accomplished, strange to say, at the behest of the bankers. The Federal Reserve Act provides, as you well know, for a Federal Reserve Board of seven, appointed by the President, approved by the Senate. That Act also provides for a Federal Advisory Council of twelve, elected one man from each regional bank, constituting an advisory board which, in conjunction with the seven men at Washington, will see to it that every amendment that is needed to be made to that law shall be along the lines that are technically right and in full justice to the banking interests and to the people at large. That particular advisory council was, curiously enough, opposed by the bankers, and it was said: "If you have a proper commission or board there is no necessity for multiplying bodies for the consideration of the subjects which shall come before that board." But the commercial interests of the country insisted upon the other course, and contended, in both House and Senate, for the necessity of installing such a Council in addition to the Board politically appointed. And now that it has been done, it is conceded not only by the bankers but by the Federal Reserve Board itself, that this Advisory Council of twelve highly trained bankers will constitute a bulwark of safety which will make the Federal Reserve Act ultimately a great success.

In the last session Congress passed the Federal Trade Commission Bill. That regulation which began with the railroads, which extended itself after years to the bankers, it is proposed to extend through the Federal Trade Commission to business.

And I do not, for one interested in business as much as I am in banking, want the business men of this country to make the mistakes that have been made by others who preceded them, but here as they have the opportunity, before the Federal Trade Commission is actually appointed, to see to it, through some great commercial body that shall have the right because it is already representative of the commercial interests of the United States, that there shall be created, not as a part of the law but as a voluntary contribution to the law, a commissioin that shall study, subject by subject and problem by problem, the questions which must be studied by the Federal Trade Commission for the regulation of business. If it is not done, then business will suffer, as the railroads have suffered during the past decades. If it is not done, error will be made, because unfortunately men appointed to public office seem to believe that they represent what they call the great public of our country, and forget that the interests that are to be regulated are just as much their constituents and have just as much right to exact loyalty and consideration as has the man on the street or the great mass of people who constitute the general public.

The day of commissions is with us. The engineers of this country are among the leading business men of the country. You occupy the strongest and most responsible positions. You have brains, energy, foresight and analytical ability. It is for you, and you as much as for any part of our great business world, to take this new situation in which the country has come through the recent passage of economic legislation, and turn it so that the errors of the past shall absolutely not be allowed to lie against the future, that there shall be as between that power regulating and the power to be regulated, a measure of co-operation, reasonable and sane, broad-minded and unselfish, that shall bring out of the present rather chaotic condition, co-operation and harmony, and benefit to the people and to the business interests such as can never be obtained if we decline the opportunity which is now before us.

My last word to you, gentlemen, is this: There is a leadership in your group which you ought to recognize and use, for you cannot disassociate this profession of yours from the profession of general business. And as the days go by, you are coming closer and closer to the administration of the large affairs, not only of the carrier, but of the industrial life of this country. And if your profession, halted now because of a few months of depression, finds the necessity for taking some action that may allow men who enter the profession to look forward to an unbroken era of usefulness, you will only be able to accomplish your purpose by assisting to bring about a real and permanent prosperity, with National revenues sufficient to conduct the great public engineering projects upon which much of our development hinges, and likewise to so aid our transportation companies that they may be able to carry on their work; that they shall have the means and ability to develop their interests and serve the people to the fullest extent; and that industrial development, so important to your profession and in which your profession holds first place, shall be allowed to improve its condition under the wise guidance of scientific, trained minds, who have grasped, not only the principles of integrity, honesty and accuracy, but have learned to apply these principles to everyday business life.

Toastmaster: I have the honor to introduce to you—I should say, present my good friend Harry Olson, chief justice of the Municipal Court, and the next mayor of Chicago.

Hon. Harry Olson: Mr. Chairman and Gentlemen of the Western Society of Engineers:

ADDRESS OF HON. HARRY OLSON

It is bad enough to come last, at this late hour, but to be introduced by a man who has the malice that a cat has playing with a rat, to let him go and then catch him again, as he did with me, is discouraging.

Mr. Wheeler said that he had educated his boy to be an engineer. I was wondering, when I heard that, what I might say to match that. And I recall what happened at home this morning.

A doctor lives next door, and he has a little boy seven years old. I have a little girl seven years old, and they go to the same school. He calls for her every morning. And as he was there this morning, I called him "Doc." He said, "I am not going to be a Doc." I said, "What are you going to be?" He said, "I am going to be an engineer." I told the mother, "She can go with him right along."

I feel at home here because I noticed that there wasn't any outward ripple of laughter when Mr. Wheeler referred to me as "that distinguished jurist." Just imagine what would have happened if he had said that at a bar association. Of course, you engineers are subtle and you may not have shown your thought.

But I feel like the man who was accosted by a policeman up at Lincoln park. I have a friend who lives over in Michigan, and some years ago he had a yacht, which he took around the lakes for a trip; and he came down here to Chicago, and he had his boat near the Rush street bridge. David Swing, the noted preacher, knew him, and told him that he ought not to stay down there. He said, "That is a dangerous place for you to stay over night. Why don't you come up to Lincoln park to the lagoon?" He took the suggestion and went up to the lagoon. He stayed there over night, but in the morning quite early while he was getting his breakfast, a policeman came along and said, "What are you doing here?" "Well," he says, "I am getting my breakfast." "Well, you get out of here." He said, "I will when I get through with my breakfast." "Well, you will go now; don't get smart." "Well," he said, "I am not smart, but I am going to finish this breakfast first." Finally the officer said, "Where do you belong " "Why," he said, "I live in Michigan." "Huh," he says, "you don't belong here? Well, if you don't belong here you have a right here. If you belong here you have no right here." On that principle, of course, I may feel comfortable here.

But then anyhow I don't have to be much of a judge, with a number of engineers—or a lawyer. That reminds me of a judge who was out on circuit, and he wired to the new district where he was going, for quarters at the hotel. They had overlooked assigning him a room, or had assigned his room, rather, to another man, an Irishman. When he got there, they said, "The hotel is full. There is a convention in town. We are very sorry, but we will have to look around and see what we can do." "Well," he said, "I have reserved a room," and he gave them the number. "Well," they said, "We just let that room to an Irishman." "Is he a nice clean fellow?" "Oh, I think he is still up, and we will go and get him out." "Oh," he says, "I will go up with you and see." They got up there in the room and woke up the Irishman, and as the judge got in with him, he said to Pat, "It's a long time, Pat, since you would sleep with a judge in the old country." Pat says, "Well, faith, but it's a long time since you would be a judge in the Old Country."

Mr. Wheeler had my speech. I was going to talk about business efficiency. But I am going to confine it to the courts, at this late hour.

Some time ago Chicago sought a new charter at Springfield. We were going to govern ourselves. A German city like Berlin or Munich would not think of such a thing as letting the country people outside decide how they should run their city, what they should do in public and social questions in relation to that city. But here in this country the state passes general laws that affect us in many intimate business and social ways which we feel perhaps were better if they were left for ourselves. The only proposition in that charter amendment that got through was the provision in relation to the abolition of the justices of the peace, and the establishment of a new court that was going to come along with a new city charter. We didn't get any other provision through. That court has been in existence now about eight years, and I want to sketch, just briefly, some of the striking features of that court.

Its organization was borrowed from England. It was planned and based on the court machinery there that lies back of the High Court of Justice in London. The court was given an organization through the judges being made practically a board of directors with an executive officer, who was called the chief justice. They were given control over the clerks and bailiffs, having the right to fix their number and their salaries. They were given the right to fix their own procedure, and were required to meet once a month to look into their business.

It was required in the law that the chief justice should audit the business of the court. That grew out of the circumstances of large defalcations in two of the courts in this county, that had happened just a few years before.

This organization came into existence, and in about three months the court established a debtors' court under a new law. It was an amendment of the old act, in some forty-two sections, with four or five added. So that the law we are now operating under is a good deal different from the law under which the court was instituted.

One of the first things that the court did will interest you business men. The procedure was simplified. It was simplified on the basis of the English court, and today we are the only court in the United States—except one or two that may have imitated us—but we were the first court originally to go on that basis.

The plaintiff is required in these commercial cases to state his cause of action, in a statement of claim under oath. The defendant is required to state his affidavit of merits under oath. The result is that both sides must come to the court, having first been sworn as to the issues, so that the court merely tries the issues.

Now, what has that done? Well, I can illustrate that by saying this: Suppose in a common law court you were to sue, and we have the common law procedure here that they had in England a hundred years ago and which they abandoned about forty years ago—you would file what was called a declaration of the common counts, which would recite that you sued for money had and received, or goods had and received. You didn't tell what you sued for. The defendant only had to say "Not guilty," file what they call the general issue, and he didn't have to say what he was not guilty of.

The case was put on the docket. It remained there three to five years until the court reached it for trial.

Now, what would happen in a court under this new procedure? Why, the plaintiff must state what it is about. If it is for 5,000,000 brick, he states that. At six dollars a thousand, he sets that out. That he had delivered them, and that they are not paid for, and he swears to it. The other man must come into court, and he can't say not guilty, but he must say first: "Did you buy or contract for so many million of brick?" "Yes, sir." If he says nothing, it is taken for granted that he did. "Did you agree to pay four dollars or six dollars for them?" And he answers under oath, "I agreed to pay four." "Were they delivered?" "Yes." "Have you paid for them?" "No." And in that court the issue is four dollars or six dollars. It is a simple subject.

Now, it does this: It results in two-thirds of the commercial cases in that court being disposed of on the return day, in a branch court where the case first comes up. For example, if the suit be less than $1,000, the return day is in five days, when the affidavit of merits must be made. If it is more than $1,000, it must be in fifteen days that he must make the affidavit.

And we find in an experience of now nearly eight years under that procedure, that two-thirds of the judgments in the Municipal Court of Chicago are entered on default, because the defendant cannot make the affidavit of merits without committing perjury, and, therefore, does not make it. The result is that the volume of business in this court is very great in comparison with the other courts. I will illustrate that quickly by simply giving you the figures of last year in the three courts:

The Superior Court entered judgments last year of a million and about nine hundred thousand.

The Circuit Court, one million two hundred thousand.

The Municipal Court, four million six hundred thousand—more than twice both courts combined.

This year it entered judgment for five million four hundred and thirty thousand.

The court is thought of by the general public as a police court, as a successor of the justice of the peace, and yet it is the largest commercial court in the world, because the High Court of Justice in London only enters judgments of about four million dollars annually.

The reason why it has such a volume of business is not due merely to the business we have in Chicago, but the Carmack Amendment to the Hepburn Act permits a shipper to bring suit against any railroad along the line. Therefore, the Idaho sheep shipper, instead of suing the railroad out in Idaho, brings his suit in Chicago, because if he brought his suit in Idaho he would have to come here and get the witnesses who saw the sheep and who could testify to their conditions to come out there, or to send their depositions (and there would usually be from five to ten), while if he brings his suit here in Chicago all he has to do is to send a short deposition that the sheep were all right the last he saw them. And that is simpler and quicker. And besides, we have splendid lawyers here who will take it on a contingent fee, and that lawyer in Idaho would want a deed to the farm as security.

Now, the court quickly specialized its business. It sent the domestic relations cases, or family quarrels to one court. That was important, because one judge sitting there could learn what was the basis of a great many family disputes. We soon found that we required a physician, because of the conditions there disclosed. We found when we got the physician that men had epilepsy, or men had heart disease, and they were supposed by their wives to be lazy, and she took the wash rag to him once in a while, or the rolling pin. But when she found out that he had heart disease, she took him home and said, "I am not surprised, the doctor says your laziness is nature's compensation for the heart."

We find dementia precox a common form of insanity, prevalent in that court as the basis of a good many of these troubles. In case the people are poor, they don't get the aid of eminent specialists to tell them what is the matter and they don't know.

To show you how handicapped the judge is without the doctor, I will tell you one or two instances:

In the court of domestic relations one day a colored man came in, charged with deserting his wife and four children. He had just returned from five months in the house of correction, where he had been many, many times, sentenced here in Chicago for similar offenses. When he came in the door the judge noticed that he was a dwarf, and having a laboratory, he sent him there. We found he was a Cretin. He had no thyroid gland. That made him a dwarf. We scaled him on the Binet scale, and he was feebleminded. He was ten years old mentally. We sent for his wife, and she was a dwarf, a Cretin, and scaled nine years old. We sent for the four children, and they were dwarfs, Cretins, and young. The doctor said these children might be grown to mental maturity and physical stature. Armour & Company donated the thyroid glands of the animals, and the United Charities undertook to administer the medicine, and these children may grow into the intelligent beings and have the physical stature that they ought to have. That is an illustration.

I will show you another: A child had been adopted about eight times. Every time he was adopted he was returned. Every one who saw him liked him and thought he was a very interesting child. He was over the normal age by over two years, which made him appear very bright. But it was found that he was a Sadist, and he was brought back after having been adopted, because he would kill chickens and kill cats—not drown them, but physically slay them. And he had made an attempt upon a baby. He would have to be guarded, the doctor said, for all his life to safeguard others.

I was in the Boys' Court, a court established for the trial of boys between seventeen and twenty-one, after the Juvenile Court age, and to my mind a more important court than the Juvenile Court. And I saw a boy come in there whom the policeman said was a very intelligent boy. He was from Russia. He appeared to be very bright. The policeman said, "There is something the matter with him." I sent him to the laboratory. He had a report from some institution that he had mania-depressive insanity. The report came back that he had something else, and the doctor said, "He will imitate you unconsciously." So I spoke to him and held up my hand, and he imitated my speech and my action. I held up the other hand and he did the same. I held up the right hand and he did the same, until the crowd in the court room were getting amused at his automatic imitations. I asked the doctor what that meant, and he said the emotional centers were feeble-minded, while the intellectual centers were not, and he might be able to be brought out of that condition with proper care at the Detention Hospital, so he was given that rather than the House of Correction.

Not long ago the Aldermanic Crimes Commission undertook a study with the police department how vagrants could be rounded up to put so-called criminals out of business, because there is a wide misunderstanding about what a criminal is, even in that body and in the police department. They were brought in, three of them. One was found to have been taking dope. He took it in the arm. He was a dope fiend, and it would take from two to six months to straighten him out, and he was sent to the house of correction. The second had alcoholic dementia. It will take two years to straighten him out, but he could not be sentenced for more than six months. The third refused to be examined, but his mother came back later and asked that he be looked over by the doctor. It was found that he was a high grade pervert.

Now, we found in the Boys' Court that of those examined—of course they are a highly specialized group—245 were selected as possibly having something the matter with them. Of those 245, 217 were found to be definitely feeble-minded, or 84 per cent of those taken at random.

The same proportion holds true in the Morals Court, where the cases of prostitution were brought for study and examination. They run about 84 per cent feeble-minded. It has not generally been known that our slums are caused by that class of people and their breeding.

Mendel's Law of Heredity was rediscovered by a Cambridge professor only in 1900. Mendel had discovered that law some forty or fifty years ago, but the fact had been concealed in a pamphlet and in his time its meaning was not understood. He wrote a pamphlet about the breeding of sweet peas. And since 1900 the psychologists of the world have been busy, and have done what the alienists have not done up to that time—arrived at a method of accurately measuring mental intelligence. Binet and Seamon, one an alienist and the other a psychologist in Paris, scaled the school children of that city, and the psychologist examination took their name because they standardized the tests, although this had been used in Germany for more than thirty years, ten years prior to the time they standardized it in Paris. It has been used in different countries in Europe and in England, and the scale is now standardized and accepted in the psychological world when the work is done by a competent expert.

We have, therefore, in the Domestic Relations Court, in the Morals Court, and in the Boys' Court, the greatest clinic of abnormal psychology in this country. Any medical college anywhere would be delighted to get the opportunity that is thus afforded, brought in there by four thousand policemen in a city of two million and a half of population—a vast field for scientific work.

Before selecting a man to head that institution, I talked with Stewart Payton, the noted biologist of Princeton University. He said: "I hope you will guard yourself in your selection." And I said to him. "Well, I have deferred appointing that man because I was asked to appoint a jail doctor, a specialist in bad diseases to that place, who had had one year's study in a night medical school and who had previously been a policeman." "Well," he said, "you need an alienist there, you need a psychologist of European or German training. He must be a cereologist." I didn't know what that was, and he explained that that was the effect of certain specific diseases of heredity. "He must be an anthropologist." Requirements, you see. that are difficult to supply.

I had been on committee A for recording data concerning criminals of the American Criminal Law Society, and I knew it was difficult to supply that place. All throughout the country the cities are trying to imitate us, and are making the blunder of not getting sufficiently capable men to hold that position. You must know at once that one must be an outstanding alienist to do the work. Well, it is quickly seen, and I discovered it for that matter for myself early in the Criminal Court, that a great deal of crime is disease, mental or physical, to the extent that the defect was the cause of the crime. Repeatedly in the Criminal Court when I was a young man over there, I saw the prisoners brought up from the jail and they looked poorly from a physical standpoint, and poorly from a mental standpoint, and that was before Mendel's Law of Heredity was discovered and modern psychology really had its birth, and we were not guided and could not be guided by science at that time.

But the criminal that is most dangerous and most numerous is the adolescent from fifteen to twenty-one years of age. That is true in all countries. The largest number of crimes, serious crimes, are committed by that class. Only two per cent of the population are ever charged with crime at all, and therefore, it appeared since that was uniform in various countries—those two sets of statistics—that there was something inherently defective in the youth when he showed up so quickly after responsibility began and he got of that age. Responsibilities come to those defective classes. They are not able to go out into the world and compete with the normal on a normal basis. They get jobs at washing dishes, and they can't hold them for more than a month at a time. They go into factories and try to make good, and can't. They go into the railroads and there are wrecks. They go into the shops and there are wrecks. The business men haven't generally understood what the situation was, but of course after having a man for a month or two, they soon identify the incompetent person. The doctor would not—or, an ordinary doctor would take considerable time to identify such an individual, unless he resorted to a psychological test. The teacher would not discover him for six months and the court, of course, could never discover him in the ordinary run of cases. The result is that the court has called upon the medical profession to bring in its modern science in dealing with this class of cases. It will mean a revolution of the criminal law. It will mean a revolution of the custodial institutions such as Pontiac.

I stood with an eminent psychologist as they marched by and he pointed out many boys that were feeble-minded—about forty per cent. He said that this institution was built at a time when the alienist did not know what he knows now, and before the psychologist was on the modern basis or it would not have been an institution such as this. It ought to be rather a farm colony, a home colony where they were guarded and under control.

Especially is that important in the case of the women of child-bearing age, because we will never get rid of the slum until we quit breeding the slum. Mendel's Law of Heredity tells us with a certainty of science and experience that if two defective strains marry, all the children will be defective. Godard had pointed out that where a dominant marries a recessive, the family afterwards will contain some recessives and some dominants, a recessive strain will come out here and there along the line. But where two dominants marry, all the children will be dominant. We have not understood that. We have blamed the police. Why don't the police handle it? And the police departments of all cities are blamed for these defective classes, and they are treated as criminals and ne'er-do-wells, and the police are called upon to round them up. Are they dangerous? Yes. You get one of them, a youth say of eighteen or twenty years of age; he is desperate, he can't make a living in the ordinary ways and somebody talks to him about a robbery. He gets a gun. He meets you. He has the intelligence of a seven-year-old, and he asks you for your money, and in some little altercation he shoots and a citizen is dead.

The police don't understand the subject. Neither do the prison authorities, as a rule, although they are beginning now. You know that men like Dr. Henderson advocate the parole law. He says it is a good law. It is when applied to the normal, because the normal quickly understands that society has machinery to control him. The police are right on the other hand, because all the penitentiaries are turning loose those defective classes without any knowledge that they are defective, and they come back again and again. And they complain about the parole law, and they are right. The penitentiaries and the reform schools should have alienists and psychologists to pass upon this material, and when the individual is a menace to society and bound to be a menace as long as he lives without control, he ought not to be thrown upon a community where he may take the lives of the worthy in that community.

Now, in this mass about fifteen per cent perhaps are injured by reason of difficult labor at the time of birth, injury to the brain, bleeding of the blood vessels through careless attendance on the part of the physician. The laity haven't understood that. The doctor is interested in the mother and has not understood the matter—especially when the first child is born, in that regard. And therefore, about fifteen per cent, perhaps, are injured at that time or in early life from falls and injuries to the brain that leave them in the same condition. But they are not the danger to society that the hereditary class is because they will not reproduce their kind.

The criminal law, therefore, is destined to change as are these institutions. We need to guard and to control this class. We need to ask the legislatures for institutions fit for them and for their kind, and then we will get rid of the slum, and the police department will not always be under the blame for permitting those conditions.

The sociologist of the old type was always attributing these troubles to environment. He thought that a bad environment produced them. Well, it may in the long period of the years, but it did not produce that individual who is found in the slum. He was generally produced by heredity.

But, to go on; my time is about up, I see, and I haven't got started.

Well, I will hit some of the high spots. One of the high spots I want to mention to you and have your influence for in the community, is that you see to it that the personnel of the court—of the trial court, shall be as strong as it can be. We have gone on the theory that anybody will do for the courts of first instance, but we are going to have a good judge up here in the Supreme Court and the Appellate Court, we are going to see that it is decided right at last. Well, now, how does it work out? Let me illustrate that by taking a tailor shop illustration.

Suppose you were to go into a tailor shop, run like our courts have been run. Who would they have for the cutter and fitter? Why, any old fellow that could get ahead in the primary, because a group of people voted more for him than for somebody else. He is selected as the cutter. Did he ever cut? No. No, he never cut. Has he had any experience? Why, no, he has not had any experience. He has got a license and he is admitted to the bar, we will say, of the cutters. He is to cut the suit and a similar workman will sew it together. And finally you are going to have at the end of the line the chief cutter and fitter of that establishment. He is going to look it over. "Why," he will say, "you have got the pants leg on where the sleeve ought to be, you have got the sleeve on where the pants leg ought to be, and the pants are built hindside before. Reversed and remanded"—in the language of the court." Reversed and remanded to whom? To the same cutter. "Well," you say, "the cloth is spoiled." Why sure, the value is all out of it for the litigants. And that is the way with the average lawsuit.

Ex-President Taft from this platform speaking to the Legal Aid Society the other night, urged that upon the listeners. He said: "We need in the court of first instance, such as the municipal courts, capable men, because," he says, "the volume of business is very great and, therefore, must be despatched with great rapidity. To despatch business with great rapidity and accuracy, requires the best lawyer you can get."

But we have gone on the theory that if we had him in the Supreme Court everything would be lovely.

I saw the effect of that in the criminal courts. In fact, I made a stipulation with Mr. Deneen when I went there that I would not be required during my stay to practice before a really poor judge. And I was always thankful that I had the opportunity to go before men like Tuley and Gary and Frank Baker and Frank Adams, leaders of this bar and bench in their time. Their cases did come back from the Supreme Court very often—the criminal cases very seldom. We don't realize what that experience means. I remember a young law student had been over to England. He had been in at the Crippen trial, where Lord Alverstone, the chief justice of England was presiding. It over-awed this young college professor and he could not stop telling about the robes and the air of state about that trial where Lord Alverstone had presided. I shocked him by saying that the record shows that Lord Alverstone didn't do a very good job of it. "What?" I said: "The record don't look good to a lawyer." He said, "It don't? Why?" I said, "No." He says, "Do you mean that any of our Chicago judges could do it?" "Why," I said, "we have men like Kersten, who sits over in the Criminal Court and has for a long period of time. He would try that case more accurately." I said, "Lord Alverstone never tried any criminal cases. He didn't have any experience with criminal law, and the record shows it." It was perfectly shocking to the man, the state and the robes and everything had overcome him. But it takes experience to try cases accurately, both at the bar and on the bench. And we ought to come to a quick understanding of that in this country and build up our lower courts. The higher courts will have much less to do if we do that.

We must unify and make a business administration of our courts. In this court of ours we have an auditor that goes right through it every month and makes annual reports and monthly reports. We have the efficiency data of the business done each month by each judge, and the actual work he does is printed in red. The collateral work is printed in black, so we simply have to look at the red figures to see whether he is efficient or not.

The courts are isolated instead of being branch courts. That grew out of the old times when we had sparsely settled communities and we had our circuit court here, and our district court there, independent of each other. But in these modern times we need a unified court here in Chicago. We should not have all the courts that we have. We should have one court for Chicago, and all the other courts should be branches or divisions of the main court with appropriate officers of divisions, as, for example, the Probate, Domestic Relations, Juvenile and Boys', should be under one presiding officer and one business management, subservient to the charge and management of all the judges. And then we must come to it in our states so that we will have a unified state court, so that when you go into a court you are in all the courts, both above as well as below. For example, now you go into the Municipal Court and the case is decided and you go to the Appellate Court. You have got to pay for a record. You have got to have the papers copied. It is required that they be printed just so, in such type, so far from the margin. It costs money, fifty or a hundred or two hundred dollars to prepare the record, sometimes a thousand dollars or two thousand dollars in the larger cases to prepare what was said and done below, and take it to the appellate division or take it to the Supreme Court division. The record ought to be merely removed by a clerk from the lower branch of the court to the higher branch of the court and save the expense. But that would be unheard of in the law to save the expense.

You know we lawyers are not looking ahead, as a rule, as you do in your profession. If there is a new invention, you have to get it and get it quick, because the economy and the efficiency of it demands that you do so. You could not hold your place unless you kept up with what is happening, and in fact, sometimes ahead of what is happening in your line. But with us, the older a case is that we can find, the more numerous times that thing has happened over and over again in all the courts of England and Canada and the United States, the safer we feel.

The lawyer has been trained by years of study in the schools, and years of practice afterwards, to look backward and to risk nothing unless it has happened before, no matter how simple it is, and that is the excuse for it.

Now, I went down to Philadelphia to help them get a court, and the judge there was having a great deal of trouble with the bar and was feeling discouraged. I said, "Now, will you follow my advice?" He said he would. I said, "Well, you ignore the bar for about two years and do this; get your credit men together and educate them on this simplified pleading that we are using and that they are using in Canada, and then discuss it, have meetings about it and work up sentiment with the credit men of Philadelphia. Then organize the women for a juvenile court, for a domestic relations court, and get them interested in that and keep them separate. Then organize the laboring men into a body that wants speedy trials in personal injury cases. Organize your grocers into a group that wants some action short of five years in a claim for groceries of fifteen or twenty dollars—organize them."

He organized the women; he organized the credit men; the grocers he called the Market Street Business Men's Association. And the labor unions were organized. Then he had a big meeting in one of the halls at Wanamaker's store, and another in a theater in the evening, to which no lawyers were invited except those who were to speak. He brought in Roscoe Pound from Harvard University. He brought Judge Goodnow from our Domestic Relations Court here, and I went along with Judge Mack, who sat in our Juvenile Court.

A committee of five lawyers of the Philadelphia Bar Association came to spy out and ask questions and to embarrass the speakers and see what was going on in slow old Philadelphia. When I was talking they asked something about the powers of the chief justice, as if it was a serious matter for other judges that he had so much power. I knew that some of their judges had gone to Florida and stayed away so long they had to send committees after them. And he wanted to know what authority we exercised on vacations. And I said, well, it was prescribed by law, and we never had to go to Florida for a judge to get him to try a case. The result was that this committee of five lawyers got up an amendment for five more judges for the old courts. The mass meeting appointed a committee for a municipal court which got their bill through at the legislature of Pennsylvania. The Supreme Court declared the five new judges' bill unconstitutional, and the municipal court bill constitutional, and they are in business today.

January, 1915

How did they get there? Why, their people outside of the bar took the lead, of course.

Down in Cleveland they invited the credit men to come, and invited just a few lawyers. And the credit men started out to get the court and the lawyers who didn't attend hurried to get in on it, but those who got in on it first were elected judges of the new court.

A businessman, one of the largest businessmen in this country, dropped in to see me one day, and he said: "They tell me that you know what this institution costs." "Yes." "They say that you can tell it in ten minutes." "Yes." "Do you keep books like that?" "Yes." "Can I see them?" "Yes." He saw them. "Well," he said, "I think that we ought to have something done in speeding up the courts and organizing the courts. Why don't the lawyers do that?" I said, "They are too busy. Some of them are hired for that. It depends on which side of the case you are whether you want speed." I said, "We are pulling against each other. We are busy." He said, "Can't they be hired?" I said, "Yes." And he set aside a fund annually for the promotion of justice in the United States, a layman, so that the business communities are taking hold of it, and now we lawyers are scrambling in as lively as we can. We are going to get into the band wagon before the thing is full, but some of us have got to stay on the hind steps.

The best thing that could happen for law reform right here in Chicago is that a committee of engineers—five engineers and five business men and three lawyers were appointed to look into the matter. I say that seriously because we are inert—but I must not go back on my profession. We are trying to do something, trying to keep in the leadership, and I assume that the bar will get busy.

I remember being called hastily to Springfield by a committee of lawyers who were afraid a certain bill was going to pass. It had two thousand pages. It rewrote all the laws. It had in it a provision that any lawyer who cited a decision of a Supreme Court in a court of justice, should be fined a hundred dollars, and of course, the Bar Association was excited. They ought to be. And they thought I knew the governor. And they said, "The thing has passed one house and I guess it will the other."

So I went to see the governor. "Well," the governor said, "You tell that Bar Association to get busy." He said, "Some of these wild-eyed fellows will pass a law in this state to drive capital out of the state. We will have something that none of us want if we don't get busy."

But our Bar Association is working along and getting busy from time to time, and they are doing it throughout the country.

Ex-President Roosevelt made his attacks upon the courts and asked for recall of judges and recall of judicial decisions. If he had called for business organization and business administration in the courts he would have been better off than calling for the recall of decisions, because that was what was really the matter. We can have recall of judges if we like. I like the proposition that a judge should be put up with nobody against him—"Shall he be recalled?" If you don't like him, vote him out, he is running against his own record. If he is running on his own record then there will be some tenure of office for a judge to look forward to.

These are matters that concern you because you have interests in the courts. You realize that. We have learned the value in this court of dealing with experts. Over in the Criminal Court when I had a cause of death I called in a pathologist like Hektoen. When the cause of death was chemical, I called a noted chemist like Haynes.

I wanted to say to Mr. Wheeler that we discovered the young man who is at the head of the reserve bank in Chicago, McDougall, twelve years before the government discovered him. He was our expert, and he went through the Milwaukee bank over night. We knew all about it by morning. He was the quickest man on figures I ever saw.

We have learned that we have got to go into expert fields for information and utilize it and develop it.

I want to thank you for your attention.

MOVING PICTURES SHOWING CONCRETE CONSTRUCTION.

FILMS FURNISHED BY UNIVERSAL PORTLAND CEMENT CO.

Presented at a Meeting of the Society December 7, 1914.

CONCRETE STREETS, ROADS AND ALLEYS.

The pictures shown in the first reel were taken in the course of an expedition which covered several thousand miles of territory in the Great Lakes states in the summer of 1914. The examples of concrete road construction are typical of the conditions at several representative points. This type of pavement is suitable for city pavements as well as for cross-country highways. Those seen in this reel, which included only half of the total length of film, vary from ten to seventy feet in width and are laid in stretches from one to approximately twenty-five miles in length.

Inasmuch as efficiency in construction and facility in extending the work are highly important in the great mileage of highways to be paved throughout the country, the several methods of handling material are of special interest. On the smaller jobs it may be more economical to transfer material by teams and wagons because of the low cost of the investment required for equipment, although the unit cost of transportation may be relatively high. Motor trucks are a more efficient means of moving material, particularly as at Spencer, W. Va., where the narrow roadway winding along the hillside is accessible only from one end, necessitating, as is seen in the pictures, a side dumping body. Where extensive paving operations are to be carried on over ordinary dirt roads, in level country as in the neighborhood of Detroit, Michigan, trains of tractors drawn by traction engines, carrying perhaps twenty-five or thirty yards at a time, have been proven very practicable and are operated at low unit cost although at necessarily slow speed. Probably the employment of an industrial railway equipment,—including locomotives, dump cars, portable track, and special loading devices,—as in connection with the extension of the Wayne County, Michigan, highway pavements and the rebuilding of the old National Pike at Zanesville, etc., Ohio, is of as great engineering interest as any. With concreting plants working from both ends of this National Pike construction progress has been unusually rapid and totaled as much as one mile per week. It has been figured in connection with the Wayne County use of an industrial railway, that the net cost of hauling was not more than sixteen cents per ton mile, including all expenses.

Concrete Silo.

The pictures in this reel of film were made in the fall of 1914, and illustrate methods of construction of concrete structures for the farm.

This was perhaps an average silo, which when built of an inside diameter of 16 ft., with 6 in. walls and 45 ft. high, would have a capacity for over 200 tons of silage,—sufficient to supply the stock on an 80 acre farm, say 30 head for one year or 60 head for six months.

The sheet steel forms are readily elevated on the central support or mast which likewise carries the crane by means of which the concrete is placed in position. A gasoline engine, or other power device, is part of the usual equipment on farms in these days, and the mixing and placing may be accomplished readily by making use of farm labor available during the slack season. Probably 75 barrels of cement were required for a concrete silo of this size and the fact that the expenditure for this comparatively small amount of material was all that might be required to go outside of the immediate vicinity may be regarded as an additional reason for the popularity of this type of construction.

Concrete on the Farm.

The permanence of concrete, due to its immunity from oxidation, makes concrete posts, among other things, of special value to the farmer. Such fence posts are also coming into more general use along railroad lines for the same reason. The construction shown on this film was being done with a comparatively simple equipment and included principally a gang mold, used in sizes with capacities from two to ten posts at a time. The concrete was simply mixed in an ordinary mortar box and shoveled into the molds and made compact around the steel reinforcing rods by oscillation. The concrete hardens in the molds over night and the posts are then removed for curing. This process involves sprinkling with water three times a day and exposure to the air for about three weeks. Such posts are made comparatively cheaply, particularly when farm labor is made use of between seasons.

The practical necessity for good drainage may be met readily by the use of concrete tile, such as may be turned out by the machine shown in operation in these pictures. With everything in good running order, 6 in. tile may be turned out in lots of from 500 to 2,000 per day, or at the rate of from 500 to 700 per man, and at a cost of about the same or less than that of an ordinary fence post, according to the labor available, the conditions of the season, etc.

PROCEEDINGS OF THE SOCIETY

Minutes of Meetings.

Extra Meeting, December 30, 1914.

An extra meeting (No. 883), a special meeting of the Electrical Section, was called for Wednesday, December 30th, 1914, at 12:30 p. m., with about 20 in attendance. The object of the meeting was to make nominations for the Executive Committee of the Section, to be voted on at the regular meeting of the Section in January, 1915.

H. M. Wheeler was nominated for Chairman.

C. A. Keller for Vice-chairman.

F. J. Postal for member of the Executive Committee for three years.

G. T. Seely and E. W. Allen remain on the committee.

Meeting adjourned about 1 p. m.

Extra Meeting, January 4, 1915.

An extra meeting (No. 884) was held Monday, January 4, 1915, in the interests of the Hydraulic, Sanitary and Municipal Section. The meeting was called to order about 7:50 p. m. by W. D. Gerber, Chairman, and with about 45 members and guests in attendance.

The nomination and election of members of the Executive Committee of the Section for 1915 was in order.

The nominations were:

G. C. D. Lenth for Chairman.

W. W. DeBerard for Vice-chairman.

J. H. Libberton and Douglas Graham, members of the Executive Committee; all to serve one year.

On motion, the Secretary was requested to cast a ballot for these. W. D. Gerber, retiring chairman, remains on the committee by the rules of the section.

The following resolution was presented to the meeting by Mr. Pearl, by request:

Whereas, The President of the Sanitary District of Chicago appointed a Commission early in 1912 to investigate and report among other matters on the water power development of the Sanitary District, which report, after careful investigation, has recently been made public; and

Whereas, Certain members of the Sanitary District, the City Council of Chicago and the Daily Press have poured out a torrent of fretful rebuke and personal insinuation against the individual members of the Commission, all apparently because the facts and conclusions of said report were not what had been expected; and

Whereas, Among the members of this Society signing the report were Lyman E. Cooley, John Ericson, L. K. Sherman and William Artingstall, all engineers of reputation, experience and good standing in this community, who have devoted the most of their professional lives to the service of the public; therefore, be it

Resolved, That this Society views with regret this public attempt to abuse men who were apparently trying to do their duty to the public in setting forth facts as they found them and testifying to the truth as they saw it, and the Sociey would point out for the benefit of the public officials, who have been conspicuous in this controversy, the following proper relations with engineering advisers, which it wishes to emphasize at this time as a matter which vitally affects the public welfare:

First. That an engineer's first duty to his client is to tell him the truth, no matter where it may lead, or how unpalatable it may be.

Second. That engineering and engineering economics are subject to natural law, which cannot be altered to suit the whims of human nature.

Third. That the most serious disgrace that can come to an engineer is to conceal, pervert or distort natural and economic law, either to please a client or temporarily advance his own interests, and so ultimately lead his client into difficulties.

Fourth. That an experienced engineer of standing ranks as a confidential professional adviser, feeling keenly his responsibilities, and whose integrity and conscientiousness, when properly established, should be appreciated and upheld by his client.

Fifth. That engineers, while not infallible or superhuman, are more apt than laymen to be right in their findings on engineering facts and economic truth connected with engineering matters.

And be it further Resolved, That while the Constitution of the Western Society of Engineers provides that the Society "Shall neither endorse nor recommend any individual or any scientific or engineering production," it does provide that the opinion of the Society may be expressed on "Such subjects as affect the public welfare," and it is the desire of the Society, by this resolution, to point out that the public welfare is vitally affected by any pronounced attempt on the part of public officials to suppress, conceal, distort or overawe the carefully prepared opinions of experienced engineers, reporting on public questions for the public interest.

The Society would further point out that if the findings of an engineering report are open to question, there are a number of proper and dignified procedures that can be adopted to check its conclusions.

And be it further Resolved, That copies of this resolution be printed and sent to His Honor, the Mayor, and the heads of City Departments, the individual members of the City Council, the President and members of the Sanitary District, and the Daily Press.

Some discussion was offered by C. C. Saner. On motion, the resolution was referred to the Board of Direction for action, with a request that the Section be advised of the Board's action.

There being no further business, J. E. Mason, assistant to the Secretary, read the paper of the evening on "The Salem Conflagration, June 25, 1914," as the author, Charles H. Smith, of Boston, could not be present. There were some lantern slide illustrations. Discussion followed from Messrs. Gerber, Chase, Graham, Lenth, Cone, Chamieovitch, Postel, Baker, and others.

Meeting adjourned at 9:50 p. m.

Annual Meeting, January 13, 1915.

The 45th Annual Meeting and Dinner of the Society (No. 885) was held Wednesday, January 13, 1915, at the Auditorium Hotel. The meeting was largely attended, about 390 members and guests being present. The speakers consisted of President Lee, President-elect Wm. B. Jackson, Mr. Douglas Malloch (Toastmaster), Rev. R. A. White, Mr. Harry Wheeler, and the Hon. Harry Olson. Much good fellowship was manifested.

Meeting adjourned a little after 11 p. m.

Extra Meeting, January 14, 1915.

An extra meeting (No. 886), the second session of the annual meeting, a smoker, was well in the Society rooms Thursday evening, January 14, 1915, after an excursion during the day to the southwest part of Chicago visiting the Corwith plant of the Crane Co., the Clearing Yard, and the Sears-Roebuck plant, where lunch was served. Five hundred were on the excursion.

An illustrated lecture on the California Exposition, the Grand Canyon and Yellowstone Park, with other views by the way, was given by George Frederick Wheeler in the evening. There were other moving pictures, and music and refreshments concluded the program of the evening. Cider and ginger bread supplied the refreshments, with pipes, tobacco and cigars.

The meeting adjourned about 11:30 p. m.

Extra Meeting, January 25, 1915.

An extra meeting of the Society (No. 887), a meeting of the Electrical Section held jointly with the Chicago Section of the A. I. E. E., was held Monday evening, January 25, 1915. The meeting was called to order at 8 p. m. by F. J. Postel, chairman of the Electrical Section, with about 80 members and guests in attendance. The Secretary read the minutes of the meeting held December 30, 1914. The chairman stated that election of officers for the Section was in order, and as there were no new nominations submitted, on motion, the Secretary was instructed to cast the vote for the ticket presented.

H. M. Wheeler was elected Chairman of the Section.

C. A. Keller was elected Vice-Chairman.

F. J. Postel for member of the Executive Committee for three years.

Messrs. G. T. Seely and E. W. Allen remain on the Executive Committee.

The meeting was then turned over to E. W. Allen, Chairman of the Chicago Section, A. I. E. E., who introduced N. W. Storer, of the Railway Depratment of the Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa. Mr. Storer presented his paper, "Economies in Power Consumption in Electric Railways," with stereopticon illustrations. Discussion followed from H. H. Adams, H. A. Johnson, W. Thorne, E. J. Blair, Wm. B. Jackson, J. W. Mabbs, T. Milton and W. E. Symons, with a closure from Mr. Storer.

Meeting adjourned at 10:25 p. m.

J. H. Warder, Secretary.

ANNUAL REPORTS.

Secretary's Report.

January 13, 1915.

To the Board of Direction, Western Society of Engineers, Chicago.

Gentlemen:—I herewith respectfully present the annual report of the proceedings of the Society for 1914.

The growth in membership has been less than that for the last few years, owing to the depressed business conditions. The membership of the different grades and of the Society as a whole, December 31, 1914, is shown in the following table:

	Dec. 31, 1914
Honary Members	3
Members	774
Associate Members	227
Junior Members	122
Affiliated Members	41
Student Members	22
Total	1,189

Death has claimed the following:

Robert S. Draper, admitted March 6, 1906; died March 17, 1914.

Emil Gerber, admitted June 2, 1890; died April 16, 1914.

Alfred Noble, admitted Dec. 20, 1893; died April 19, 1914.

Wm. H. Pratt, admitted June 5, 1899; died September 5, 1914.

B. Schreiner, admitted July 20, 1907; died July 28, 1914.

Benezette Williams, admitted October 14, 1872; died June 22, 1914.

Forty meetings of the Society, including the Sections, have been held as follows:

The 44th Annual Meeting (No. 844 of the meetings) and Dinner was held at Hotel La Salle, Wednesday, January 7, 1914, with addresses from the retiring president, Albert Reichmann, and the newly-elected president,

E. H. Lee; also from Dean Mortimer E. Cooley, University of Michigan; S. E. Kiser, of Chicago. Dr. E. W. Lewis, of Lewis Institute, was toastmaster.

Thursday, January 8, Extra Meeting (No. 845). A smoker in the Society rooms with diversified entertainment and refreshments.

Monday, January 12, Extra Meeting (No. 846). The annual meeting of the Bridge and Structural Section. Prof. W. M. Wilson, M. W. S. S., presented his paper on "Movable Bridges."

Monday, January 19, Extra Meeting (No. 847). The annual meeting of the Hydraulic Sanitary and Municipal Section. Past-President Alvord addressed the meeting on "The Engineering Lessons from the Ohio Floods."

Monday, January 26, Extra Meeting (No. 848). The annual meeting of the Electrical Section with the Chicago Section A. I. E. E. in attendance. Past-President B. J. Arnold addressed the meeting on "City Transportation, Subways and Railroad Terminals."

Monday, February 2, Regular Meeting (No. 849). Mr. E. J. Mehren, of "The Engineering Record" of New York, addressed the meeting on "The Making of a Technical Paper."

Monday, February 9, Extra Meeting (No. 850). The Bridge and Structural Section. Mr. Ernest McCullough, M. W. S. E., presented his paper on "Reinforced Concrete Columns."

Monday, February 16, Extra Meeting (No. 851). Dr. Patrick S. O'Donnell addressed the meeting on "Radium" with an exhibit.

Monday, February 23, Extra Meeting (No. 852). The Electrical Section with Chicago Section A. I. E. E. in joint attendance. Mr. Hill, of the G. E. Co., described "The Switchboard for the Operation and Control of the Panama Locks."

Monday, March 2, Regular Meeting (No. 853). Messrs. A. S. Zinn, M. W. S. E., and L. D. Cornish, designing engineer for the Panama locks, described, with lantern slide illustrations, the "Locks and Spillways of the Panama Canal."

Monday, March 9, Extra Meeting (No. 854). The Bridge and Structural Section. Mr. Carl Weber, M. W. S. E., presented his paper on "The Cement Gun."

Monday, March 16, Extra Meeting (No. 855). Mr. Andrew Cooke presented his paper on "Government Regulation of Railroads from the Investors' Standpoint." Mr. Samuel O. Dunn, editor Railway Age Gazette, presented his paper on "Valuation of Public Utilities from the Railway Point of View;" and Mr. Harold Almert, M. W. S. E., presented his paper on "Public Utility Regulation from the Standpoint of the Public and the Engineer."

Thursday, March 23, Extra Meeting (No. 856). The Electrical Section with the Chicago Section A. I. E. E. in joint attendance. Mr. B. H. Glover, of the Underwriters' Laboratories, presented his paper on "Electrical Inspection" as practiced by the Underwriters' Laboratories.

Monday, March 26, Extra Meeting (No. 857). Ladies' Night. Mr. A. H. Andrews gave an illustrated lecture on "The Cliff Dwellers."

Monday, April 6. Regular Meeting (No. 858). Mr. Andrews Allen, M. W. S. E., presented his paper on "The Engineering Opportunities of Our Coal Mining Fields."

Monday, April 13, Extra Meeting (No. 859). Bridge and Structural Section. Mr. B. J. Sweatt, M. W. S. E., presented his paper on "The Third Avenue Reinforced Concrete Bridge at Cedar Rapids, Ia.," with illustrations.

Monday, April 20, Extra Meeting (No. 860). Prof. H. H. Stoek, M. W. S. E., presented his paper on "The Mining Laboratories of the University of Illinois."

Monday, April 27, Extra Meeting (No. 861). The Electrical Section with the Chicago Section A. I. E. E. in attendance. Mr. F. G. Gasche, of the Illinois Steel Co., presented his paper on "Power Problems in the Steel Business."

Thursday, April 30, Special Extra Meeting (No. 862). Addresses from Dr. George A. Soper, of New York; Mr. James D. Watson, of Birmingham, Eng., president of the Institute of Sanitary Engineers, and Mr. Arthur J. Martin, of London, Eng., past-president of the Institute of Sanitary Engineers, addressed the meeting on sanitary matters and the disposal of sewage.

Monday, May 4, Regular Meeting (No. 863). Smoker. Capt. W. Robert Foran, formerly with the English Army in East Africa, gave an interesting and illustrated account of some of his travels and experiences in East Africa.

Friday, May 8, Extra Meeting (No. 864). In the interests of Engineering Students. Capt. H. B. Sauerman, M. W. S. E., of the Engineering Corps, I. N. G.; Mr. Isham Randolph, M. W. S. E.; Dean Raymond, of Armour Institute; O. P. Chamberlain, M. W. S. E.; Prof. P. B. Woodworth, M. W. S. E., of Lewis Institute; Prof. J. F. Hayford, M. W. S. E., of Northwestern University, and Dean W. F. M. Goss, M. W. S. E., of University of Illinois, addressed the meeting on engineering matters.

Monday, May 11, Extra Meeting (No. 865). Bridge and Structural Section. Mr. A. T. North read his paper with illustrations on "Grading Yellow Pine Timber for Structural Purposes."

Monday, May 18, Extra Meeting (No. 866). The Hydraulic, Sanitary and Municipal Section. Messrs. Irwin S. Osborn, of Toronto, Can.; John Fetherston, of New York, and Edward R. Pritchard, of Chicago, spoke in an informal manner on "The Disposal of City Wastes."

Monday, May 25, Extra Meeting (No. 867). The Electrical Section with the Chicago Section A. I. E. E. in joint session. Mr. D. P. Gaillard read his paper with illustrations on the "Universal Use of Electricity on the Panama Canal."

Monday, June 1, Regular Meeting (No. 868). Mr. F. William Grevè, Jr., Assoc. W. S. E., of Purdue University, read his paper on "Characteristic Curves of Centrifugal Pumps."

Monday, June 8, Extra Meeting (No. 869). Bridge and Structural Section. Mr. Alexander C. Brown, of Cleveland, Ohio, read his paper with illustrations on "Locomotive Cranes and Their Use in Modern Industries."

Wednesday, June 10, Extra Meeting (No. 870). The Electrical Section with the Chicago Section A. I. E. E. and Illuminating Engineering Society (Chicago Section) in joint session. Prof. A. H. Ford, of Iowa City, Ia., read his paper on "The Design of Illuminated Signs," and Mr. Matheny, of the Department of Electricity and Gas, Chicago, read a paper by P. E. Haynes on "Chicago Street Lighting."

Monday, June 15, Extra Meeting (No. 871). Hydraulic, Sanitary and Municipal Section. Mr. W. G. Potter, M. W. S. E., read his paper on the "Sewage Disposal Plant of Aberdeen, So. Dak."

Monday, September 14, Regular Meeting (No. 872). The Bridge and Structural Section. Prof. Morton O. Withey, of Madison, Wis., presented, in abstract, his paper on "Permeability Tests on Gravel Concrete;" also Mr. N. M. Stineman, Assoc. W. S. E., presented, in abstract, his paper on "Reactions in a Three-legged Stiff Frame with Hinged Column Bases."

Monday, October 5, Regular Meeting (No. 873). Mr. H. E. Goldberg, M. W. S. E., read his paper with illustrations on "Arithmetical Machines."

Monday, October 12, Extra Meeting (No. 874). Ladies' Night. Mr. W. R. Patterson, M. W. S. E., gave an illustrated lecture on a trip through the Yosemite and Yellowstone National Parks.

Monday, October 19, Extra Meeting (No. 875). Hydraulic, Sanitary and Municipal Section. Mr. Robert M. Feustel, of the Public Utilities Commission of Illinois, read his paper on the work of that commission.

Monday, November 2, Regular Meeting (No. 876). Mr. Howard F. Weiss, director of The Forest Products Laboratory, Madison, Wis., presented "The Work and Some Accomplishments of the Forest Products Laboratory."

Monday, November 9, Extra Meeting (No. 877). Mr. L. S. Marsh, Mem. American Chemical Society, addressed the meeting on "High Explosives."

Monday, November 16, Extra Meeting (No. 878). The Hydraulic, Sanitary and Municipal Section. Mr. J. W. Link, M. Am. Soc. C. E., presented, with illustrations, his paper "The Coon Rapids Low Head Hydro-Electric Development on the Mississippi River near Minneapolis, Minn."

Monday, November 24, Extra Meeting (No. 879). Electrical Section with the Chicago Section A. I. E. E. in joint session. Mr. S. E. Doane, of the National Lamp Works of the General Electric Co., Nela Park, Cleveland, O., presented his paper, "Electric Lighting—a Factor in Civilization" with illustrations.

Monday, December 7, Regular Meeting (No. 880). Prof. John F. Hayford, M. W. S. E., Northwestern University, addressed the meeting on "The Surveys and the Decision in the Costa Rica-Panama Boundary Arbitration."

Monday, December 14, Extra Meeting (No. 881). The Bridge and Structural Section. Dr. Hermann von Schrenk, of St. Louis, read his paper on "Modern Uses of Wood" with illustrations.

Monday, December 21, Extra Meeting (No. 882). Mr. William O. Lichtner, M. W. S. E., read a paper by Sanford E. Thompson, of Massachusetts, and himself, jointly, on "Construction Management."

Wednesday, December 30, Extra Meeting (No. 883) of the Electrical Section for nominations of officers of the Section for 1915. H. M. Wheeler, C. A. Keller and F. J. Postel were nominated as members of the Executive Committee.

Attention is invited to another event this past year, viz., the installation of the 100-foot Length Standard in the basement of the City Hall at the expense of this Society, who transferred the same to the City of Chicago for the use of the public. This was described at length and in detail, with illustrations, in our Journal for September, 1914; Vol. XIX, page 735.

The Journal has been published monthly during the past year except the months of July and August. It amounted to 1,028 pages of text, besides the index, and contained many folding plates and other illustrations.

Very respectfully yours,

J. H. Warder, Secretary.

Librarian's Report.

January 13, 1915.

To the Board of Direction, Western Society of Engineers, Chicago.

Gentlemen:—The Librarian reports for 1914 the continued use and growth of the Library of the Society. The increase in the number of volumes accessioned is almost identical with that of 1913, being 343 volumes. Of this there were 91 volumes of engineering and scientific periodicals bound by the Society; 64 volumes of gifts (a number of these from the library of the Railway Age Gazette); 49 volumes were purchased by the Society, and 29 volumes were sent us by publishers in exchange for reviews or reading notices in our Journal.

The library, as a free reference library of an engineering, technical and scientific character, is filling its place in the community.

Very respectfully,

J. H. Warder, Librarian.

Report of the Chanute Medal Awards.

November 17, 1914.

To the Board of Direction, Western Society of Engineers, Chicago.

Gentlemen:—Your committee appointed to canvass the papers presented before the Society during the year 1913 and make recommendations for the award of the Chanute Medals, begs leave to make the following report:

We recommend that the medal for the best paper in Civil Engineering be awarded to O. H. Basquin for his paper on "Columns."

We recommend that the medal for the best paper in Mechanical Engineering be awarded to T. V. Salt for his paper on "Manufacture of By-Product Coke."

There was but one paper presented in Electrical Engineering, and while it possessed considerable merit, your committee does not feel that a medal should be awarded.

Respectfully submitted,

(Signed) { W. C. Armstrong, Chas. B. Burdick, H. M. Wheeler,
Committee.

Report of Judges of Election.

January 8, 1915.

The undersigned judges of election, having canvassed the ballots cast for officers of the Western Society of Engineers for the year 1915, have the honor to report as follows:

Total number of votes cast	399
Total number of ballots rejected as irregular	8
Total number rejected as not qualified to vote on account of non-payment of dues	5
Total number of ballots counted	386
Number of votes cast for President:	
B. E. Grant	187
Wm. B. Jackson	194
Number of votes cast for First Vice-President:	
Ernest McCullough	350
Number of votes cast for Second Vice-President:	
C. B. Burdick	240
I. F. Stern	138
Number of votes cast for Third Vice-President:	
P. B. Woodworth	360
Number of votes cast for Treasurer:	
C. R. Dart	358
Number of votes cast for Trustee for three years:	
H. J. Burt	138
O. P. Chamberlain	158
W. A. Hoyt	18
L. J. Putnam	52

Respectfully submitted,

(Signed) { E. N. Layfield, J. W. Pearl, M. M. Fowler,
Judges of Election.

TREASURER'S REPORT, DECEMBER 31, 1914.

To the Board of Direction,
Western Society of Engineers,
Chicago, Ill.

Gentlemen:—I respectfully submit herewith a statement of the Treasurer's account for the year ending December 31, 1914, as follows:

January 1, 1914, cash in bank	$ 946.42	
Total cash receipts during year 1914	*19,271.03	
		$20,217.45

*Includes two loans made from Corn Exchange National Bank, net amount, $1,978.39.

Total cash disbursements during year 1914	†$19,528.06	
Balance in bank December 31, 1914	689.39	
		$20,217.45

CASH RESOURCES (PAR VALUE).

Total cash resources December 31, 1913		$14,446.42
Cash resources December 31, 1914:		
Investment in bonds at 5 per cent	$11,000.00	
Investment in bonds at 6 per cent	4,500.00	
Cash in bank	689.39	
	$16,189.39	
Less net amount borrowed	1,978.39	
	$14,211.00	
Loss in cash resources, 1914	235.42	
	$14,446.42	$14,446.42

Respectfully submitted,

C. R. Dart,
Treasurer.

FINANCIAL STATEMENT FOR YEAR 1914.

CASH.

Balance in bank January 1, 1914	$ 946.42	
Petty cash	75.00	
		$ 1,021.42

RECEIPTS.

Members' dues and subscriptions	$11,926.55	
Entrance fees	685.50	
Subscriptions	185.18	
Advertising	2,329.74	
Sales of Journals	134.52	
Interest	798.34	
General printing	385.05	
Rentals	490.50	
Miscellaneous	357.16	
Loan, Corn Exchange National Bank	1,978.39	
		19,271.03
		$20,292.45

DISBURSEMENTS.

Services	$ 3,696.80	
Journal services	2,920.43	
Journal expense	3,865.02	
House expense	3,838.94	
Stationery, postage and exchange	1,052.93	
General printing	1,241.75	
Library	252.82	
Library expense	53.86	
Furniture and fixtures	74.46	
Medal account	37.50	
Miscellaneous	478.55	
Investment in bonds	2,015.00	
		$19,528.06
Balance in bank and on hand December 31, 1914		764.45
		$20,292.45

J. H. Warder,
Secretary.

C. R. Dart,
Treasurer.

†Includes two bonds purchased at net cost of $2,015.

January, 1915

BOOK REVIEWS

THE BOOKS REVIEWED ARE IN THE LIBRARY OF THIS SOCIETY.

Use of Water in Irrigation. By Samuel Fortier, Chief of Irrigation Investigation, Office of Experiment Station, U. S. Department of Agriculture. McGraw-Hill Book Co., New York, 1915. Cloth; 5½x8 in.; 265 pages; many illustrations and tables. Price, $2.00.

An interesting book, one of the Agricultural Engineering Series, of which E. B. McCormick, formerly of the Kansas State Agricultural College and now connected with the Office of Public Roads, U. S. Department of Agriculture, is consulting editor.

The book treats of "The Irrigated Farm," "Necessary Equipment and Structures," "Preparing the Land and Applying Water," "Waste," "Measurement, Delivery and Duty of Water," and "Irrigation of Staple Crops."

The location and selection of a farm under irrigation is of much consequence, and depends much upon the wishes of the prospective settler as to the kind of farming he expects to follow; and this is based on his personal experience and what he has learned as to various aspects of the problem. The would-be settler should carefully investigate the climate, soil, drainage, crops that can be raised, the transportation of these to market, and not forget the social and educational advantages of one or another location, assuming that there is a family with young people to be cared for. Special consideration should be given to the character of the soil, that it contains the plant food necessary for the growth of the crops that are to be cultivated, for to make up deficiencies in the supply of plant food is an expensive and time-consuming work.

Land open to settlement by purchase or entry is explained at some length, and from the figures presented it amounts to about 12,000,000 to 13,000,000 acres. The water supply comes mostly from streams, but there is much land irrigated from wells, springs, stored water supplies, and lakes. The subject of water rights is sometimes rather complicated, and the settler should see to it that his water rights, as transferred to him, are as clearly understood and stated as his rights to the land. The settler is also interested in the soil of the arid and semi-arid regions. Soil moisture, and movement of the same, complete this chapter.

The author of this book gives some valuable instructions as to necessary equipment and structures, a knowledge of which would have saved many settlers much misery and loss. This includes also the creation of ditches and their lay-out, the regulating devices to control the water, culverts, drains, and pumping outfits. In addition to the details it is frequently necessary, in improving the land, to remove native vegetation, sage brush and its allies, tree stumps, etc., and various tools to assist in this and other work are shown. Of much consequence in connection with this work is the waste, measurement, delivery, and duty of water. The descriptive notes and illustrations make this readily comprehended.

The final chapter discusses at some length the irrigation of staple crops, including the harvesting and storage of the crop, the number of irrigations and amount of water required. Altogether the book is a valuable one and should be widely distributed in the arid regions. Even in what is known as the humid regions there are many occasions when irrigation, done with knowledge and judgment, would be profitable to the cultivator.

Construction of Masonry Dams. By Chester W. Smith, Consulting Engineer. McGraw-Hill Book Co., New York, 1915. Cloth; 6x9 in.; 279 pages; 68 text figures with 16 plates. Price, $3.00.

This new and interesting book does not discuss the subject of the design of dams so much as the construction, with costs, and covers details of value to constructing engineers. Whereas the engineering press has published descriptions of particular dams, their dimensions, design, etc., these articles have not gone so much into the involved principles of construction. Much work that may be involved in the construction of any specific dam, as earth and rock excavation, pumping and the like, have not been included in this work, as the subjects have been treated in other books. But the book does contain a great deal of valuable information to those engineers who are interested in serving estimates of cost when called upon to furnish a report on some project for the benefit of those financially interested.

The "Introduction" of 4 pages is interesting and suggestive.

Chapter I., of 19 pages, pertains to "Exploring the Site" by borings, core drilling, etc., with illustrative examples from some notable dams recently built, as Olive Bridge and Wachusett. In Chapter II. the matter of diversion work is considered, with costs of actual examples. Then comes "Preparing the Foundation" in Chapter III., starting the masonry, taking care of the water and grouting, with data on two grouted foundations. "Masonry Construction" is the subject of Chapter IV., of 22 pages, and includes sand, natural or manufactured, mortar, concrete, stone, cyclopean masonry, and conditions governing progress in which the arrangements and moving of derricks has an important part in the cost of the work.

In Chapter V. is the subject of "Quarrying," with conditions affecting cost with tabulation of costs of production of stone at the Roosevelt Dam. Then comes "Face Work" and miscellaneous features in Chapters VI., VII., VIII. Plant and Power and Installation required, and Power Consumption, is treated in the next two chapters, of 22 pages. Chapter XI. treats of Assembling Materials, Crushing and Mixing, followed in the next chapter with Transportation of Materials, as Cableways, Chutes, Belt Conveyors, etc. Chapter XIII. treats of Probable Future Methods to increase output and secure efficiency. The final, Chapter XIV., of 38 pages, takes up the important matter of Estimation of Cost and contains many valuable figures. Finally, Chapter XV. gives a partial list of existing dams with descriptions and costs, covering nearly 60 pages.

An index of 7 pages seems to be very full and completes a valuable book for those interested in the subject, whether as construction engineers, or others interested as students of engineering work.

MEMBERSHIP

Additions:

Casler, William A., Chicago..............................Member
Felt, C. F. W., Chicago..................................Member
Kushlan, Max, Chicago........................Associate Member
Larsen, Peter M., Chicago....................Associate Member

Transfers:

Drought, Orville H., Milwaukee, Wis., Junior to Associate Member.

Deaths:

Bransfield, J. T., Chicago, Jan. 21, 1915.

January, 1915

RULES FOR ESTABLISHMENT OF BRANCH ASSOCIATION OF THE WESTERN SOCIETY OF ENGINEERS.

(1) Branch Associations of the Western Society of Engineers may be established by the adoption of a Constitution, which shall be approved by the Board of Direction, and by organization of the proposed Branch Association thereunder.

(2) Said Constitution shall provide:

(a) That all members of the Branch Association shall be members, in good standing, of the parent body.

(b) That all fees and dues assessed by the Branch Association against its members shall be in addition to regular fees and dues required by and paid to the parent body.

(3) A copy of the minutes and proceedings of each meeting of the Branch Association shall be filed with the Secretary of the Western Society of Engineers within ten days after the meeting.

(4) The Western Society of Engineers may publish in the Journal such proceedings of the Branch Association as shall be approved by the Publication Committee.

Journal of the
Western Society of Engineers

VOL. XX FEBRUARY, 1915 No. 2

CONSTRUCTION MANAGEMENT

By Sanford E. Thompson and William O. Lichtner, M. W. S. E.

Presented December 21, 1914.

Machinery in many industries has been developed to a point where the limitation of mechanics prevents further marked advances. It is being recognized almost universally that the next important development must be in the line of management methods. Factory managers, therefore, are giving particular attention to management methods, with already notable results in increase in output and benefit to the workmen.

In a similar manner, although more slowly, the attitude of construction engineers and contractors during the past decade has been undergoing a marked change. They are realizing generally that something quite radical must be undertaken in the introduction of economies in operation in order to balance the increase in wages of skilled and unskilled labor and the rising prices of materials.

Such improvements in construction methods involve:

(1) Introduction of improved machinery where machinery is economical.

(2) Introduction of improved methods of handling labor and machinery and standardizing their methods.

(3) Reduction in waste of material.

(4) Elimination of unnecessary operations of the workmen.

(5) Relieving the skilled worker of duties which the unskilled man can do.

(6) Increasing the productive capacity of each man.

Following along the lines of development in factory operations, it is now being realized that the same principles, which we may term Scientific Methods of Management, are applicable to construction work. These have been put to the test in a number of cases and the results have proved conclusively the applicability of scientific methods to construction operations. In making so sweeping a statement as this it is recognized that no cut-and-dried scheme can be applied to every piece of construction work. Just as in factory work, the methods of attack and the processes to be followed vary with the character of the work. But the general principles of planning the work, standardization of operations, and training of the men, are adaptable to any kind of work provided either the job is of long duration or the construction company (as is almost always the case) is handling similar work right along, so that an organization once developed can be transferred from job to job.

RESULTS OF SCIENTIFIC METHODS IN CONSTRUCTION.

The most convincing proof of the value of any plan is the fact that it has been carried out successfully. As a result of actual experience in construction work, it has been proved that scientific methods of construction give:

(a) Low unit costs.
(b) High wages to the workmen.
(c) Completion of work in a minimum time.
(d) Uniformly high quality of work.

When the work is planned out and handled systematically, we may say scientifically, greater skill and effort is required on the part of the management, and the question naturally arises whether the results produced are simply smoother working of the labor mechanism, or whether, on the other hand, it actually pays in dollars and cents. As an illustration of actual results, two or three cases may be cited before taking up the details of the methods.

In concrete construction work it is frequently stated and is a known fact that the cost of the form work is the determining factor whether a profit or a loss is incurred by the contractor. Taking actual unit costs under ordinary methods in comparison with similar unit costs under scientific methods of constructing reinforced concrete buildings of typical design of beam and girder construction, we find as follows:

Operations—	Cost of Labor under Ordinary Methods.	Cost of Labor under Scientific Methods.
"Making form work....	1¾c per sq. ft.*	1c to 1½c per sq. ft.
"Erect and strip" form work	6c per sq. ft.	4c per sq. ft.
Bend, assemble and place reinforcing steel.	$7.50 per ton	$4.90 per ton

The figures in both cases include job expenses but not general overhead.

On one job under scientific methods the "making" of the form work for a 6-story concrete building, 200 ft. by 600 ft., was done at practically one-half the cost of exactly the same work by the same company under the old methods; and this notwithstanding that they had made a detail study of their costs for several years to reduce them as low as possible. This saving was due directly to the application of scientific management methods.

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*This is a figure lower than the majority of the construction companies ever get even under very favorable conditions.

In house construction similar results have been produced. In one case where scientific methods were installed by a residential building company and the carpenter work laid out so as to give definite jobs to each man with a liberal reward for accomplishment, two buildings out of a group of twenty about to be constructed (no two of which were alike) were selected to compare work by day labor with that handled by scientific management methods. On these two houses all the carpenter work was handled by straight day labor and the carpenter foreman selected for the job was the most experienced foreman in the employ of the company—in fact, he formerly had sub-contracted for this work at low cost. The other eighteen houses were built by improved methods of management, the carpenters being paid a bonus for accomplishing the work laid out for them in the required manner and time. On the houses built by the ordinary day-work methods, the increased cost of the work over that obtained on the other eighteen houses with the improved methods was as follows:

Setting of first floor joists cost 78 per cent more than with task and bonus.

Erecting first floor curtain walls cost 26 per cent more than with task and bonus.

Erecting second floor curtain walls, cost 16 per cent more than with task and bonus.

Erecting first floor sub-floor cost 54 per cent more than with task and bonus.

Erecting second floor sub-floor cost 59 per cent more than with task and bonus.

In the work of common laborers, such as trenching and backfilling for sewers and water pipe, large reductions in cost have also been effected. For example, in a case where the digging was of an exceptionally hard and varied character, being a very stiff tenacious clay, the following results were obtained:

Operation—	Unit Cost— No Task Work.	Unit Cost— With Partial Task Work.
Excavation	48.0c per cu. yd.	34.8c per cu. yd.
Pipelaying	11.1c per lin. ft.	4.5c per lin. ft.
Backfilling	34.6c per cu. yd.	10.6c per cu. yd.

These results have not been due, as might be thought at first sight, to requiring the workman to do two or three times the amount of work he formerly accomplished, but in a large degree to thorough planning of the work in advance, studying the actual details of the work, and teaching men how to perform their tasks in the easiest possible manner.

The savings, then, were obtained not by merely hustling the work nor in any degree by slighting it, but to the much more essential features of:

(a) Economical design and layout of construction operations.

(b) Laying out in advance the method of handling the work to reduce to a minimum the quantity of construction material.

(c) Selection of the best tools and materials.

(d) Arranging the processes to simplify the work, and teaching the men how to do it in the best way.

(e) Designating in advance the amount of work to be done by each man.

(f) Giving the men a definite money incentive to encourage them to do a large day's work.

(g) Eliminating the time ordinarily lost by workmen, such as waiting for orders, waiting for foreman to lay out the work, waiting for materials, looking up tools, using improper tools.

PRINCIPLES.

The general principles, then, that may be applied to construction operations are similar to those which have proved so satisfactory in shop management. As Mr. Taylor so ably states ("Principles of Scientific Management," by Frederick W. Taylor, p. 35), scientific methods develop the initiative of the workmen, that is, their capacity for hard work, their goodwill and their ingenuity, to a far greater extent than is possible under the old method, while the management also assumes the new duties of gathering the traditional knowledge which in the past has been possessed only by the workman, and reducing this to rules which help the workmen in their daily tasks. Mr. Taylor groups this and three other types of duties which involve new and responsible burdens for the management under four heads and discusses these as follows:

> *First.*—As explained above, they develop a science for each element of a man's work, which replaces the old rule- of-thumb method.
>
> *Second.*—They scientifically select and then train, teach and develop the workman, where in the past he chose his own work and trained himself as best he could.
>
> *Third.*—They heartily coöperate with the men so as to insure all of the work being done in accordance with the principles of the science which has been developed.
>
> *Fourth.*—There is an almost equal division of the work and the responsibility between the management and the workmen. The management take over all work for which they are better fitted than the workman, while in the past almost all of the work and the greater part of the responsibility were thrown upon the men.
>
> It is this combination of the initiative of the workmen, coupled with the new types of work done by the management, that makes scientific management so much more efficient than the old plan.
>
> Three of the elements exist in many cases, under the management of "initiative and incentive," in a small and rudimentary way, but they are, under this management, of minor importance, whereas under scientific management they form the very essence of the whole system.
>
> The fourth of these elements, "An almost equal division of the responsibility between the management and the work-

men," requires further explanation. The philosophy of the management of "initiative and incentive" makes it necessary for each workman to bear almost the entire responsibility for the general plan as well as for each detail of his work and in many cases for his implements as well. In addition to this he must do all of the actual physical labor. The development of a science, on the other hand, involves the establishment of many rules, laws and formulae, which replace the judgment of the individual workman, and which can only be effectively used after having been systematically recorded, indexed, etc. The practical use of scientific data also calls for a room in which to keep the books, records, etc., and a desk for the planner to work at. Thus all of the planning which under the old system was done by the workman, as a result of his personal experience, must of necessity under the new system be done by the management in accordance with the laws of the science. Because even if the workman were well suited to the development and use of scientific data, it would be physically impossible for him to work at his machine and at a desk at the same time. It is also clear that in most cases one type of man is needed to plan ahead and an entirely different type to execute the work.

The man in the planning room, whose specialty under scientific management is planning ahead, invariably finds that the work can be done better and more economically by a subdivision of the labor, each act of each mechanic, for example, should be preceded by various preparatory acts done by other men. And all of this involves, as we have said, "an almost equal division of the responsibility and the work between the management and the workman."

To summarize: Under the management of "initiative and incentive" practically the whole problem is "up to the workman," while under scientific management fully one-half of the problem is "up to the management."

Perhaps the most prominent single element in modern scientific management is the task idea. The work of every workman is fully planned out by the management at least one day in advance, and each man receives in most cases complete written instructions, describing in detail the task which he is to accomplish, as well as the means to be used in doing the work. And the work planned in advance in this way constitutes a task, which is to be solved as explained above, not by the workman alone, but in almost all cases by the joint effort of the workman and the management, those in the management doing a considerable part of the work which in the past has been done by the workman alone. This task specifies not only what is to be done but how it is to be done, and the exact time allowed for doing it. And whenever the workman succeeds in doing his task right, and within the time limit specified, he receives an addition of from 30 per cent to 100 per cent to his ordinary wages. These tasks are carefully planned, so that both good and careful work are called for in their performance, but it should be distinctly understood that in no case is the workman called upon to work at a pace which would be injurious to his health. The task is always so regulated that the man who is well suited to his job will thrive while working at this rate during a long term of years and grow happier and more prosperous, instead of being overworked. Scientific management consists very largely in preparing for and carrying out these tasks.

METHODS.

Cost keeping has been developed recently by contractors to a marked degree and the advantages of knowing what each part of the work is costing from day to day is apparent in providing an opportunity to follow up the heads of the various branches where costs are running high. This, however, is really the limit of its effectiveness since a mere record of costs does not in any way show how to handle the work in a less expensive manner.

The aim of scientific management is to find the best and cheapest way to accomplish a piece of work and provide means for doing it in this fashion.

Formerly much construction and even shop work were carried on with no detail structural drawings and many of the directions were given by word of mouth. Nowadays a question as to whether or not the making of designs or construction drawings reduces the cost of work, would be considered absurd since the economical advantages of the drafting room are obvious. Yet we frequently handle construction work in a most haphazard way with no definite plan and no definite arrangement of men and materials except as the occasion requires from day to day or from hour to hour.

To handle work systematically it is necessary to:

(1) Plan the work in advance.

(2) Determine the best methods to employ in construction.

(3) Lay out individual or gang work for the various men.

(4) Train the men to accomplish their duties in the best and shortest way.

(5) Provide an incentive so that each man will be glad to do a full day's work without being driven to it.

Many construction companies are carrying out a part of these principles, but few are developing all of them with anything like the effectiveness possible.

To illustrate in detail the methods that have proved successful, we may take the construction of a reinforced concrete building. To still further confine the description and give more details of the work, we will consider simply the making of the form work. In taking this special case, however, it is recognized that the same principles have been found by experience to apply to various other types of engineering construction both in private contract and municipal work. As a matter of fact, the fundamental principles are identical with the principles required in shop work.

In discussing in this paper the phases of the work, emphasis is placed on methods that are in whole or in part comparatively new rather than those which are basic in all work regardless of the method of management adopted. These newer methods involve special construction designs, planning and routing the work, standardizing methods, and a study of time in which each small element of the work should be done.

In any construction company the duties of the engineer, aside from his relation to the financial interests, may be two-fold:

(a) Duties involving the structural design and engineering features of the construction.

(b) Engineering which relates specifically to the construction plant and the methods of handling the details of the construction work.

Instead of both of these functions devolving on one man, the chief engineer, the duties in a large construction company can best be separated, the chief engineer handling what may be termed civil engineering while the treatment of the construction organization and methods in full detail requires the services of a new man termed the "production engineer." It must be understood that his services do not entail an extra cost to the job because his duties actually replace the work usually done by men less competent to perform the high class of work required, and result in improvements in methods and cutting down the number of employes so as to save a far greater amount than the salary of this officer. In a company handling a small amount of work one man may serve both functions. In another case a member of the construction company may act as chief engineer.

Design.—Under scientific methods of management the work of the designing engineer is increased because in order to properly lay out the work he must prepare detail drawings or sketches for the concrete, the reinforcing steel, and the form work. In other kinds of construction similar detail designs have been found economical. For example, in house construction complete framing plans should be made. It is appreciated that many construction companies follow such methods to a limited extent, but it is the object of this paper to show how these may be extended with economy of cost. A more extended discussion of the details of certain features of this work is taken up further on in this paper.

The making up of all material lists follows the making of these detail sketches, the lists being worked up in such a manner that they can be used not only for ordering materials but for checking their receipt upon the job. In addition to this work, the designing engineer must, with the advice of the job superintendent, actually design on paper the plant which is to be built for handling the construction.

These various features of design, that is, all of those that relate to the method of work, handling of materials, and listing the materials, are under the supervision of the new production engineer.

Planning and Routing.—One of the most important features under the new type of management is what is termed the "routing" of the work, which is also under the supervision of the production engineer. This involves planning out in detail and in writing all work connected with the construction of the building just as we plan the structural design and for a similar purpose, usually to save time of the workman and insure a higher quality of work. This means planning just how each part of the work is to be done, in what sequence the various parts of the work will follow each other, the size of gangs of different trades required from day to day to get the work done in schedule time, and the schedules for ordering materials so as to have them on hand when required. After the work has all been planned, graph charts are made for the home office and for the job, designed so that the home office and the superintendent can see at a glance just how far ahead or behind a job is at any time.

It takes time to plan out the work in detail and may even slightly delay starting the actual construction, but it pays in the long run, for when the work does start it will go along far more quickly and at a much less cost than if it had been done by ordinary methods. Experience has proved what a short-sighted and costly policy is that sometimes followed by construction companies, which requires the superintendent and some workmen to be on a job 24 hours after the contract is signed to indicate their goodwill to finish the work in the minimum length of time.

As the name indicates, the route man directs the movements of all materials of which the structure is to be made in minute detail, so that they shall be delivered at the right place with a single handling and the minimum of expense. In order to do this he must be a practical construction man of experience, who posesses the ability to visualize the job from beginning to end and to record this in such a manner that the superintendent and field force can carry out the details as planned. The location of the jobs with reference to the home office and their size determines whether all the routing can be done by one route man at the home office or whether only the main details shall be handled there and the other details consigned to a job route man. In the case discussed the job is assumed to be handled direct by the route man at the home office.

The route man first visits the job with the job superintendent, assuming that the production engineer and designing engineer are already familiar with the project, and by a careful study of the surroundings decides on the location of the job office, mill saws, stock piles, tool sheds, track sidings for railroad cars, location of concrete mixers, and any other necessary things which will need ground space. He then works up a ground plan on a fairly large size scale showing the location of all features of the plant. This preliminary planning saves considerable money over the old plan of waiting for materials to arrive on the job before considering the placing of it.

Take, for example, the locating of the lumber piles. The route man receives from the designing engineer the schedule of the lumber to be used in the form work. From this list he lays out the piles of lumber, separating each thickness, width, and length, and designates on the ground plan where each pile is to be placed so that when the lumber arrives on the job every stick of lumber is carried direct from the car or the wagon to its proper place and located as conveniently to the saw-mill as practicable. When a stick 1½ in. by 8 in. by 12 ft. long is wanted it will be found in a certain pile. This saves much re-handling of lumber and a lot of lost time hunting for a piece of a certain size, to say nothing of the loss of material and time cutting up large stock because suitable small stock is buried under it.

The kind and quantity of equipment on any particular job is generally determined by the available equipment owned by the company, but it often pays to rent or buy a certain equipment in order to get the work done more quickly or at a cheaper cost. For instance, it is usually found to be a paying proposition to install a power-driven circular saw on any job using considerable form work, because of the saving in time and lumber. A consideration of such matters involves also the best methods of operating.

From the details furnished by the designing engineer, the route man plans the work and has the necessary material issued and operation tickets made out, as described further on in this paper. In this way the material lists gotten out by the designing engineer are all checked before the job is started. The route sheets and graphical charts next made up are the key to the successful carrying on of the work in accordance with the route man's plans.

The route man sends to the job superintendent the field plan showing the location of the job office, mill saw, stock piles, etc., so that he can do all preliminary work while the route man is arranging the routing. The superintendent gets together his organization of foremen, job-order-of-work men, office and engineering force. The plans, route sheets, graph chart and tickets are sent to the job as soon as finished. These must be studied carefully by the job superintendent and he must enforce the work in every detail according to schedule. This does not, as might appear at first thought, take the individuality away from the superintendent, but simply relieves him of much detail which can better be handled by the route man in the office. The route man, of course, must keep in close touch with the superintendent and avail himself of his experience in all matters while the plans are maturing. Having planned the work, it is absolutely necessary for the job superintendent to follow instructions explicitly, otherwise confusion will arise.

It is evident that the duties of the job superintendent under the new methods are somewhat changed, in fact the title "superintendent" might well be changed. He is not given free hand as when he was allowed to run the job pretty much according to his own notions. Formerly, so long as his costs were within the

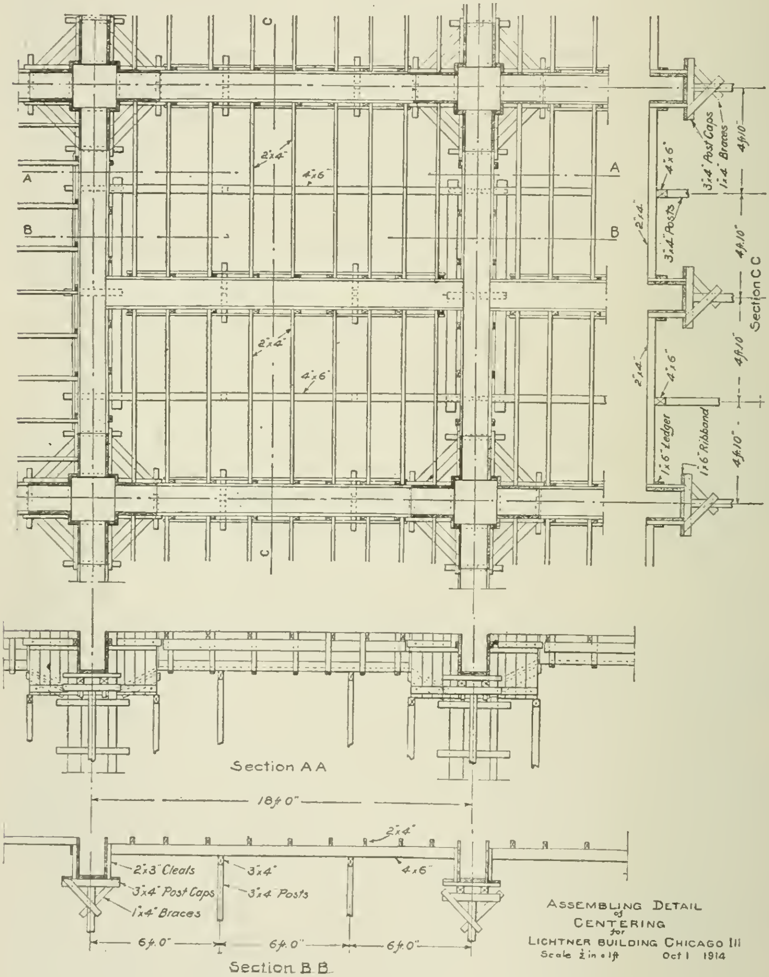


Fig. 1. Typical Design Showing Assembly Details.

original estimate, he was not taken to task. This practice is not fair; in fact, one may cite case after case where the superintendent has been commended for some good costs he has obtained and then reprimanded for high costs on some other job which were due not to his methods of management but to the estimator figuring the cost on the first job too high, while on the second job he did not allow enough for the special construction or difference in design. Under the newer methods of management such features as the design of the form work is standardized and separated into units so that the cost of the labor on one job is accurately comparable with that on another job.

The job superintendent is responsible for the correctness of the work. He is the construction company's representative who deals with the owner and architect and settles all small differences which arise on every job.

DETAILS OF OPERATION.

To properly handle on the job such work as form making, plans showing the design must be given to the individual carpenter, means must be arranged for providing necessary material, and the quantity of work done by each man must be recorded.

The necessity for detail form designs made up under the direction of the designing engineer has already been mentioned. Although these are naturally made up in the drafting department of the home office, they affect the actual operation of the job so intimately that they are best described at this point.

Form Design.—Unless the forms are designed so as to use the smallest amount of material in the best possible way, economy is, of course, impossible. The layout must take into account not only the labor cost but also the quantity of lumber.

The customary practice of most construction companies has been to leave the selection of type of forms to the job superintendent, who in turn leaves it to his carpenter foreman already overburdened with executive work. On the other hand, while the design should always be discussed with the job foreman, a different type of mind from that ordinarily possessed even by a first-class foreman is required to present plans or sketches in such detail that they can be read by an ordinary carpenter without trouble.

To simplify the methods, therefore, it is necessary that the plans for the forms be made in the drafting room. A typical design showing assembling details is shown in Fig. 1.

Labelling Forms.—To locate each form readily it must be numbered or lettered in such a way that it will not get mixed up with other forms or parts of forms of different dimensions. The plan used is shown in Fig. 2, which is a key plan for the form work. All forms of a given dimension should be marked alike so that they can be used interchangeably.

The mnemonic symbols (i. e., memory symbols) have been found to be the most satisfactory way of designating the forms. These symbols are shown in Fig. 2. The notation at the bottom of the figure gives the key to the symbols and you will note that as far as possible the letter used in the symbol is the first letter in the word. You will note also that the position of the letter has

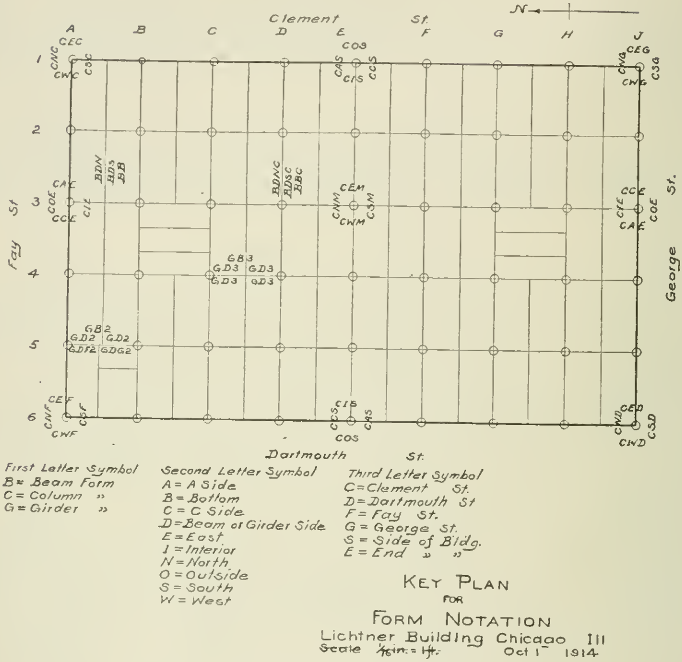
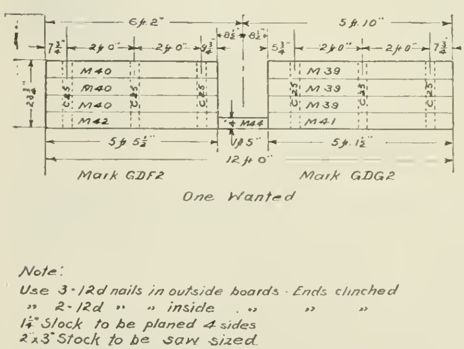


Fig. 2. Key Plan for Form Work.



Lumber Schedule, Girder			GDF2 GDG2
No. of Pcs.	Size	Length	Mark
6	2"x3"	1 ft. 11½"	C25
3	1¼"x6"	5 ft. 5½"	M40
3	1¼"x6"	5 ft. 1½"	M39
1	1¼"x 5¾"	5 ft. 5½"	M42
1	1¼"x 5¾"	5 ft. 1½"	M41
1	1¼"x4"	1 ft. 5"	M44

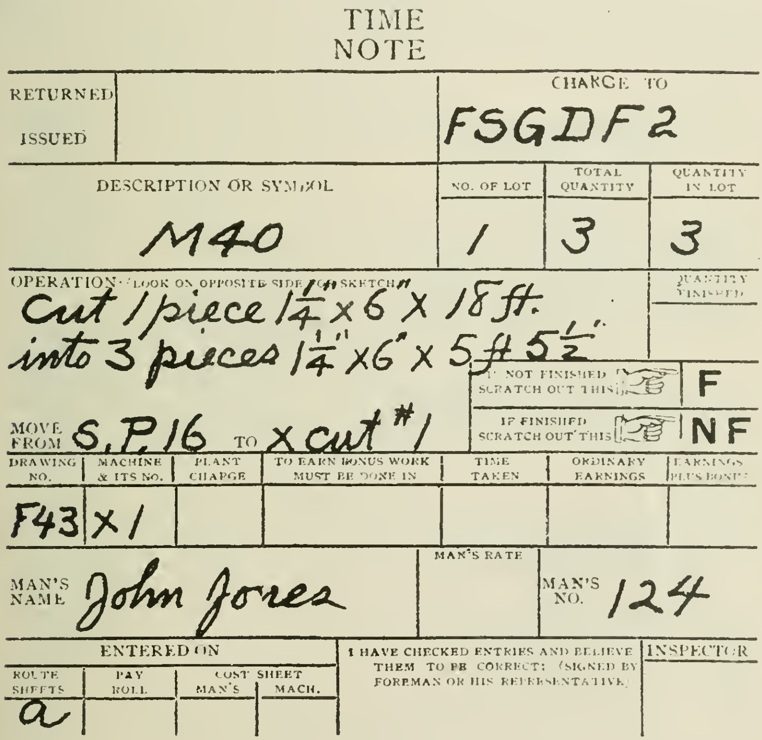
DETAILS OF GIRDER FORMS
for
LICHTNER BUILDING CHICAGO Ill.
Scale ½ in = 1 ft. Oct 1 1914

Fig. 3. Typical Girder Form Details.

a meaning, also that the letter *B*, when the first letter in the symbol, stands for beam, while *B* as the second letter stands for bottom. The figure between the letter generally indicates location. Take the symbol *G D F 2* as an illustration. This symbol reads as follows:

1st letter *G* for girder.
2nd letter *D* for side.
3rd letter *F* for Fay St.
Figure *2* for No. 2 girder.

To illustrate how each form is detailed, girder *G D F 2* and *G D G 2* is shown in Fig. 3. These sketches are made on sheets 6 by 12 in.



TIME NOTE

RETURNED
ISSUED
CHARGE TO: FSGDF2

DESCRIPTION OR SYMBOL	NO. OF LOT	TOTAL QUANTITY	QUANTITY IN LOT
M40	1	3	3

OPERATION (LOOK ON OPPOSITE SIDE FOR SKETCH) Cut 1 piece 1¼ x 6 x 18 ft. into 3 pieces 1¼" x 6" x 5 ft 5½"
QUANTITY FINISHED
IF NOT FINISHED SCRATCH OUT THIS — F
IF FINISHED SCRATCH OUT THIS — NF
MOVE FROM S.P.16 TO X cut #1

DRAWING NO.	MACHINE & ITS NO.	PLANT CHARGE	TO EARN BONUS WORK MUST BE DONE IN	TIME TAKEN	ORDINARY EARNINGS	EARNINGS PLUS BONUS
F43	X 1					

MAN'S NAME John Jones — MAN'S RATE — MAN'S NO. 124

ENTERED ON: ROUTE SHEETS a | PAY ROLL | COST SHEET MAN'S | MACH.
I HAVE CHECKED ENTRIES AND BELIEVE THEM TO BE CORRECT: (SIGNED BY FOREMAN OR HIS REPRESENTATIVE)
INSPECTOR

Fig. 4-a. Operation Ticket.

and only penciled on white drawing paper which can be readily blue printed. Each drawing is made complete in detail together with the material list. The lines for the cleats are shown dotted as the cleats are placed on the "make benches" first, and the form boards are then thrown on top of them and, after being clamped in position to draw the boards together, are nailed to the cleats.

Figure 3 shows also that each board is marked with a number preceded by *M* and each cleat is marked with a number preceded by *C*. This is to differentiate between the form boards and cleats so that the move men and carpenters looking at a certain number will know whether to look for a cleat or a form board. An *M* number is assigned to a board of a certain thickness, width and length, and it does not matter where this certain dimensioned piece goes into a beam or girder or column, it is always, on this job, given that particular number. A list of all the *M* numbers is kept and in this way a cross-index is made up between the *M* numbers and the dimensions.

MOVE
ORDER

RETURNED / ISSUED		CHARGE TO: FSGDF2		
DESCRIPTION OR SYMBOL		NO. OF LOT	TOTAL QUANTITY	QUANTITY IN LOT
M40		1	3	3

OPERATION: Cut 1 piece 1¼" x 6" x 18 ft. into 3 pieces 1¼" x 6" x 5 ft 5½"

QUANTITY FINISHED:

IF NOT FINISHED SCRATCH OUT THIS ☞ **F**

IF FINISHED SCRATCH OUT THIS ☞ **NF**

MOVE FROM S. P. 16 TO X cut #1

DRAWING NO.	MACHINE & ITS NO.	PLANT CHARGE	TO EARN BONUS WORK MUST BE DONE IN	TIME TAKEN	ORDINARY EARNINGS	EARNINGS PLUS BONUS
F43	X 1					

* MAN'S NAME	MAN'S RATE	MAN'S NO.
John Jones		124

ENTERED ON: ROUTE SHEETS	PAY ROLL	COST SHEET MAN'S	COST SHEET MACH.	MOVED BY	GANG BOSS OR INSPECTOR
a					

Fig. 4-b. Operation Ticket.

The symbols serve not only as instructions to the workmen, but they also provide a means for readily scheduling the material lists and in some cases making it possible to order the lumber in advance to exact lengths. The plans show the workman just exactly what he is to do, so that he can go right ahead with the actual work of carpentry without bothering his head about the way the form is

*Should read, William Burke, 262, see page 144.

to be built and without chasing all over the yard after lumber, as is frequently the case on a concrete job.

Operation Tickets.—The next operation is to convert the information on the plans to such form that it will serve as a guide in the concrete job under consideration for the handling of the materials, the sawing of the lumber, and the layout of the sequence and times of work for each carpenter or pair of carpenters.

From the plan, therefore, operation tickets, shown in Fig. 4, are made out. The ticket shown at the top of the figure is made out in triplicate by means of carbon paper. The three tickets are known as the time ticket, the bulletin board ticket, and the move ticket. For convenience in spotting these various tickets a color scheme is used. The time tickets are yellow, bulletin board tickets

BULLETIN
BOARD

HOOK NO.	TO FOLLOW JOB ON HOOK NO.	CHARGE SYMBOL		
		FSGDF2		
DESCRIPTION OR SYMBOL		NO. OF LOT	TOTAL QUANTITY	QUANTITY IN LOT
M40		1	3	3

OPERATION
Cut 1 piece 1¼" x 6" x 18 ft.
into 3 pieces 1¼" x 6" x 5 ft 5½"

MOVE FROM S. P. 16 TO X cut #1

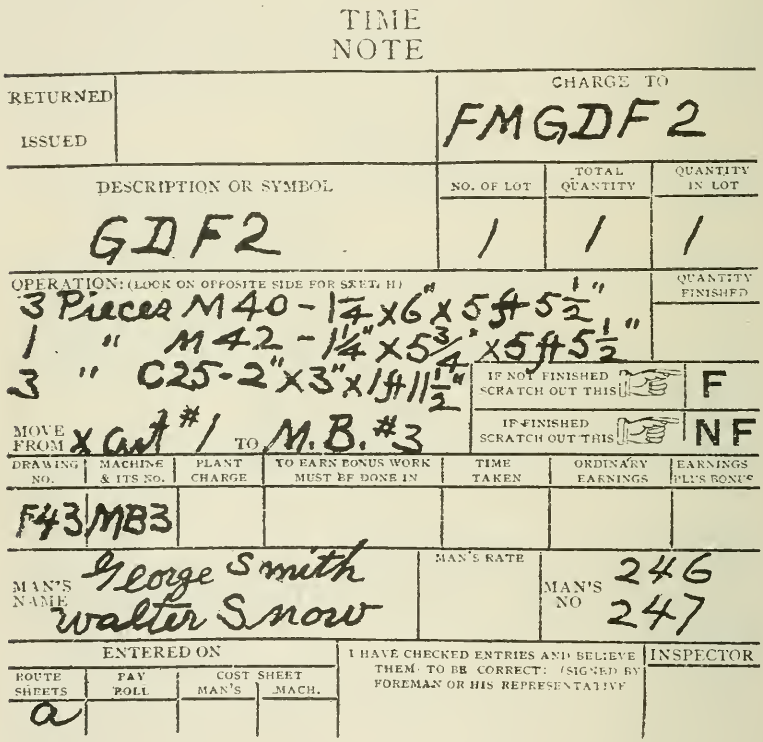
DRAWING NO.	MACHINE & ITS NO.	PLANT CHARGE	TO EARN BONUS WORK MUST BE DONE IN	TIME TAKEN	ORDINARY EARNINGS	EARNINGS PLUS BONUS
F43	X1					

Fig. 4-c. Operation Ticket.

pink, and the move tickets white. By making in triplicate with carbon paper, time is saved and the clerical errors avoided. These tickets, all made out at once, constitute written instructions for cutting so many pieces of a certain size of lumber and calling them *M* —, moving these same sticks, and making them up into forms.

The method of procedure to accomplish this is substantially as follows:

The move man, that is, the laborer who handles the lumber, goes to the field office and receives the white move ticket for, say, 1 board from pile No. 16 in the yard, which is the pile for 1¼ in. by 6 in. by 18 ft. lumber. In most cases, of course, a number of boards are scheduled and handled together. He carries board to cross-cut saw No. 1. The moveman marks a tag with *M* 40 in large figures and takes it to the end of the pile of lumber. As soon as this is done the moveman signs this move ticket and returns it to the office. This is equal to a receipt or statement that the *M* 40 boards of the required number have been delivered to the saw. The cross-cut saw man next calls at the office and is given the time ticket which corresponds to the move ticket just returned and goes back to his saw and finds this pile of *M* 40 lumber which he saws to the length indicated on the ticket. When the man in the field


TIME
NOTE

RETURNED
ISSUED

CHARGE TO
FMGDF2

DESCRIPTION OR SYMBOL	NO. OF LOT	TOTAL QUANTITY	QUANTITY IN LOT
GDF2	1	1	1

OPERATION: (LOOK ON OPPOSITE SIDE FOR SKETCH)
3 Pieces M40 - 1¼" x 6" x 5 ft 5½"
1 " M42 - 1¼" x 5¾" x 5 ft 5½"
3 " C25 - 2" x 3" x 1 ft 11½"

QUANTITY FINISHED

IF NOT FINISHED SCRATCH OUT THIS F
IF FINISHED SCRATCH OUT THIS NF

MOVE FROM X Cut #1 TO M.B. #3

DRAWING NO.	MACHINE & ITS NO.	PLANT CHARGE	TO EARN BONUS WORK MUST BE DONE IN	TIME TAKEN	ORDINARY EARNINGS	EARNINGS PLUS BONUS
F43	MB3					

MAN'S NAME George Smith, Walter Snow
MAN'S RATE
MAN'S NO 246, 247

ENTERED ON

ROUTE SHEETS	PAY ROLL	COST SHEET MAN'S	COST SHEET MACH.
a			

I HAVE CHECKED ENTRIES AND BELIEVE THEM TO BE CORRECT: (SIGNED BY FOREMAN OR HIS REPRESENTATIVE)

INSPECTOR

Fig. 5-a. Operation Ticket.

office gives this ticket to the cross-cut saw man he keeps the corresponding pink bulletin board ticket in front of him, so that he knows what job the cross-cut saw man is working on. When the cross-cut saw man finishes cutting up these boards he returns the yellow time ticket to the office and signs it, which shows that he has sawed these boards to the correct length. The inspector examines the work to see if it is properly done, and if not the workman is required to do it over again. By stamping on the ticket the time when it was taken out and again when it is returned, the time for doing a particular job is accurately kept, which makes the cost-keeping system as well as the time-keeping accurate and reliable.

The tickets for the sawing of the *M* 42 boards and the cleats *C* 25 are handled in the same manner. The field office man checks off his route sheet each time an operation is done so that he can tell as soon as he has all the lumber required to make up that girder form. He now issues a move ticket to the move man to place this lumber to make-bench No. 3. After all the lumber is delivered to bench No. 3 the carpenter from bench No. 3 goes to the field office and gets his time ticket to make girder form *G D F 2*, Fig. 5. The route sheet is again checked off to show when the girder is finished.

BULLETIN
BOARD

HOOK NO.	TO FOLLOW JOB ON HOOK NO.	CHARGE SYMBOL
		FMGDF2

DESCRIPTION OR SYMBOL	NO. OF LOT	TOTAL QUANTITY	QUANTITY IN LOT
GDF2	1	1	1

OPERATION
3 Pieces M40 - 1¼"x6"x5 ft 5½"
1 " M42 - 1¼"x5¾"x5ft5½"
3 " C25-2"x3"x1ft11½"

MOVE FROM X Cut #1 TO M.B. #3

DRAWING NO.	MACHINE & ITS NO.	PLANT CHARGE	TO EARN BONUS WORK MUST BE DONE IN	TIME TAKEN	ORDINARY EARNINGS	EARNINGS PLUS BONUS
F43	MB3					

Fig. 5-b. Operation Ticket.

All forms which are alike are made at the same time with one operation ticket.

Bulletin Board.—For convenience in handling the time tickets and displaying them so that the job order-of-work man can get at them quickly and so that any one connected with the work can see just exactly what is being done by the different workmen, a bulletin board is made which is hung on the wall of the planning room of the field office and contains three lines of hooks. The top line is labelled "WORK IN PROGRESS;" the second line, "Work to be done READY," and the third line, "Work to be done NOT READY." Each man or gang of men, if more than one is to work on a particular job—as where two carpenters work in pairs—has a set of three hooks in a vertical row to receive their tickets.

Task and Bonus Based On Time Study.—In order to obtain complete advantage of the methods which have been described, the work should be handled with some definite incentive, such as a bonus to be paid when a man accomplishes a piece of work laid out for him in the required time and manner. In this way the workman receives a fair reward for doing his work well and faithfully.

MOVE
ORDER

RETURNED / ISSUED		CHARGE TO: FMGDF2		
DESCRIPTION OR SYMBOL		NO. OF LOT	TOTAL QUANTITY	QUANTITY IN LOT
GDF2		1	1	1

OPERATION: 3 Pieces M40 - 1¼" x 6" x 5 ft 5½"
1 " M42 - 1¼" x 5¾" x 5 ft 5½"
3 " C25 - 2" x 3" x 1 ft 11½"

QUANTITY FINISHED

IF NOT FINISHED SCRATCH OUT THIS ☞ F

IF FINISHED SCRATCH OUT THIS ☞ NF

MOVE FROM X Cut #1 TO M.B. #3

DRAWING NO.	MACHINE & ITS NO.	PLANT CHARGE	TO EARN BONUS WORK MUST BE DONE IN	TIME TAKEN	ORDINARY EARNINGS	EARNINGS PLUS BONUS
F43	MB3					

* MAN'S NAME	MAN'S RATE	MAN'S NO.
George Smith Walter Snow		246 247

ENTERED ON				MOVED BY	GANG BOSS OR INSPECTOR
ROUTE SHEETS	PAY ROLL	COST SHEET MAN'S	COST SHEET MACH.		
a					

Fig. 5-c. Operation Ticket.

To determine the time required to do a job, detail time studies are necessary to find the unit time required for each individual operation, so that these unit times may be added up to fit any piece of work.

In a paper of this kind it is impossible to go into the details of the methods of making the studies so as to lay out in advance

*Should read, William Burke, 262; see page 144.

the work of each man.* We may say simply that these studies have been made and used with great success for work of almost all kinds and types.**

System vs. Red Tape.—Perhaps the most radical departure from ordinary contractors' methods is the introduction of the Operation Tickets described above. To many, especially of the older school of engineers and contractors who have accomplished such excellent work by rule-of-thumb methods, the practice of so much detail will doubtless savor of red tape and will be criticized as a needless overhead expense. The fact is, however, that you cannot increase output to a large extent, you cannot keep all the men busy all the time, unless you have some such system as this to definitely indicate the work each man has to do, to know just what each man is doing at all times, and to insure both against loafing and delays which, although usually considered unavoidable, yet can be entirely prevented. The plan of operation tickets described is the simplest and easiest way to obtain these results.

Fig. 6. Laying Out Forms.

It must be remembered, furthermore, that if change in methods of handling and performing the work cuts, say, 25 per cent off of the cost of all the labor and an equal sum from the material quantities—and these are reductions that have been made over and over again and can be normally expected—this saving pays for any extra clerical assistance many times over. Moreover, the plan is subject to modification on different types of work, and is readily adapted without changing the essential features.

The advantages in the use of operation tickets are:

(a) They are written instructions to the workmen instead of verbal.

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*See paper by Sanford E. Thompson, "Time Study and Task Work," Journal Political Economy, May, 1913.

**Tables showing times making and erecting forms of different kinds, made up from tables prepared by Mr. Lichtner, are given in Taylor and Thompson's "Concrete Costs," pages 630 to 677.

(b) Each ticket is signed by a workman, which makes it possible to trace back errors and determine who made them.

(c) Every minute's time of every workman gets charged to some definite operation.

(d) Each division of work gets charged with the correct amount of time actually spent on it.

(e) The workman, knowing that the time spent on each job is recorded accurately and compared with similar work of other workmen, sees to it that the ticket is returned when the job is finished without wasting time.

(f) The company has a means for determining the best methods of operating and the cheapest type of construction, such as in the design of form work.

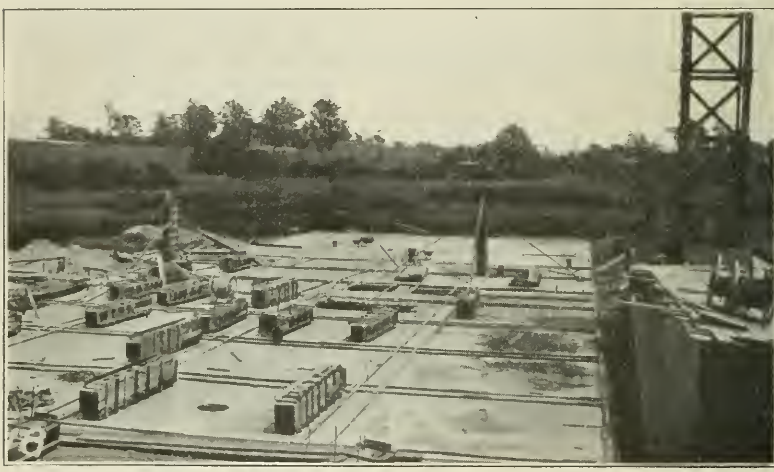

Fig. 7. Forms In Place.

(g) The really good workman is distinguished at once from the self-assertive type who frequently receive undue credit.

(h) Bonuses can be paid dependent upon output of each workman so as to give the workman more money, while the company gets the work done for less money, quicker, and of better quality, than by any other means.

Other Types of Construction.—Although the description of methods applies chiefly to reinforced concrete building construction, the principles, as has been emphasized already, are applicable to nearly every kind of construction work. Sometimes, although this must be avoided if possible, the work must be distributed to gangs instead of individuals or pairs of men. In some classes of work, such as earthwork, the routing may be of a very simple nature and stress must be laid on the standardization of tools or the measurement of material or both. In other cases, such as pipelaying, the training of the men is of the greatest importance.

Whatever the class of construction, it must be recognized at the start that results cannot be obtained in a minute, nor can they be obtained without a considerable initial expense. An organization must be developed, men must be trained to properly handle the work, and the management, that is, the members of the company, the superintendent and the foremen, must be brought to realize that a proportionally large number of office men, "non-sweaters" as they have been called, means a great diminution in unit cost, pro-

Fig. 8. Girder Forms.

vided these office men are engaged in work which is really productive by eliminating labor on the part of the skilled and unskilled workmen. The actual reductions in costs through scientific methods, which are cited at the beginning of the paper, simply represent what may be normally expected under ordinary conditions.

DISCUSSION.

G. C. D. Lenth, M. W. S. E. (Chairman): I am sure we have all been much interested in the paper presented this evening.

When Mr. Lichtner was showing his lantern slides, he showed a building which presumably was constructed in Chicago. How did the scheme work out in Chicago?

Mr. Lichtner: The location of the building given in this paper is fictitious.

O. P. Chamberlain, M. W. S. E.: The same question occurred to me that Mr. Lenth mentioned, that is, in connection with this method of performing labor by tasks instead of by hour work or day work, whether difficulty has not been experienced with our labor organizations, I surmise, from my experience in Chicago, that it would be difficult to get the average Chicago mechanic or laborer of any class to work on piecework. I would like to have Mr. Lichtner enlighten us as to how this method of handling labor is regarded by the Trade Unions.

Mr. Lichtner: I do not know of any case where this method has been tried out in New York City or Chicago, where the Trade Unions are strongest, but it has been operated in cities where Trade Unions are fairly strong. When this is the case we do not pay the Union man a bonus, because one of the rules of the Union is that the men are not allowed to accept a bonus of any kind and are not allowed to do piecework. The thing that the men did do, however, was to take their instructions in writing, which meant that they accepted our tickets and that was all we asked of them.

Mr. Lenth: Along that line, I know of some heavy steam shovel construction work in which the contractor from day to day, from the cut and width of the trench, decided the length of trench to be dug by the steam shovel crew. By a series of experiments he determined that a certain length of trench could be dug in a day, and he told the steam shovel crew the amount of work that was required—say 200 feet—and that if they finished that amount by half past three in the afternoon, they could stop work and have an hour for themselves. That is the closest approach to the scheme which Mr. Lichtner has told us about that I have seen in Chicago. In that case the contractor paid his crew 20% more than the average contractor pays, and he got, as a result, about 33% more work.

Mr. Ernest McCullough, M. W. S. E.: I wrote a series of articles in 1905 for The Contractor, which series was later printed in book form and had a good sale, the title being "The Business of Contracting." In those articles I showed how modern principles of efficiency might be applied to the business of the ordinary contractor. There has always been a desire on my part to suggest something to help the men who do the bulk of the contracting in all countries, men who work on limited capital and are not always employed; the men who get perhaps one job out of eight or ten figured and whose bids are based more on a knowledge of local conditions, habits of mind of officials in charge of the work and a close knowledge of the habits of other bidders against whom they pit themselves.

In the last paragraph of the paper appears the statement, "Whatever the class of construction, it must be recognized at the start that results cannot be obtained in a minute, nor can they be obtained without a considerable initial expense." For a large contracting company confining its operations largely to one kind of work and getting most of the work on a percentage, or on a "cost-plus" basis, it is possible to carry out such an idea, but suppose we consider the case of a general contractor who tackles every kind of work, buildings, bridges, river improvements, highway work, sewer and water works construction, etc. His work is sometimes in the country, sometimes in small towns and sometimes in large cities, but it is not constant and he is unable to keep up a large force of office help. The anxiety of the contractor to get some men on the job as quickly as possible is something every superintendent is up against.

The position of the job superintendent under the conditions mentioned is ideal. The authors of the paper say, "It is evident that the duties of the job superintendent under the new methods are somewhat changed, in fact the title "superintendent" might well be changed. He is not given free hand as when he was allowed to run the job pretty much according to his own notions. Formerly, so long as his costs were within the original estimate, he was not taken to task." At the top of page 11 we find this statement,—"The job superintendent is responsible for the correctness of the work. He is the construction company's representative who deals with the owner and architect and settles all small differences which arise on every job." In the many years I served as foreman and superintendent for contractors my fortune never brought me such a pleasant place. I would like, out of curiosity, to have a job like that and see how it would go. Perhaps the many days of battling on work where I was to all intents and purposes the contractor, spoiled me for a job run from the office on a card system. To run a job in the way the majority of contractors must run it, because of the overhead cost attached to a perfect system such as that outlined in the paper this evening, requires a very high degree of construction management and executive ability.

Wages have been increasing and with the increase in wages has not always come increased output but the cost of living has been increased. Mr. Louis D. Brandeis lately said, "The demands for shorter working time, for higher earnings and for better conditions cannot conceivably be met unless the productivity of man is increased." This statement explains the why and wherefore of scientific management in a nutshell. The productivity of men employed by contractors has been increased by taking from the men on the job the necessity for thinking beyond their task. The brains of the company are located in the head office, the convolutions of the brain being represented by masses of red tape, the gray matter being represented in white, yellow, red, green and other colored sheets and cards. The job superintendent is an operator at a switchboard receiving and transmitting calls. Such highly developed systems are good, as we all know, for large organizations where the initial expense can be borne and a large overhead expense carried, which can be reduced to a small per cent of the cost because of the large volume of business. But we need something better adapted to the sporadic contract undertaken by the individual, or the very small company, lacking capital and working in sections of the country where each job means a new organization. There must be considerable waste on such work, but as many contractors make some money, might it not be possible to enable them to earn more and be more humane to their men by the introduction of common sense methods adapted to the understanding and financial ability of the average contractor?

Suppose I consider some personal experience. My first experience was gained shortly after graduation when I secured a job cementing the joints of sewer pipe, being later promoted to foreman of a house connection gang, where I learned to lay a house connection across a beautiful lawn without injuring its appearance and without having any surplus dirt to haul away. Later I caulked lead in the joints of water pipe, worked in sidewalk gangs, made macadam roads, etc. I was for years superintendent on sewer and water works and paving jobs and also on reinforced concrete work. It was my observation, that the rate of wages has less to do with the amount of wages than is generally thought. I mean that when you work in a district where men get $1.25 per day of 10 hours it is usually because they are worth no more. The total amount of wages on the job is likely to be close to what it would have been had it been possible to import higher priced men from larger cities who are specialists in the class of work attempted. Usually, however, the good man deteriorates when he is taken to a small town if he does not actually try to form a union among the local laborers, returning to the city drunk and happy after wishing this on to the contractor. In one small city the rate of wages before we took a sewer contract was $1.50 for 10 hours work. On account of agitation of labor organizers and scarcity of labor we were paying $2.25 for 9 hours work before the job was done. At the same time we were carrying on a similar job in a large city where the rate of pay was $3.50 for 8 hours work. The unit costs were lower in the larger city with the shorter hours and higher wage, the difference being in efficiency solely. Pottering around town on odd jobs and occasionally digging a garden patch is a poor training for the strenuous life of a digger of sewer trenches. Is there any parallel to be drawn between such cases and the cases of unit costs of the small contractor and the highly developed contracting corporation?

Generally a contractor bids on work after a study of some "cost data," assisted by a wise young man in the office of a larger company. After the contract is awarded he spends a few wakeful nights going over the figures in his mind to see if it is indeed true and if he forgot something. Then he puts a few men to work to satisfy the clamor of the other party to the contract and inserts an advertisement in a paper for a superintendent. I have obtained the position of superintendent a number of times under such circumstances. Perhaps many men in this room have had similar experiences. The first thing the superintendent is up against is the local labor, its sufficiency and the pay it wants. No one ever saw a dollar man yet who did not want three dollars to do work he understood men were paid three dollars to do elsewhere. The labor question is ever with us. Local labor is seldom efficient and imported labor belongs to the "drifting" class. I found on investigation that the majority of laborers are drifters because they were hopelessly in debt. They endeavored always to quit or be fired before pay day to escape the importunities of creditors and bill collectors. Many a good man who is thus situated can be held on a job a long time by paying him each night. Sometimes the convivial man can be held by paying him daily, because he fritters away small amounts, whereas a whole week's pay, or two weeks' pay, deals him a blow in the head and renders him unconscious for a long time. On some work in the south I ran across a type of white man that interested me. He worked three days and the next three days he loafed on the job in his best clothes waiting for pay day. He is hopeless. To pay such a man in the evening means a two-day layoff, so he works only one day in three. The colored labor I found better. The colored men could be spurred to hard endeavor whereas crowding a white man angered him. The colored man would work one week and lay off three days after pay day, but by paying him nightly he would work all the time, except that about once in two or three months he would lay off for a week because he said he was tired.

Some men are drifters because they have drifted for so long a time they have it in their systems. I was in charge of one piece of work for about a year, where we were supposed to keep 400 men constantly employed. We had good camps and fine cooks and the climate was all that could be desired. The pay was high, yet when the work was completed we found on the various pay rolls 1700 names and only 11 men had stayed clear through the job. Many of the men had started and stopped several times. This was a large job, one that today would be handled by a well organized company operating under systems like those mentioned this evening. It happened, however, in the instance mentioned, that the contractors who took the work had barely enough capital to meet the first pay roll and were continually harassed by creditors throughout the continuance of the contract, finally making a small profit. However, on this closely run job we had a cloudburst and a dynamite explosion with a number of men injured at times.

This same drifting labor is the most appreciative of system and knows when a job is being run right. Such men know when the boss is fit and from the comments heard it is not always the job with the greatest amount of system and most numerous cards that is considered as being handled right by the man on the spot. I mean that while results may be achieved that are satisfactory to the contractors the workmen see that the job superintendent is not always a man who could be trusted with more responsibility than that with which he is at the time intrusted. Opposition to system does not come, as a rule, from the laboring man when the system is really systematic, but it is the superabundance of papers to be signed that irritates. I early learned to reduce it to a minimum. Because a job does not bristle with hooks on which to hang blanks and is not plastered with special forms does not mean it is not systematically run. Every good man will carefully plan his work ahead and all successful men have fairly well developed systems which work satisfactorily. They can be helped, however, but to date the help has been given only to the men who have considerable capital and can plan their operations a long way ahead with considerable initial outlay.

In my work, attending to the sporadic job, I found it unwise to carry men from one job to another. It was poor policy to send for a man. If a man who had proven good on one job turned up on another looking for work it was safe to employ him, but three men out of four are spoiled by sending for them, unless they are members of a large organization, and instead of being out of work are merely on furlough, as it were.

I had one piece of work on which the company had a lot of older employees, my having the position being due to the fact that these men had not been getting results. They were not loyal workers so I finally had to discharge one. Three days later he was back and the head of the company sent me a letter telling me to try and get along with "the boys" as he had no other place to put them and they had been with him so long he hated to turn them adrift. These fellows were actually robbing him, not alone by loafing, but by petty grafting, getting commissions on supplies, etc. I took the first train to headquarters after the man came back and told the boss that I was held responsible for results and results could only be obtained when I had positive control. I made no complaints about the men other than that they were not as good men as I needed and if he preferred to keep them then he could get another superintendent. The result was that I went back the following day with an increase in salary and that all the old timers went home.

One experience always sticks out strongly in my life because it was the worst of its kind, although several other jobs of a similar kind were given to me. A couple of men borrowed money to put up a certified check to get a contract to do street work in a small town. They were awarded the contract and obtained bonds so the money in the bank was released. It was again loaned to them on an assignment of the contract, not recorded, and they went to a large city to purchase equipment for they owned nothing. They obtained a stone crusher, bins, wagons, roller, etc., making a small payment down and giving notes for the balance. These notes were discounted at local banks. Then a superintendent was sought and the job fell to me. It was up to me to get enough work out in the first week to meet a payroll the following week. The city engineer gave us an estimate every two weeks and we paid off the men on the alternate

Saturdays. In many ways the job might have been better handled and money saved if the contractors had had capital. But they had assigned the contract in one town for money to make an advance payment on a second hand plant and had assigned it a second time with the local bank in the town where the work was going on, in order to get a line of credit to help out when the estimates did not carry the pay rolls. By and by an investigator came down to see about the notes for the plant and I learned of the difficulties they were in. For a time it was serious, but I managed finally to have them assign the contract to me and I assumed all outstanding obligations. If this had not been done they might have landed in jail, and only sixty days before they were strangers to me! I lost a few hairs and obtained some gray hairs on that job. It was work all day and worry all night, but it was finally cleaned up. We repaired the second hand plant, which was in poor shape by that time, painted it up and sold it to the town for maintenance purposes. The money obtained from this transaction was the sole profit on the job above actual costs and out of it I paid myself my own salary, which was just about what would have been coming to me had everything been all right. I saved two men from jail and nearly went there myself for them, but they were not grateful, thinking there must have been some concealed profits to which they were entitled.

It was always my practice to lay my work out ahead and get things ready for a first class start. In practice it was hard to do. The owner wants dirt flying within 24 hours after the contract is signed. The contractor wants the estimates to take care of the pay rolls, figuring frequently on standing off bills for materials. Several times my employers complained of slow starts but we always managed somehow to finish in time. While the profits were sometimes good it was the initial outlay that made trouble. A first class superintendent to make good with the average general contractor handling jobs costing usually less than fifty thousand dollars, on a capital of about one-half this and perhaps having money tied up in certified checks on bids for other work, must be able to start on hot air and end up with a profit in cold cash. This he cannot do and also break in a cost keeping and time recording staff. We want from men who make a study of systems, a good, clear method for handling jobs on which every man is new, from the superintendent down to the water boy. I believe in efficiency, and when system means efficiency I am for good system. When system means the pre-organization of a large staff at considerable initial expense and with which results cannot be obtained in a minute, then I believe the efficiency experts have to revise their message to engineers—perhaps add a postscript.

J. F. Hayford, M. W. S. E.: I supposed I would be immune tonight. The only thing I care to say is this,—that I am rather familiar with the principles of scientific management as written up by Mr. Taylor and Mr. Emerson, and I am quite willing to go on record as being of the belief that those principles may be applied to advantage in any kind of work, even to University teaching as an extreme. Also, that the principles may be misapplied on any kind of work. If applied sensibly, they insure wonderful results. My positiveness in believing they can be applied to any kind of work is based on having applied them in two kinds of work where it is ordinarily supposed that they could not be well applied,—surveying, on the one hand, where I had some experience in applying the principles before reading about them; and routine work of computing, on the other hand, where I had a hand in applying those principles to a rather complicated class of computing. They bring the results. I am glad to be on record as one of the believers that those principles can be applied to good advantage and with wonderful success in any class of work whatever. Also that they can be misapplied and increase the cost when one goes to an extreme in any class of work.

C. A. Keller, M. W. S. E.: Scientific management means more than efficiency, working mainly for the profit of the employer. It means also a betterment in the working conditions, i. e., welfare work, such as savings funds, profit sharing schemes, safety regulations, recreation and library facilities, etc., which are profitable to the employes.

Aside from the items mentioned in the paper of the evening, the following are of importance and should be included:

1st. The minimizing or elimination of changes in plans commonly known as extras.

Extras are caused principally by changes in plans and these, if complicated, sometimes cause more work in the office than the preparation of the original plans, in addition to delays in the execution of the work. Generally speaking, unit prices for additions and deductions should be agreed upon before work is started, thus saving time and money in settlement of the extras.

2nd. The foreman should understand that the cost of the work he is directing is being followed up and that his ability is measured with others who have done similar work before.

If the foreman understands that his work is being systematically followed he will be apt to call his employer's attention to many points which are not included in ordinary methods or which are delaying him in his progress.

3rd. Keep cost accounts "up to the minute" and after the work has been done, analyze and check up the actual cost with the estimate and original plans with a view of explaining the differences.

In a well organized cost-keeping system it is very important to have units standardized so that they mean the same to everyone concerned. All changes should be ordered in writing, and followed up systematically. The distribution of material and labor should be done by a competent man.

4th. Prepare a diagrammatic schedule of progress and follow up diligently.

The schedule of progress should be in the form of a diagram and should be prepared from past experience on previous jobs, also on the probable delivery of the principal machinery and material and the number of men who can effectively work together at the same time. The schedule should be continually checked up with the actual progress by indicating such progress on the same diagram for record. Another way of checking up progress and particularly eliminating delays is to have regular meetings of all the men in charge of the different classes of work or sub-contracts for the purpose of determining who is delaying the work and how to overcome the difficulties.

Referring to the task idea in the latter part of this paper, under the heading of "planning and routing," it seems to me that the author has extended the scientific management idea too far by tying up the individual workman with too much red tape. Scientific management on the job should mean elimination of rehandling of materials as far as practicable. In other words, materials should be delivered, as much as practicable, directly at the point where they are to be used and just before actually needed. Scientific management should also mean that the organization from the superintendent to the individual workman should be as simple and as clear as possible, placing the responsibility of the work in few hands. The ticket system as outlined is cumbersome and is apt to run the overhead expenses up too high. There is likely to be too much time lost in planning and following the work. In other words, the job will probably be burdened by excessive overhead expenses.

Mr. Lichtner: I would like to refer to a job in New York State where we used the ticket system with carpenters who were Union men. We did not give the workmen any bonus, but we figured the time that each job should take just as if the job were to be done on a task and bonus basis. Instead of giving the men a bonus of, say, 40%, I gave them 40% more time to do the job, so that if the carpenters finished the job in the time I figured it should be done, it would cost the company the same amount of money as if it had been done by carpenters working with a bonus or an incentive, but, of course, the company did not get their work finished as fast as if they could have paid a bonus to the men. By keeping the time on the tickets in this way we were able to give to the superintendent on the job a list each morning, showing what each pair of carpenters had accomplished the day previous. This gave the figured time as compared to the actual time, so that he was able to see which pair of carpenters came up to the standard we required. If the work was not quite up to the standard, this fact was impressed on the particular carpenters concerned, and the next day they would generally do better.

The tickets also served in the cost-keeping system, as the pay of the workmen can be made up from these tickets, and in this way every minute of time for which the men are being paid is charged to some particular kind of work. This means that the cost-keeping system is "kept up to the minute," as Mr. Keller calls it in his remarks, and besides each particular part of the work is properly charged with all the time actually spent upon it.

From the studies on different kinds of work we know what any particular work should cost, and if it comes within that amount, we know the men are working up to the standard we have set.

On work where the time of each job is not figured and entered on tickets such as are described in this paper, it is very essential to figure each day what unit costs each foreman made. The best way to bring this to each foreman's attention is to plot on cross-section paper the unit costs of each day's work. A separate plot is made of each foreman's work so that he can see at a glance how each day's cost compares with every other day's cost. A heavy line is drawn on the plot showing what a good unit cost would be, so the foreman knows that any point above this heavy line means his costs are running high and that if points are below the heavy line his costs are running good. Of course this creates competition between the foremen, as these curves are in the job office and are looked over by all the foremen.

In regard to the overhead and all the red tape about the tickets, I do not agree with Mr. Keller, as the overhead for designing form details shown on the screen is a very small item. On one company's work where the "making" of form work costs about 1¼c per square foot of contact surface area, which included the cost of the overhead, the cost of detailing each and every form amounted to 6/100c per square foot surface area. On another job where practically every form had a separate drawing the cost for drawing the details was 4/10c per square foot of surface area.

Another point which has been brought up is in regard to whether systematizing pays on all kinds of work. If, for example, you have only one job a year, it would not pay you to go to the trouble of taking elaborate detail time studies, but you can do things on a smaller scale than would be done on a large job or on a class of work where you would have a number of jobs. One way would be to take good overall times on one gang of men, and note very carefully the conditions and amount of actual lost time, and then set a standard for a good gang of men. Another plan which might be adopted if, for instance, there are several trenches to be dug near each other, is to start a gang in both of these at the same time, and then give some kind of a bonus or prize for the gang who shall finish their work first. In this way competition will be created between the gangs, and the work will probably be gotten out at a very good cost.

You probably know that scientific management has been used on practically all kinds of work, and you may be interested to learn that it is even now being introduced into the banking business. From the results we have already obtained, we expect to show them how to do everything in the bank except to open their vaults.

F. H. Cenfield, ASSOC. W. S. E.: I cannot add much to what has already been said, but I am very much interested in the paper and discussion.

The City of Chicago has maintained a staff of efficiency engineers and accountants as a division of one of the departments in the Municipal Government, and has been doing considerable work along efficiency lines. It has been stated by other speakers this evening that practically all labor, even common labor, in the city's employ, is unionized. However, it has been possible to standardize much of the work, and I believe as more study is given to the subject, it will be possible to standardize all the work that the city has to do.

You will probably recall that about two years ago the Efficiency Division of the Chicago Civil Service Commission was called upon to standardize street cleaning. As a result of this, a very thorough investigation was made, in cooperation with the Bureau of Streets, definite standards and schedules of work for all street cleaning were established and put into operation, and at present approximately 1600 street cleaners are working in this city in accordance with definite schedules and standards of work.

Our Division is now working on unit cost systems, to be applied to the construction, maintenance and operation of the various plants of this city, and we hope through this to establish standards and get specific information, to be able to point out to construction foremen and superintendents the weak points in their administrative work. This work is all done in cooperation with the department heads, superintendents, and their engineers.

I notice that the construction cost system upon which we are working resembles very much the system Mr. Lichter has talked about this evening, except we believe we will be able to eliminate a great deal of the tedious clerical work by substituting the tabulating machine for segregating unit costs. We all know that such machines have been quite widely adopted for handling the accounts of cost systems of railroad companies and other private enterprises.

One important thing in connection with all unit cost work and especially in connection with construction work, is to have unit costs available at once. We believe that the mechanical system of segregating these costs will give us the maximum information with the minimum of effort. When the conditions are properly analyzed and unit costs obtained, based upon these conditions, it is believed that they will constitute a basis or a standard for judging the effectiveness of all other similar work. For instance, we believe, in caisson digging, by properly analyzing the cost of the work, it will be found that the unit cost of similar sections under similar conditions should be the same as for all caisson digging.

M. R. Hunter: I would like to call attention to some track elevation work on the Chicago, Rock Island & Pacific R. R. in this city, in the vicinity of 79th street, where management principles are being applied, some of which have been discussed here.

Unit costs are kept, and the engineer in charge knows at the end of each day what it has cost him for concrete per yard, what each mixer has accomplished, and so on. In this manner he can keep tab on all phases of the work, and when he finds costs running high, can regulate them.

The engineer of track elevation is in charge of the work, and has under him, right out in the field, an auditing department, a train master for the operating end, an engineering force, and a construction force. The execution of the work is kept entirely separate from the engineering. There is also a cost engineer, who has charge of figuring all costs. The men are paid a sliding scale, which is possible inasmuch as company forces are utilized. The various departments represented report to the engineer of track elevation, and he does not have to go back to the general office to obtain requisitions for supplies or the supplies themselves. In other words, everything that is needed to carry out the work can be found right at the field office, and they are not dependent, from the delay that would ensue from the necessity of going back to the general offices to carry on any phase of the work. Of course, the engineer of track elevation reports to the chief engineer, but owing to the broad-mindedness of the Rock Island officials, he has not been hampered in any way.

Before the work was started everything was planned out carefully, and tests made.

The magnitude of the work may be realized when I say that it is expected that seven years will be required to do the work, and that $10,000,000 has been set aside for this purpose.

At the 79th Street crossing of the Chicago & Western Indiana and Rock Island roads, the traffic averages 500 trains per day, and the traffic operations have not been delayed in any way, to the delight of the operating officials. Although the right-of-way is not any too great, all the new tracks are raised to their full height and put in condition for operation before any trains are run over them. At the same time, to one side, two tracks are maintained to carry the present traffic, and in this manner they are not hampered in their work, nor are the operating officials seriously handicapped by slow orders.

The reason I brought the matter up at this time is that the work is located here in Chicago, and I thought possibly some of the engineers present might like to go out and see the work.

Carl Weber, M. W. S. E.: I have listened to the paper this evening with a good deal of interest. It seems to me, however, that two entirely different points in the paper and its discussion have been somewhat confused. One is cost analysis, and the other is scientific management. As a matter of fact, I have not been able to find in the paper any points regarding scientific management which are not already used in every up-to-date building concern. I have not done any work in the last ten years where similar systems have not been followed. It is common practice today to have the forms for reinforced concrete buildings designed by competent engineers, and I hardly believe that there is any construction firm of consequence which will leave the design of the forms to their foremen on the job.

As far as scientific theories are concerned, all is well and good, but one principal point must not be overlooked and that is the human element of our working forces. The success of construction work is largely dependent upon the skill of the workmen employed, and, as a matter of fact, well trained working forces are today the largest asset of any firm engaging in such work. It is absolutely necessary that careful plans be made for every job and that every detail of the work itself is previously determined and agreed upon. However, I believe it is going entirely too far if we employ a complicated ticket system as shown this evening where every man is to report on every detail of the work done by him during the day, or even to receive his working materials and do every bit of timber cutting, etc., after certain ticket instructions.

This would be a great handicap to any work, and, as a matter of fact, the average workman would make out tickets which the man in the office could not read if he tried to. This portion of the work should be left entirely to material clerks and time keepers.

It is necessary to have a correct daily report system in which all the important items are carefully put down so that after the completion of the work, or at any time during the process of the same, the cost of every portion can be checked, and, if possible, means should be found to reduce the cost of every operation by careful cost analysis.

In my practice I have found that the success of construction work is not altogether dependent upon scientific management systems of tickets and slips, but that a good many forces enter the problem which cannot be disposed of by any such methods. In the class of work in which I am principally engaged, weather conditions, for instance, are a very important item and it is often necessary to change the plan of operation several times every day in order to meet the conditions causd by changes in weather and temperature. No advance plans can be made for any such emergencies, and the man in charge of work of this kind must be able to determine without advance notice just what to do to maintain a steady progress of the work.

In past years I have employed numerous foremen, superintendents and managers, a good many of whom have come to me with well formed ideas about scientific management and all such things. However, in actual practice, I have found that a man who has no such systems at all, but who understands his workmen and knows how to make the best out of every opportunity, is by far the better manager.

After what we have heard tonight this may not sound right. However, gentlemen, it is an absolute fact.

J. W. Lowell (with Universal Portland Cement Co.): Do you not think the term "Common sense management" would be more acceptable to contractors in general, because being less likely to create initial prejudice? For some years my duty has in part consisted of watching and studying construction methods, especially as connected with the building of concrete roads, and in practically every instance the contractor who displayed common sense, or if you choose to call it so, scientific judgment, in the prosecution of his work, not only attained the desired results with greatest economy, but the product of his efforts was superior to that of those who work from day to day guided by "hindsight" rather than by foresight.

The one instance that most forcibly impressed itself upon my mind had to do with the case of an experienced contractor who undertook to build 16 miles of road for $121,000, and based his estimates for aggregate costs on the expectation that he would be able to mine and wash them himself at a location near the job. As a matter of fact, the contractor never prospected to ascertain whether gravel could be found where expected. The result was that after purchasing, erecting and operating a plant for the handling of gravel for at least three weeks, he found it necessary to give up and haul purchased material nearly 16 miles. The contractor failed and in doing so lost everything simply because he neglected to display good management in his business.

B. C. Groh, M. W. S. E.: My work is a little different from that described tonight. The firm with which I am connected manufactures and installs electrical apparatus, and we use the bonus system on all our installation work. An estimate is made of the field labor cost of an installation before it is started. The cost units from which this estimate is made are based on similar jobs. The foreman and other men who are detailed on this particular installation are all trained men. Upon the completion of the work the total labor cost is determined, and, if under the estimate, the difference is divided, one-half going to the company and the other half going to the men; the proportion given each man depends upon his wage and the amount of time spent on the job. The foreman in charge of the work is not given very detailed instructions as to the manner of handling the men, but he is, however, given very detailed specifications.

We have found the bonus system very satisfactory, so far as our installation costs are concerned, and it is quite popular with the men. As an indication of how the men feel relative to the bonus system, I will state that we have difficulty in selecting men to go out on installation work, owing to the many applications we have from the men in the factory. We allow them a rather low allowance for living expenses while on such installation work, and the fact that the men are so anxious to be detailed on field work would indicate that the bonus system in our work is satisfactory to them.

Mr. Lichtner: It has been very gratifying to hear what several of our members have had to say in regard to the good work which they had done or been connected with where a great deal of time and thought had been expended to handle their work along scientific lines. It is to the men of this constructive caliber that system really means something more than a lot of "red tape" and "tickets," for they realize that the degree to which it is advisable to carry the system is determined by a detail study of all conditions of the particular job under consideration. It is just as foolish for an engineer or contractor to go to one extreme of using no system except that which they can exercise by sheer force of personal magnetism, as it is for them to work out a most elaborate system for a small job which they probably took just for the purpose of holding over a crew of men.

If any engineer or contractor,—and there are a number here tonight—believe, as experts claim, they can formulate absolute rules and regulations by which every kind of a job can be handled without even training men, they have either been misinformed or have not given the subject careful thought. A "postscript" to these men should be—don't hire experts for your work, for you do not need them.

Some of the reasons for the opposition to Construction Management are as follows:

(a) A great amount of poor work has been put through under the direction of incompetent men.

(b) Contractors and engineers have undertaken to run their work under the laws of Construction Management, but have failed to have their organization properly coached as to what was going to be done and to have instilled into their men the necessary enthusiasm.

To illustrate: On my last trip here to Chicago, I was introduced to a contractor who was personally acquainted with my friend and who was very much interested in construction management. After we had gone over his proposition, and I had submitted figures to him which had been the result of systematizing absolutely similar work for another contractor, he became so much interested that he wanted to try it out right away on this new job. If this proposition had been a case of selling a man some building material, I would have taken the order without further comment, but it was not a matter which could be handled in this way. Instead, therefore, of advising him to push it through I showed him the absurdity of his starting this job on any system except the old one he had always used, for it would have been impossible to have taken his superintendent and foremen in hand on such short notice and gotten them into the proper frame of mind, so that they would know how things were planned under the new order of things and how they fitted into the organization. If organizers would be more careful in this regard, better returns and bigger results would be gained.

(c) Good judgment has not been used in some cases as to the extent to which it is advisable to carry Construction Management on a particular job, and the attempt has been made to carry out a very elaborate scheme where a very simple one should have been used and vice versa.

Mr. Cenfield spoke of substituting the tabulating machine for segregating unit costs to eliminate a great deal of the tedious clerical work. A lot of attention has been paid to the use of tabulating machines in office work, and there is hardly an office of any size where one or more machines are not used, so why not make use of any of these labor saving machines in the field office on construction work? There is a machine on the market now which replaces the ordinary time stamp clock which stamps the time by perforating the ticket. In this way the tickets can be put through their machine which is an adding machine, whereby the totals of a particular operation or division of work are automatically calculated.

Prof. J. F. Hayford states that he has applied the principles of scientific management to the rather complicated class of computing and on surveying, which bears out our contention that if the problem on hand is properly and systematically studied, no matter how intricate the proposition may be, it is possible to analyze it so thoroughly as to predetermine and control a great many things that under the old scheme would be absolutely out of the control. If anyone had suggested anything like this not more than ten or twelve years ago, they would have been considered crazy, but today these things are not the dream of a theorist but the works of an idealist.

DISCUSSION FOLLOWING THE PRESENTATION OF THE PAPER BEFORE THE BOSTON SOCIETY OF CIVIL ENGINEERS, JANUARY 13, 1915.

Mr. Lichtner: I would like to call your attention to an error in Fig. 4-b on page 14. The name John Jones should not have occurred there, as he was the sawyer who cut the stock. The move order should have been signed by William Burke, whose number was 262. The same is true in Fig. 5-c on page 18. This move order should also have been signed William Burke, whose number is 262, he being the moveman for moving the sawed stock from the saw to the make benches.

I was in hopes that there would be some discussion before I was called upon this evening, because I would be much interested to see how the members of this society would discuss this subject. It brought out a large attendance at the Western Society meeting in Chicago, and some very interesting discussions ensued by those who came primed to show us where construction management could and could not be applied.

Mr. Garrod: I would like to say, Mr. President, that our company has done a good deal along the efficiency lines about which Mr. Thompson has been talking to us tonight. We have found it a very great advantage to use a system closely following on Mr. Thompson's outlines in the making up of forms, and to a limited extent in the routing of the forms from place to place in the building after they are made up. We thoroughly believe in systematizing as far as possible. We don't think that we have run up our overhead in such a way as to make this form work uneconomical on any job on which we have applied the methods as have been described. We haven't found a very great difficulty in getting our workmen and our superintendents who have been using the other methods to adopt the newer methods so far as we have been able to introduce them. The great trouble seems to be to get men trained sufficiently, and to keep such men with us when they have been trained, who are able to apply the methods thoroughly and scientifically. So far, form work has been the item that we have concentrated upon, but on some work which we have at present under construction we are routing other portions of the work besides the forms, the steel, for instance, and to a limited extent, concrete and other parts of the finished structure. We find that it is decidedly advantageous to have a definite plan of progress from the start to the finish of a job, and the nearer that we can come to keeping up to that definite, predetermined plan, the nearer we come to ideal efficiency in what we believe to be the proper costs for the work in hand.

I might say that as a development of this work, we have made it a principle to use a "bogey score," our estimating man preparing a score ahead which would show a good performance, even better than has been the average of good performances,—for what he thinks the work can really be done and for what it should be done. This is put into the hands of the superintendent, discussed thoroughly between the traveling superintendent, the job superintendent, and often with his foremen and route clerks, and is understood by them, not as something impossible of attainment but something that should be obtained on his particular job, and every effort is made towards the accomplishing of this result.

One thing that Mr. Thompson has stated again and again in his paper is that this system, if properly applied, should give a good quality of work,—that nothing should let down on the quality by reason of applying these methods. I have found that sometimes the desire to get work of a low cost has affected the quality. It should not; there is nothing about the scheme that is essentially demoralizing in the quality of the work. It seems to me that it is a thing that can and should be guarded against, not only by inspection but by thorough understanding from superintendent down regarding quality.

As far as the application of task and bonus to the work is concerned, it has been done by us successfully on some jobs. So far, we haven't been able to apply it on as many jobs as we would like to have done, but we are expecting to apply it increasingly as our knowledge of what our men can accomplish and what they should accomplish increases.

If there are other points that are brought up in the discussion I may have the privilege of speaking again, but at present I believe I have mentioned in the main our company's experience with scientific management methods.

Mr. Leslie H. Allen: If anybody had told us ten years ago that construction management on the lines laid down by Mr. Thompson was a coming development I think we should have scouted the idea as fantastic and impossible, but as Mr. Thompson says, "the most convincing proof of its value is that it has been carried out successfully." With this statement we must couple Mr. Thompson's concluding remark, "it must be recognized at the start that results cannot be obtained in a minute, nor can they be obtained without considerable initial expense." Any contractor who wishes to put into operation a system of carefully laying out work in advance in this way, must put in a lot of initial expense which may seem unproductive, but it is only by sticking to it that real tangible results can be attained.

One of the difficulties, I think, in laying out this sort of work with a thorough preliminary study is the fact that so much construction work has to be done in such extreme haste; we have to get started and get work under way sometimes almost before the plans are drawn, and very often there is no time to put in the careful study on the layout of the work that one would like. Especially is this the case where contractors are starting this work. With our own company, we have to such an extent standardized our form design that we can very rapidly determine on the style of form construction to be used and lay out the work. But if we have a new type or an unusual type of construction to lay out it takes longer, and a contractor using Mr. Thompson's methods for the first time would find it very difficult to get his scheme of operation laid out and put into working order in time to make use of it on a rush job.

Then again, we have to consider the character of the men who are doing the work and also the character of the superintendents who are to superintend it. It has been said that the control of this work is taken to a large extent out of the hands of the general superintendent, but the general superintendent is, after all, the boss of the job, and, unless he is heartily in sympathy and is helping the system along as well as he can, you cannot expect success on the work. If the superintendent is only passively interested or actively hostile to the work, you cannot expect it to go forward successfully. New methods are always regarded with some suspicion, especially by superintendents of the older type. There are two types of superintendents at work today for contractors. One is the type who have worked first as mechanics and worked slowly up and have grown into it. Then there is the new type of college men who have jumped into it,—men who have done more head work than hand work, who work by reason rather than by instinct or experience. These latter are the men who have made the greatest successes of the scientific management methods as laid out by Mr. Thompson.

Mr. Thompson states that it is necessary to "lay out individual or gang work for the various men." I am not quite clear just what is meant by that sentence, and I would like to emphasize the fact that work should be laid out with regard to the actual man who is doing it. The routing clerk has a tendency to lay out his work according to the men's check numbers, regardless of their relative efficiency. A gang of carpenters, for instance, are simply numbers in his mind. The contractor is certain, especially when working in a new city, to pick up some men who are not efficient, and there must be some discrimination, some care exercised, in the assignment of jobs to men who can do them. The best carpenters must not be assigned to rough work while the poor carpenters are working on finish and cornices, which has happened in cases where the efficiency of each man is not taken into account in assigning jobs.

The paper deals more with form work than with any other part of construction work. There are three principal operations in form work,—the making, the erecting and the stripping. Mr. Thompson says that there can be a saving of from three-quarters to one-quarter of a cent per square foot on the making. The making is the first step that the routing clerk handles, and undoubtedly good costs can be achieved on the operation, but when you consider that the panels made are used anywhere from three to five times, the saving of half a cent on one panel is a very small saving on the square feet of forms in a building. The operation of erecting is the really important part of the work, and one's chief energies should be concentrated on this, dividing into the lumping, that is, the getting of the forms to the men on the job by unskilled labor, and the erection of them by skilled labor. It is very important to let nothing be done by skilled labor which can be done by unskilled labor. Then comes the stripping, which is looked upon as anybody's job, but which is almost as important as the erecting and needs equally careful handling, otherwise, forms that you intend to use four or five times may be ruined, or the concrete itself may be damaged. It is equally important that the form work stripped should be moved in proper order to the place where it is to be used next. If the work stripped is carried up at random by a gang without much direction and dumped down on any place, the sorting out is quite an expense.

As to the routing of reinforcing steel, we have done this to some extent on jobs where there is a lot of regular bending and placing. On jobs with beams and girders where the building is long and there are many floors of the same type there can be considerable economies. But we have not been able to achieve any economy where the work is irregular and few beams are alike.

One point that must be borne in mind and that is apt to make or mar the operation of the system on the job, is the picking up of hitches and unexpected delays. If in the stripping of the first floor half the beams are so damaged that they have to go back to the mill for repairs, the routing clerk has to pick this up at once and devise some system of getting them back and forward again. If a delay of that sort meant holding up the whole of the operations, it is obvious that there would be quite a delay and the system would get a bad name on that job. One of the most important duties of the routing clerk is to see that delays are met with, that no hitches are allowed to upset or delay the work, but that everything is carried forward smoothly.

The cost of the form details and the routing have been discussed. We have found on small jobs where we have used a routing system successfully that the combined cost of the form design and routing has run as high as forty cents per hundred square feet of form work erected. On large jobs having half a million square feet or more of forms, forms have run as low as fifteen cents per hundred square feet. The amount saved on form labor has been very much greater than this in every case.

Mr. Lichtner: In regard to Mr. Garrod's point of quality—of course with the task and bonus or even without the task and bonus that is one thing that we always insist upon—we have taken care of it by having very much closer inspection than on day work. If the work does not pass quality the men are not paid a bonus. In this way you do not penalize the men, for it means nothing more than that you refuse to give them the extra bonus. I have had occasion sometimes to compare by careful test the quality of work under task and bonus and work by day labor, the task and bonus being done much more rapidly. Comparisons have shown that task and bonus work was better in quality than day work, provided it had been extended to such a point that the product was inspected systematically. When inspection is once established, the quality of work is improved.

Mr. Allen brought up two points which I would like to discuss, one in regard to the qualifications of a route man and the other the question of giving the workmen the kind of work for which they are best fitted.

The route man to properly route a job must be absolutely familiar with all details of the work and be as well or better qualified to handle it than the superintendent or foreman. This means that the route man must be capable of handling all emergencies. By this I do not mean that he is to make decisions without consultations with the superintendent and foreman, for cooperation and mutual understanding between these men are the first requisites to successful routing.

The changes that occur in construction work are of course very troublesome whether there is any system or not. They are almost identical in nature, however, to the changes that are frequently required almost every day in manufacturing establishments, due to the coming in of a rush order or the breaking down of a machine or change in the quality of goods, and all such changes are taken care of. In fact the methods permit changes to be made with less confusion and less probability of error than under ordinary management.

In regard to giving the men the kind of work for which they are best fitted, we have two means of bringing this about. By working the men on tickets on which the allotted time for getting out the job is placed, we find at the end of each operation exactly whether the workmen are accomplishing the work in the allotted time and which ones are falling down. This may be due to the workman being a poor one or it may be due to the workman being assigned to work for which he is not fitted. In both these instances we locate the men by their falling down on their time. This is taken up with the superintendent and foreman.

This consideration of reasons for the failure of men in their tasks is the second reason for overcoming the second point. The cooperation of the foreman means that he will take up the qualifications of the different workmen with the route man, so that they can be given the work for which they are best qualified. The poor workman after being tried on several kinds of work, if found inefficient in all of them, can very easily be weeded out.

Further illustrating the second point, that is, giving men work for which they are fitted, we had on one job two carpenters who could frame up double the amount of any other carpenters on the job, so we assigned all the rough framing to these two men. One of them was all brawn and muscle, while the other did all the measuring but was not quite as strong. The brawny fellow had a brother who would not do this rough framing work but would wait for some interior finish work to show up. In this way it was possible for him to keep always in trim and he could therefore do the work in about half the time of any other carpenter.

This company found that the task and bonus and systematizing really put the men who were most efficient for a particular line of work in the proper position.

Mr. M. W. Hopkins: I want to ask Mr. Thompson about the move slips. For instance, do I understand that these move slips are turned over to the laborers or to a labor foreman?

Mr. Thompson: They are usually turned over to a laborer foreman. That depends on the class of move man. Sometimes to the move men themselves.

Mr. Hopkins: As a rule, do the carpenters procure their own slips or the foreman?

Mr. Thompson: The carpenters. The time taken to get the slips is, in effect, a rest from their regular work, and does not actually reduce the amount of work which they accomplish in a day.

The President: I would like to ask in regard to the item of backfilling, where a reduction from thirty-four cents to ten cents is shown. What method was employed? That is, I could see in excavation where there might be a reduction, but in backfill on a trench, for instance, there must be a good deal of waste in the thirty-four cents or an immense saving in ten cents. I would like to inquire as to whether it was muscle or methods.

Mr. Lichtner: Both muscle and method. In nearly all trenching jobs the backfilling is looked upon as a legitimate place to loaf and on this particular job this work had been sometimes given to the men to keep them in good spirits.

Mr. Miller: I would like to ask if this system has been applied outside of the States, whether the system here illustrated has ever been applied to cases where we have to deal with labor different from that in the United States, such as South America or Panama, where we sometimes have extremely unskilled labor and sometimes have to export labor from here? Has that ever come under your observation?

Mr. Thompson: I have had conversations with men who have come over to this country from Russia, Finland, Australia, England and France to discuss methods of scientific management, but I think that none of them have taken up the particular problem that is spoken of by the last gentleman. I would say that we would have to get more at the definite condition before that question could be answered satisfactorily. There is no reason why unskilled labor, almost any type of unskilled labor, cannot be handled under the task and bonus, unless there are certain conditions which correspond more or less to the peonage or some such special factors that would come in. I would like to ask more particularly what the speaker had in mind.

Mr. Miller: I would say that I had a particularly hard problem recently where a sugar mill which had been under construction for a year was given up owing to the extreme losses due to the contractor not having figured on the type of labor and the cost of maintaining men from the States and replenishing them so often. We went down there and found they had to replace a crew of fifty men every six months on account of the conditions around the sugar plants. A good many times the machinery came down there wrong end to. There were donkey locomotives for hauling the sugar cane and sometimes the small fittings came down first, sometimes the boiler first and the wheels and other things later, and we had considerable trouble in that way. But we had most trouble with the labor. The peons there are not very strong and they are not very intelligent, and we usually found it necessary to take mechanics from the States and put several peons under them. They did not have any systematic method of handling men. Frequently the mechanics from here were not able to read blueprints or handle matters in an intelligent manner. While going to San Juan I met some government engineers and they informed me that I could get some good men in the island of St. Thomas, men who had been trained by the English government, and I proceeded there and got a hundred men who were excellent mechanics. They could read blueprints. We tried to arrange them in squads and teach them to use their initiative a little in making new machine parts to replace parts that would be too long in coming from the States. We had to make a machine shop and organize a method of making parts temporarily. They were colored men, almost negroes. As a joke they were called the "Irish negroes"; they talk very much like Irishmen. I found in trying to get them to bring in their time tickets and arrange for payment that it was hard to explain to them and get them to understand. Similar conditions are patent on the Panama Canal, as I have read, and were overcome there to a great extent by the engineers and I did not know but perhaps you had come across some such condition.

Mr. Thompson: The question of machinery shipments illustrates how much some of our transportation companies need more scientific methods of handling their freight. We have handled task and bonus work with illiterate men in the south, men who perhaps do not correspond exactly to yours but who could not read and write. It was simply a case of showing them how much work they had to do for a certain amount of money. In eastern Africa mine work has been handled on a task and bonus system with the natives.

Mr. Lichtner: In regard to such work down south, the men could not read or write, but when showing them how much money we would give them, we also gave them green tickets, they would put these tickets in their hat bands and the better men would pride themselves on having more tickets than others, as the tickets showed how much money they were getting.

Question: Do the contractors in the east take this suggestion favorably, or how do they feel about adopting a system of this kind?

Mr. Thompson: There is a general and widespread tendency on the part of contractors all over the country to develop along lines of management in which they pay more and more attention to planning the work, standardization, and even the making of time studies and paying bonuses to the men. The change in attitude of contractors and builders both in the east and west has been remarkable. For example, I have in mind one western contractor. Some years ago one of my men took notes on one of his jobs for the purpose of determining average costs to be used in our book, "Concrete Costs," then in preparation. They gave permission simply as a matter of friendship, but took no interest in the results obtained. About two years afterwards I received a letter from them advising me that they had begun to appreciate the advantages of such thorough studies, and planned to utilize them on work which they were doing.

HIGH EXPLOSIVES

By L. S. Marsh, mem. am. chem. soc.

Presented November 9, 1914.

In presenting the subject of high explosives I shall endeavor to give briefly the methods of manufacture, uses, and to a slight extent the historical side of the more important explosives.

While gunpowder or ordinary black powder is not generally classified with the modern high explosives, its discovery and development have been of so much importance in the general development of all explosives that a little time may be profitably devoted to it. Black powder was probably discovered by accident, and Friar Bacon, to whom is generally ascribed the discovery, did not, therefore, really invent gunpowder. It seems certain from such information as we have at our disposal that Friar Bacon about the year of 1250 had mixed up an experimental compound of some kind, the ingredients of which among others were saltpetre and sulphur. We can imagine the effect of igniting such a mixture, and if, perchance, the good Friar had rubbed some of the mixture in a mortar it is safe to assume that he was surprised at the results obtained by this simple though dangerous operation. Roger Bacon undoubtedly fulfilled the prophesy of Prometheus that, "in the latter day, a wondrous being would appear who should call forth flashes brighter than lightning and sounds louder than thunder."

Gunpowder was for years called "kraut" in Germany, and in view of its present use the other part of the word might well be added. For 500 years gunpowder remained the only explosive, and not until the year 1846 did there appear anything really new in the line of explosives. In this year, Schoenbein discovered nitrocellulose, the basis of all smokeless powders, as well as of many modern products whose uses are more in the realm of peace than of war. In the year 1799 mercury fulminate was discovered by Howard, the use of which, however, as a filler for percussion caps was not commenced until 1815. The next important step in the development of explosives was the discovery by Sobrero in the year 1847 of that exceedingly important and highly explosive compound, nitroglycerine. Little use was made of nitroglycerine until the invention of dynamite because of the fact that nitroglycerine could not be handled and transported, in the liquid state, without very great danger. The first practical use of nitroglycerine was made during the construction of the Hoosac Tunnel, the nitroglycerine being transported to the work in a frozen condition. In 1875 Nobel discovered that an explosive composed of a mixture of collodian cotton and ordinary dynamite gave greatly increased results on explosion, this same investigator having discovered dynamite as we ordinarily understand the term, in the year 1867. Blasting gelatine, discovered by Nobel in 1875, and referred to above as the mixture of collodion cotton and dynamite, is probably the most powerful explosive, weight for weight at the present time, at least which can be used in any practical manner. Blasting gelatine owes its great explosive power to the fact that the excess of oxygen in the products of explosion of nitroglycerine supplies the deficiency in explosion of nitro-cellulose, the carbon burning to carbon dioxide instead of partly to carbon monoxide, which additional chemical action results in the production of more heat and therefore greater volume of gas, and greatly increased force of explosion.

There are two general divisions in the classification of explosives, namely, explosive mixtures and explosive compounds. Explosive compounds are mechanical mixtures containing various ingredients in the form of grains or finely pulverized material, these ingredients supplying a combustible and an oxygen carrier. As an example of an explosive mixture, gunpowder is the first one which comes to mind and is to all intents and purposes the most important of all explosive mixtures.

Explosive compounds are those substances which contain within the individual molecule the necessary substances or elements to produce an explosive wave when detonated or otherwise broken up. As an example of an explosive compound we may refer to many of the hydro carbons and compounds of organic origin, such as the nitro compounds of ether, acetone, phenol, glycerine, cellulose and a large number of other organic compounds.

Black gunpowder is one of the most common, and, from a practical standpoint one of the most important of all explosives, and its manufacture while not without danger is, however, less liable to cause trouble in the process of combining the various ingredients than some of our other forms of explosives. Black powder, as made in this country, consists of potassium nitrate 75 parts, carbon in the form of charcoal 15 parts, and sulphur 10 parts. The first requisites in the manufacture of black powder is to obtain strictly pure materials, then the proper grinding and mixing of the three ingredients named above. The potassium nitrate supplies the oxygen necessary for the combustion of the carbon. In the manufacture of gunpowder the materials are first ground then sifted into grains of various sizes, after which the materials are weighed out in 50 pound lots. The mixing of these ingredients is accomplished by means of a rotating drum which is supplied with paddles traveling in an opposite direction to that of the drum itself. After the materials are thoroughly mixed in this manner they are taken to the incorporating mill which resembles the ordinary edge runner largely used in some of our older cement mills for the purpose of grinding slurry. The rollers of the incorporating mill weigh about 4 tons apiece and the charge of mixed materials is placed on the bed of the mill to a definite depth made necessary by the fact that if the layer is less than one-fourth of an inch thick there is great danger of explosion, while if greater than one-half inch in thickness the incorporation of the ingredients will not be satisfactory. The process of incorporating usually required from three to four hours and the product is known as mill cake, which is broken up into lumps of uniform size by machinery especially designed for this purpose. These lumps or particles are now made into press cake by means of hydraulic presses to further insure the complete homogeneity of the product, the press cake being again broken up and passed through sieves of different size mesh in order to produce powder grains of various sizes. The size of the powder grain is of great importance, as, upon the size of the grain depends the rapidity of combustion and, therefore, the shattering effect of the explosion.

Probably the most important explosive of modern times is gun cotton, this being largely used for filling shells and mines used in modern warfare. Gun cotton is probably the most easily handled and safest of all of our modern explosives. In order to gain an idea of the manufacture and composition of gun cotton we must start with the substance called cellulose. Cellulose is the skeleton left of the vegetable tissue after the substances whose functions rest entirely with the vital processes of the plant have been removed by chemical treatment. In order that you may observe the difference between nitrated and unnitrated cotton I am showing you a sample of cotton which has been nitrated for a period of 12 hours by being immersed in a solution of concentrated sulphuric and fuming nitric acids. The cotton used in this experiment was ordinary cotton candle wicking, and you will note that upon applying a flame to the unnitrated cotton it will burn slowly as is usually the case with such material. Applying the flame to the sample of nitrated cotton results in a quick flash with no remaining ash after combustion. The rate of propagation of the explosion in gun cotton is somewhere between 17,000 and 21,000 feet per second.

In the manufacture of gun cotton old rags and waste from cotton spinning mills are generally used, which require very careful cleansing and drying before being subjected to the nitrating process. The cleansing is accomplished by treating the cotton with a strong solution of caustic potash and then washing with running water until all traces of the caustic are removed. The material thus prepared is dried and then weighed out in batches of 16 pounds each and placed in the nitrating machine. The nitrating machine resembles somewhat the ordinary centrifugal used in the sugar mill and is so arranged that the acids used in nitrating may be rapidly removed and water allowed to run in in order to commence the washing at the very earliest possible moment after the action of the acids has been completed. During the process of nitration the cotton increases greatly in bulk and weight, the 16 pounds weighing when nitrated about 25 pounds. In order to remove all traces of acids from the nitrated cotton, washing is continued for several hours in running water, after which the nitrated cotton goes to the hydraulic press for the removal of excess water. If the gun cotton is to be stored for any great length of time, about 40% of water is left in it in order that there may be no possibility of accidental explosion as wet gun cotton is perfectly safe under all ordinary conditions. Our modern smokeless powders are made by treating gun cotton in such a way as to produce what are known as colloids. After cotton fiber has been treated with nitric acid and sulphuric acids, as in the process of nitration, it possesses a property which it did not have before nitration and that is its solubility in certain substances, most important of which are acetone and a mixture of alcohol and ether. Gun cotton dissolved in these solvents will give a light amber colored solution which, upon evaporation, will yield solids more or less viscous in their nature, the viscosity depending upon the amount of solvent left in the mixture. This resulting compound is called a colloid and is the substance used in the manufacture of smokeless powder. In the practical manufacture, on a large scale, of smokeless powders nitrated cotton is run through a machine which shreds it into small particles very much resembling paper pulp as in the process of paper manufacture. Chemical control is maintained during the process of shredding and washing in order to ascertain the presence of free acids in the mass. Gun cotton must not be permitted to retain any of the acids used in the process of nitration as they would cause decomposition and consequent accidental explosion. After the gun cotton has been thoroughly shredded and resembles bread dough it is placed in what is called a stuff chest in the interior of which revolves an endless screw which forces the cotton out through an opening at the top. The gun cotton as it is now prepared contains about 40% of water and in order to remove this excess water and prepare the cotton for the colloiding process it is put through a hydraulic press and a large part of the water removed by pressure. The pressure cannot be continued sufficiently, however, to remove all of the water and alcohol is permitted to run through the top of the cylinder containing the cotton, thus taking out all of the water by solution in alcohol. Practically all of the alcohol is pressed out of the cotton which then goes to another press and is treated with ether thus completing the process of collodization. The colloided cotton is passed through dies by means of an endless screw revolving in a drum, these dies being arranged with needles which give perforations in the resulting rope or rod of smokeless powder. These rods are of various diameters and are cut into sections or grains by means of bronze knives. As in the case of ordinary gunpowder the size of the grain determines the rapidity of combustion, and for large caliber guns smokeless powder may be made in the form of sticks resembling walking canes.

The manufacture of nitroglycerine is very similar to that of gun cotton with the exception that the substance to be nitrated is glycerine in the place of cellulose. Nitric and sulphuric acids are used for nitrating glycerine but a very careful watch has to be kept of the process in order to prevent the occurrence of disastrous explosions due to the decomposition of the glycerine and consequent rise in temperature of the mixture. The nitrating of glycerine usually requires about one-half hour after which the treated glycerine is run into tanks filled with water where it sinks to the bottom and is drawn off for further purification.

Nitroglycerine, as such, is not used to any great extent at the present time but is the basis of a large majority of the dynamites now on the market. Ordinary dynamite consists of some absorbent material such as infusorial earth, otherwise known as kieselguhr, which is permitted to absorb the nitroglycerine, the amount of this absorption depending upon the strength of the dynamite desired. Dynamites are graded according to the percentage of nitroglycerine which they contain, as for example, 60% dynamite contains 60% by weight of nitroglycerine. Some of the modern dynamites contain, in addition to nitroglycerine, other substances which supply an excess of oxygen and thus increase the violence of the explosion.

I have already mentioned the discovery of blasting gelatine and I would briefly state here that blasting gelatine consists of about 90% nitroglycerine and 10% nitrocellulose, the two substances being mixed by means of wooden paddles in a large tank or vat, and finally kneaded with the hands like bread dough until a mass, having a smooth even consistency, is obtained, the resulting product resembling a jelly like substance, soft enough to be easily cut with a knife. This mass is forced through a die as in the manufacture of smokeless powder and the rope or cable is cut by means of a bronze knife into the desired lengths and wrapped in paraffine paper to form the completed dynamite stick.

Just as we have explosives of various methods of action, so, naturally, we have three classifications of explosive actions, as follows: Explosions of low order, otherwise combustions or progressive explosions. Detonations, or explosions of high order, and fulminations, which are explosions extremely brusque in their nature.

Among those explosives which give progressive explosions or combustions we classify the charcoal powders and the nitrocellulose powders. Explosions of these substances are differentiated from explosions of high order or detonations by the fact that they take an appreciable length of time for the completion of explosive action, which is in fact nothing more or less than a form of rapid combustion. A train of black powder, a hundred or more feet in length, will require an appreciable length of time for the propagation of the explosive wave if ignited at one end, the length of time required for the combustion to be carried throughout the length of the train depending upon the size of grains of which the powder is made, the larger the grains the slower the rate of combustion.

Among the detonating explosives we should note gun cotton. nitroglycerine, dynamites and all picric acid compounds as well as a large number of nitro compounds and substances of organic derivation. The difference in action between detonating explosives and explosions of low order is due to the fact that in explosions of high order the result is brought about by a rupturing of the molecular bonds which hold the substance together, this disrupting action being started by a proper detonating explosive, usually with an electric or time fuse. In order that explosives may be properly handled and used to advantage we require exploders or detonators. Fig. 1 shows an exterior view of three sizes of electric exploders largely used for

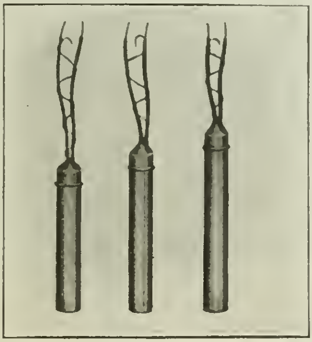

Fig. 1. Showing exterior of electric exploders.

this work. These exploders are copper shells into which is placed a suitable amount of detonating substance, usually fulminate of mercury, the cap being rated according to the number of grains of mercury fulminate which it contains. Fig. 2 shows a sectional view of one of these electric caps with the leading in wires CC, the platinum igniting wire E, and the mercury fulminate B. Current for the ignition of these exploders may be obtained from the regulation blasting magneto, from storage batteries, or from any other suitable source of electric current.

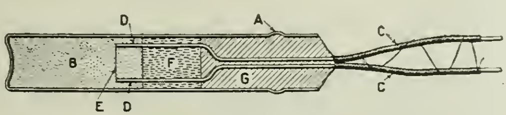

Fig. 2. Section through electric cap.

It often becomes necessary in the use of explosives to figure properly the amount of explosives required to do a certain thing, and while it is not possible to figure with extreme nicety the amount of explosives required for any purpose we have rules which are sufficiently close for practical work, and in order to understand these rules and properly apply them we must first consider what is known as the line of resistance. In Cut 1, Fig. 3, is shown a charge of dynamite represented by the black portion at C. The effect of the explosive wave is at right angles to the center of the charge, and this line is called the line of resistance. In Fig. 1, above referred to, the probable crater formed by the explosion will be ACB. The angle at which the bore hole should be driven depends upon the nature of the substance to be blasted. In Cut 2, Fig. 3, is shown a wall having two parallel surfaces and also the probable crater ACB. Cut 3 represents a horizontal undercut surface, which would require that the bore hole should be driven at a point opposite the angle at F. In a case of this kind the bore hole should not be driven all the way through but should be at least three-fourths the distance AD in order that the blast should not blow out a small crater as CFB. As the line of resistance is the longest line at right angles from the

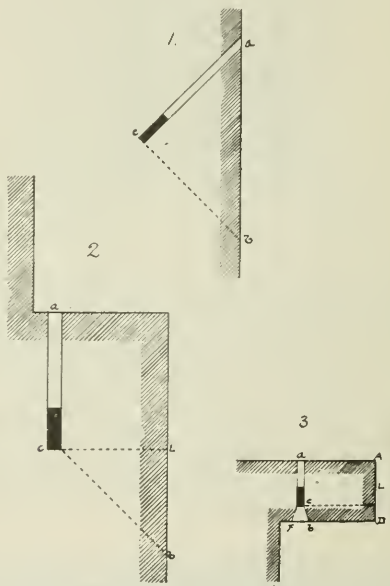

Fig. 3. Showing methods of placing explosives and probable effects.

charge in the direction explosive effect is to be carried, we may approximate closely to the amount of explosive required by the following formula: Let C equal total charge in ounces, LR line of resistance in feet, K equal coefficient of resistance of material to be blasted: then C will equal k $(LR)^2$. If value of k is not known it may be taken as 0.2. Tables are available giving the coefficients of resistance for various materials.

In preparing a charge of dynamite for blasting the matter of tamping is of great importance, as a charge which is not properly

Fig. 4. Method of placing explosive against steel rail.

Fig. 5. Explosion of charge shown in Fig. 4.

Fig. 6. Showing effect of charge shown in Fig. 4.

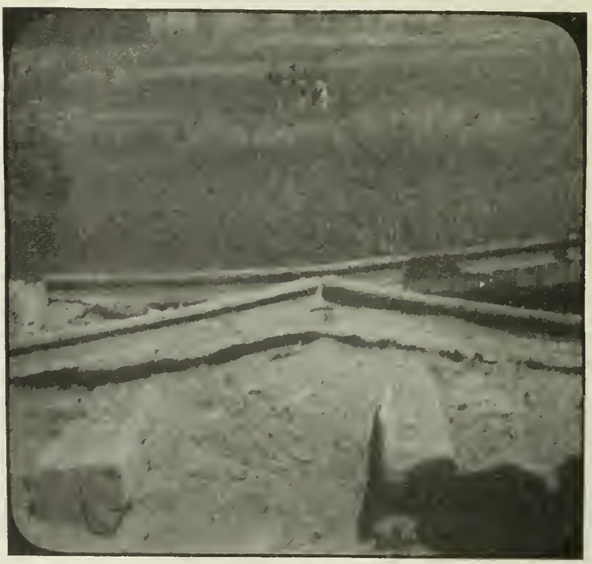

Fig. 7. Showing effect of charge placed without tamping.

tamped will not give the maximum explosive effect. Fig. 4 shows a charge placed against the web of a steel rail with a small amount of tamping; in this instance wet clay was used. The explosion of this charge is shown in Fig. 5 and the effect of the explosion in Fig. 6. It is to be noted that a large piece of the rail was blown out, in this case the piece being about 18 inches in length, and it was blown for a distance of one-fourth of a mile, the charge being two sticks or 1.2 lbs. of 60% dynamite. Fig. 7 shows the effect of the same weight of dynamite placed against the web of the rail without any tamping, the rail is bent but the damage is much less than in the former case. Fig. 8 shows the shattering effect of a charge of 4 sticks or 2.4 lbs. of 60% dynamite on a large tree, which was blown entirely down by the explosion of this charge. The diameter of this tree was about 24 inches and the dynamite charge was placed

Fig. 8. Showing effect of dynamite on tree.

in bore holes extending nearly to the heart of the tree, equally spaced about the tree.

In the handling of dynamite and all other explosives precaution should be the watchword, and familiarity with these dangerous substances should never be permitted to obscure one's ideas of safety. If there is any place where the "safety first" idea should be used first, last and all the time it is in the handling of explosives. Do not attempt to use frozen dynamite, and do not thaw dynamite around an open fire. I am well aware that this latter practice is very common and that apparently accidents are not numerous, but when an accident does happen it is sufficiently terrible to warn anyone against the practice. There are on the market suitable devices for thawing dynamite which are safe and inexpensive, and it is foolhardiness to attempt this operation without the protection afforded by a properly designed apparatus. Do not store dynamite and detonators close together. Keep them separated as the explosion of a detonator may set up an explosive wave sufficient to detonate a large amount of dynamite or other explosive. Do not tamp dynamite in bore holes with metal tampers—use wood and wood only. Do not be in too much of a hurry to investigate the causes of a misfire. Better wait and go on with other work until it is certain there will be no explosion of the charge. In spite of all directions that might be given for the careful handling of explosives there will always be found the man who will persist in crimping caps on to fuses with his teeth until he does this once too often. Crimpers are furnished for the purpose of attaching caps to fuse leads and there can be no excuse for using your teeth or a hammer.

Practically all of the explosives, which are on the market at the present time, are safe if handled in a proper manner, and just as unsafe when injudiciously handled.

Discussion.

H. S. Baker, M. W. S. E.: We use a large amount of explosives in our work,—for instance, in mining and tunnel work.

In connection with the use of dynamite in mining work, great care should be used to select a dynamite suited to such work because of the gases generated. Gases vary a good deal in different kinds of dynamite. In tunnel work the rate of progress is seriously affected by the length of time required to get the gases out of the tunnel after the shot has been fired. Carbon monoxide under certain conditions is a deadly poison, and men have often been seriously injured by breathing its fumes.

O. P. Chamberlain, M. W. S. E.: The company with which I am connected uses large quantities of explosives. It may be of interest to some of you to hear something about the blasting of the limestone rock in this vicinity. In our principal quarry we are working on what we call a 40 ft. face. That is, the quarry face is about 40 ft. high. Like nearly all quarries in this vicinity, we started on a comparatively level surface of rock. In opening up new quarries we have to open up first a place in the center for the face. Our method at the present time is to drill about ten holes for a blast along back of the face about 10 or 12 feet. We are using for this purpose now, and have been for a number of years, well drills, which are similar to the drills you have all seen worked by lifing with a drum and cable and then releasing drum and dropping the drill, used generally in this section of the country for putting down artesian wells. We have found it more economical than the air drill which we formerly used. We drill a hole to about the bottom of each one of the holes —or rather, to about the bottom of the bed of the quarry, about 40 ft. in depth. We are charging about 100 lbs. of dynamite in each one of the holes. A few years ago the custom was to put in over

200 lbs. Undoubtedly there was a great waste of dynamite in this method. We found that what was necessary was to have sufficient force in the explosion to blow out the lower part of the face and let the top fall. As a matter of fact, in our work the lower part is broken out only a short distance and shattered pretty well, and the top settles down a little. We find that in this way the blocks of stone are sufficienty shattered to be handled with the shovels.

In connection with the various kinds of dynamite used, we have had experience with the ordinary dynamite,—that is, the dynamite which is manufactured from porous clay, impregnated with nitro-glycerine, and after that for a long time we used gelatine. Gelatine has become, in this section, a popular dynamite on account of convenience in handling. It is probably more expensive to manufacture than what we call the old-fashioned dynamite.

We have been using, also, an explosive which I think was not touched on by the author this evening, that is, nitrocellulose. We have found it quite satisfactory, but we also find that people who handle dynamite have prejudices and are generally wedded to some particular kind. When we began to use nitrocellulose there was a good deal of complaint at first on the part of the blasting boss, but we have had good results from it.

I have had supervision of a good deal of blasting and have had many complaints from neighbors five or six miles away as to the discomforts from blasting. I always explain to them the precautions taken to prevent troubling our neighbors. In the vicinity in which we operate there are a number of other quarries, and I happen to know that at some of those quarries they blast 70 holes at one time. We have reduced our blasts to ten holes to avoid trouble. The shock which is felt by the people in the vicinity of a quarry of this kind I have explained (and I do not know whether my explanation has received much credence, but it is a fact) comes from the use of very small quantities of dynamite in connection with dobying and block-hole blasting. This is a process of shattering stones which are too large to handle with a shovel. The proper method is to drill a small hole in the stone, put in a small quantity of dynamite, and set off the charge. For instance with a stone measuring 12 cubic yards, we put in a small quantity of dynamite and shatter the stone.

It is very easy, although probably more expensive, as far as dynamite is concerned, to lay a piece of gelatine on top of the stone, cover with clay, and then explode, the idea being that it is a good deal more expensive to stop a steam shovel than to make an explosion. I think it is probably true that in this method of blasting 75% of the dynamite is wasted.

It is generally the expectation of visitors that in the process of explosions they are going to see rocks flying and hear tremendous noises, but as a matter of fact in an explosion of dynamite there is simply a slight rumbling noise and possibly a few flying stones, and the operation is all over.

One thing that should be of interest to those who have anything to do with the handling of dynamite is the method of connecting up the dynamite with the electric current. Many accidents have been caused by the failure to properly connect up the series of blasts. At one time at our plant we were somewhat apprehensive in our digging of the stone, from the fact that we knew we had missed one blast. For instance, suppose we had as high as thirty holes prepared as a series of blasts. If any of these holes failed to explode there is danger that later on, in the digging, the blast may explode. This has happened. The failure of the dynamite to act is almost always caused by imperfectly connecting up the electric circuit; either that, or in the battery charge there has not been sufficient electric current to cause exploding. The favorite excuse in such a case is that there is something wrong with the dynamite, but we seldom find that to be the fact. In cases in which the dynamite has been complained of, we have immediately taken half a dozen sticks of the same dynamite that has been used, and found that every one had exploded. Our experience has been that the dynamite is almost always satisfactory, if you get the proper kind of dynamite and the proper kind of powder for the particular condition.

I had hoped that the speaker tonight would touch on nitrocellulose powders and possibly give his ideas as to their comparative value with dynamite and gelatine, because we have been using that kind of explosive and feel that it is quite satisfactory.

Mr. Marsh: Regarding nitrocellulose powders, I believe they are extremely satisfactory, because dynamite which combines certain compounds will give greater and better effects than straight dynamite. Glycerine is one such compound. The nitrocellulose combinations are good, there is no question about that; they give a multiplied effect to the explosive and in that respect they are better than the straight dynamites.

B. E. Grant, M. W. S. E. (chairman): Mr. Marsh spoke of figuring charges and mentioned 0.2 multiplied by the line of resistance, but he did not say how he measured the line of resistance. Is it measured in feet?

Mr. Marsh: The coefficient is 2/13 times the line of resistance squared.

Mr. Grant: One phase of this subject the speaker did not take up, namely the laws regulating the safe transportation, storage, and use of high explosives. Up to a very few years ago the laws were very lax in this respect, but the Interstate Commerce Commission put into effect some very rigorous laws about transportation of explosives. About four years ago the city of Chicago passed an ordinance relating to this feature. We have with us tonight the gentleman who enforces that ordinance. I will call on Chief McDonnell, of the Bureau of Fire Prevention, to tell us something about that ordinance.

J. C. McDonnell: The ordinance which the chairman referred to was compiled for us, and we have tried to carry it out to the best of our ability.

I am sure you will all agree with me that the handling, transportation, and storage of explosives, is a very important matter.

I was much interested in the remarks of a previous speaker in regard to quarry explosives and the complaints received from neighboring people. Not long ago our bureau received quite a number of complaints about a certain quarry claiming that stones were being scattered in the neighborhood, and finally an ordinance was introduced in the City Council declaring the place a nuisance. Knowing the depth at which this quarry was operating, it seemed strange to me that the flying stones could so seriously affect the neighbors. So I went over there in disguise and watched the operation, but failed to see flying stones to any great extent. Things ran along until the City Council investigated for themselves. We are trying, as well as we know how, to guard the storage, transportation, and use of dynamite and other explosives, but we are not all experts in the matter.

I came here tonight with the idea of learning something, and I can assure you I have learned a great deal in listening to Mr. Marsh.

Not long ago there was a serious explosion in connection with a fireworks company on Wabash Avenue. I would be interested in hearing something in regard to the storage of fireworks. It has been generally supposed and maintained that fireworks, as a commercial commodity, are harmless when packed and stored as they were in that instance on Wabash Avenue, which disproved this theory. I would like to know how such an accident happened and why the occupants of the building did not have sufficient warning to allow them to get out of the building.

Mr. Marsh: Fireworks are undoubtedly explosive under certain conditions. They are made up from what is called meal powder for the base, and are mixed with a larger proportion of charcoal and some other inert composition to prevent a rapid combustion. It is possible, and in fact almost certain, that any of those fireworks mixtures will explode if the conditions of temperatures are right, and if they use chlorate mixtures, as they do in some cases, there is no question but what there is a chance for explosion. If we could get at the truth of the matter we would find the trouble due to some mixtures of chlorates with some other combustibles—possibly sulphur or sulphur and meal powders.

Ernest McCullough, M. W. S. E.: It is something of a disappointment to me that Mr. Marsh said nothing about "permissible explosives" used in coal mining, lists of which are published from time to time by the United States Government.

Gas which was formerly credited with all the mine explosions is now known to be merely a medium for conveying the flame of the explosive to the coal dust. It is the coal dust which explodes in mines. Charcoal used in ordinary black powder lengthens the time of combustion and assists in generating a greater amount of carbonic acid gas than is supplied by the sulphur which begins the operation, while the saltpeter supplies the oxygen necessary to support combustion. The result of using a powder composed of these materials is to produce a long flame of rather long duration. The problem involved in producing a "permissible explosive" is to get an explosive which will generate enough gas to do the work, have a short flame which cannot reach a body of gas and so cut down the duration of the flame that it will be a flash which cannot ignite the gas or coal dust, or both. The flame of ordinary black powder has a length of 50.2 inches and the duration of the flash is 15/100 of a second. Some "permissibles" have a flame with a duration of only 3/10,000 of a second and a maximum length of only 15.8 inches. The factor of stability enters into the composition of all explosives prepared to fill definite specifications as to length and duration of flame and it is plain that an unstable mixture is very undesirable in coal mining or elsewhere.

My knowledge of explosives is perhaps that possessed by the majority of engineers who have worked pretty well over the country at different kinds of work and who have had considerable experience in mining. My first powder work was in California where for a time I had a job of priming cartridges and carrying them into the tunnel to remain until wanted, the heat of the tunnel being depended on to thaw the sticks. I soon learned that the most expeditious way to fasten the priming was to do the crimping with my teeth. This worried one of the officials of the mine one day when he visited the blacksmith shop where I did my work but was told that young men could learn only by experience. I am happy to say my experience was not as disastrous as the superintendent feared it might be. The capping of the fuses and priming of the sticks of dynamite was all done in the blacksmith shop. The blacksmith amused himself and frightened me by putting some of the dynamite on his anvil and striking it. I left the shop one day when he was feeling too gay and had not gone far when the expected happened and he lost an arm. The primed sticks were placed in the tunnel and it was my duty to go in and feel of them from time to time and take them to the face when soft enough for use.

Unfortunately the greater number of men injured by improper handling of dynamite are men whose experience should teach them to be more careful, but upon whom the effect is to breed carlessness. With such men it is common practice to soften the dynamite in pails of warm water, very often with disastrous effects because some of the nitro-glycerine is washed out and floats on the surface, exploding when the water is thrown out of the pail with force. They are not afraid to thaw dynamite around open fires by standing the sticks on end resting against boards, feeling them from time to time and turning the hard sides to the fire. On one piece of work in Oregon the powder men took some dynamite to a nearby farm house and placed it in the oven of the kitchen stove, forgetting about it until they were so warm as to frighten them into leaving the house and taking the family along. The farmer rushed in and threw cold water into the oven and I have never yet understood why the stuff did not explode. A great many strange things happen in handling high explosives and man's frequent neglect of ordinary precautions with impunity breeds criminal carelessness.

With respect to size of charge, material thrown out by a blast is a cone, the volume of which may be expressed by the formula

$V = 1.05\ h^3$

in which $V =$ volume in cubic feet.

$h =$ vertical height, this for all practical purposes being equal to the inclined depth of the borehole when the angle of inclination is less than 45° vertically.

The amount of explosive to use is:

$Q = cv^3$

in which $Q =$ quantity of explosive in pounds.

$c =$ a constant depending upon the explosive.

$v =$ the length of the line of least resistance in feet.

Ordinary values of c are 0.3 to 0.45 for black powder and from 0.06 to 0.09 for dynamite and other nitroglycerine compounds. The exact value for the constant should be determined experimentally for the material to be blasted. An explosive of the explosive type should be used for soft material, while one of the detonating type is best for harder material. Whether the material is to be blown out in two or more faces also makes a difference, that is, whether the shot is placed near a corner so the force may act towards each face.

Victor R. Walling, M. W. S. E.: I would ask the speaker whether one takes any chance in throwing water on dynamite in combustion.

Mr. Marsh: I do not consider that one is taking any great chance in throwing water on dynamite in combustion, and I see no reason why water should not put out the blaze.

H. E. Goldberg, M. W. S. E.: I read in the Scientific American lately that some German had been proposing to use liquid air with charcoal as an explosive. He places the charcoal and liquid air in a hole and when everything is ready the current is turned on. In case the explosive does not explode, the air evaporates in a few minutes, after which there is no danger. Should a shovel strike the charcoal after the liquid air has evaporated, nothing happens.

I would like to ask Mr. Marsh a question. He said that smokeless powder is made by colloidifying nitrocellulose with ether and alcohol, and unless it is treated in that way it will not be smokeless. What is the difference in chemical action during the combustion of the uncolloidified and colloidified nitrocellulose? I have always understood that smokeless powder, like a potash salt, was smokeless because there was no ash left as a residue after combustion. But according to what Mr. Marsh said, neither of these substances,—the colloidified nor the uncolloidified nitrocellulose contains any potash or any other salt.

I remember one rather curious accident that happened at the factory of the Wahl Adding Machine Co. There was a vault in which was a gas fixture supposed to be in good working condition. One day a little boy went into the vault and the first thing we knew there was an awful explosion. It blew out the elevator door which was across the building, and it blew a place out of the wall, and broke many windows, while the boy, who was inside of the vault, was practically unharmed, being burned very slightly but not injured by the blow of the explosion. A number of people on the outside of the vault were injured by burns. Ever since I have been wondering how much it takes to kill a boy.

As a result of the explosion, I was asked at that time to look up something about the explosion of gases, so I purchased a book, "Mine Gases and Explosions," by Professor Beard, of the Scranton Correspondence School. I tried to get some facts from it and came across a most astonishing statement. It said that in order to burn at all a gas mixture must not contain below a certain minimum of air, nor beyond a certain maximum percentage of air; that if either of these two limits are overstepped, the mixture would not burn. This was perfectly natural. But then, he continued, that the particular mixture which had the maximum violence of explosion lay not within these limits but outside. That is, a gas that would not burn at all would explode with the greatest violence. This seemed incomprehensible, so I wrote him a letter and received a reply that it certainly is strange, but if I could not understand it, neither could he; nevertheless, it was so, because it had been so found in experimental tests. He also wrote that he had corresponded with some Professor at Columbia, who also thought it strange, but nevertheless agreed that it was so.

I was not satisfied, and commenced to look up the literature, finding this statement of percentages and maximum explosibility repeated several times. Finally I came to the fountain head of this statement, and there the mystery was explained. The original experimenter was perfectly right. With him, however, the composition of the mixture of maximum explosibility lay within the limits of combustibility and not outside. But a little while after he had published his research, somebody copied him and mixed up percentages and volumes (I don't remember which), and that mistake was copied from one to the other for some twenty years.

L. E. Ives (Engineering and Mining Journal): I would ask if it is dangerous to drop a substance like hot candle grease on mercury fulminate.

Mr. Marsh: Anything hot will explode mercury fulminate. In a constant temperature above 135 deg. F. the chances are very great.

E. E. R. Tratman (Editor "Engineering News"): One point that occurs to me is the danger in using dynamite during seasons of low temperatures. The warming or thawing of the cartridges is a common cause of accidents, both on mining and construction work. Numerous heated magazines for the storage of cartridges, to prevent freezing, have been designed, as well as numerous thawing devices. But they are not used extensively, except on large jobs, and they do not provide against the carelessness of the men who handle and use the material. These men, through ignorance or recklessness, are likely to heat the dynamite on a stove, in a kettle, or near a fire, unless some unusually stringent oversight is exercised. A recent appliance is a heated carrier to prevent the cartridges freezing while being taken from the magazine or store to the work. This has chambers arranged on the principle of a thermos bottle, to keep the cartridges at a temperature above freezing. In all cases of heating dynamite, care must be taken to avoid or watch for any accumulation of nitroglycerine leaking or seeping from the dynamite cartridges. There is probably less danger of this kind now than there was a few years ago.

In 1893 I read a paper on "Unfreezable Dynamite" before the American Institute of Mining Engineers, outlining the dangers of the thawing of dynamite and the dangerous methods often employed. This referred also to the Liebert "unfreezable dynamite," which was then being introduced for trial in this country. In this explosive. the addition of isoamylic nitrate was said to reduce the freezing point from 40° above zero (Fahrenheit) in ordinary dynamite to 50° below zero in the unfreezable dynamite. At the same time the explosive power was slightly increased and the sensitiveness to explosion by concussion was slightly decreased. It was claimed to be unaffected by damp, to be free from deterioration by time, and to cost little—if any—more than the ordinary dynamite.

Other safety explosives of a similar character have been introduced, but in some of these the safety element is accompanied by reduction in power or other objection. Neither the Leibert or other non-freezing dynamite has come into general use, and accidents due to careless methods of warming and thawing dynamite continue to occur. For one thing there should be closer restriction as to access to the magazines and the carrying or handling of the explosive.

F. G. Vent, M. W. S. E.: It would be interesting if the speaker would say something about the laws regulating the transportation of dynamite. I am aware that there are very elaborate regulations for handling explosives on railroads, but thought that anything that might be added to the subject might be of interest to people traveling on the railroads, and railroad men themselves.

Mr. Marsh: I can say little about the laws regulating the transportation of explosives, but I can tell you where you will find full information. The only explosive we use has been transported to us and so we have paid no attention to the laws governing transportation.

Mr. Grant: The City Council passed an ordinance about four years ago which covers about eight pages of printed matter relating to the handling of explosives. Up to that time dynamite had been handled very carelessly, and in some cases it was carried on street cars. The ordinance is being very rigorously enforced by Chief McDonnell. One has to have a permit to remove dynamite from the magazine; the man who handles it has to have a certificate of fitness; the man who is responsible for the use of it has to put up a bond with the city, the size of the bond being regulated by the conditions. All these matters are looked after by the Bureau of Fire Protection, and every sale of explosive has to be reported to the bureau. It keeps very close track of all explosives that come into Chicago legitimately.

Ernest F. Smith, M. W. S. E.: How soon after placing 60% dynamite charges for blasting in a tunnel would those charges have to be exploded in order to have any assurance that they will explode? In other words, how much time would we have after beginning the placing of the charges before the explosion would take place?

Mr. Marsh: With ordinary 60% dynamite you would not want to leave the charges exposed longer than six or seven hours. Otherwise, there is a chance that the nitroglycerine would have been lost from the charge and would not be able to detonate the charge.

Mr. Smith: In the event that some charge did not explode, will it become entirely insensitive in time, so that those who might come in contact with it would not be in danger of injury?

Mr. Marsh: It does not take long for a charge to become insensitive—a matter of a week or two.

W. W. DeBerard, M. W. S. E.: I ran across a scheme at Black Rock in connection with exploding a large number of charges, where the wiring system was connected in parallel. Are both parallel and series systems used in such cases?

Mr. Marsh: The series system is one that is generally used for exploding a number of charges. The parallel system could be used but would require a much larger generation of current than the series system.

Mr. DeBerard: Is it more effective?

Mr. Marsh: Of course if you have a very large number of charges you might not have complete success with the series system, due to the fact that you might be unable to get a sufficient amount of current. The parallel system would mean more complications in connections. In connecting a parallel system you would have double the connections to make in each primary. The series system is the one that is absolutely used and absolutely recommended for any number of primaries.

Mr. DeBerard: I understand that in the Black Rock work near Buffalo they used the parallel system almost entirely, and for that purpose they have large machines.

Mr. Marsh: If you have 20, 30 or 40 holes connected up in series it does take a certain amount of time for the current to reach from one hole to another, whereas in the parallel system the case is different because the resistance of your leads is much less than it is with the series system.

One method of making certain of your circuits is by the use of an ordinary galvanometer; that will be a means of preventing a lot of trouble, because when your series circuits are all completed, and you find that something is wrong with your circuit, that is the time to find out what is the matter.

Mr. Goldberg: There is one thing I do not quite understand. If the wires are all of the same size and the circuit leads are in series, then if a current be passed through the circuit, the current must be of equal amperage in all of the wires. They will, therefore, heat up equally. If, however, the wires be in parallel, and the circuit be tested as a whole, it will be impossible to tell whether the current is passing through all of the wires or only through some. It therefore seems to me that the series circuit is rather more reliable than the parallel circuit. Is this not so?

Mr. Marsh: In testing out, of course they would connect the galvanometer to the parallel leads.

Mr. Chamberlain: In connecting in series, if you should happen to have one bad place, you have spoiled your whole blast. If you have the charges connected in parallel, you lose simply that one hole and get all the rest of them. We have not been connecting in series for three or four years, but are connecting in parallel.

THE SALEM (MASS.) CONFLAGRATION,

June 25, 1914

By Charles H. Smith, Engineer and Special Inspector of the Associated Factory Mutual Fire Insurance Companies.

Read before the Society Jan. 4, 1915.

This conflagration swept over 253 acres, about one-third of the area of the city, with a loss of six lives and a property damage estimated at from $14,000,000 to $16,000,000. The total insurance covering the 1,600 burned buildings was about $12,000,000. The largest single property destroyed was the Naumkeag Steam Cotton Co., with a loss of about $3,000,000. The fire burned for 12 hours before it was brought under control.

The city of Salem is built on gently rolling ground on Massachusetts Bay, 17 miles northeast of Boston. It is one of the oldest cities in the state, as is evidenced by the many narrow streets and buildings of historic interest, most of which, fortunately, escaped destruction. At the time of the fire the population was about 45,000 with the principal industries of tanning, and shoe and cotton manufacturing.

The chief business section (and this escaped destruction) is largely of brick buildings three and four stories high, but the buildings of the side streets and the outlying factory and residential districts were mostly frame. There were many semi-detached one- and two-story frame dwellings, but of late years the three-story flat building of frame construction has made its appearance, especially in the South Salem district, where many of the poorer classes were housed. These flats were built closely together with multi-story porches front and back and of the general type shown in Fig. 2. Except for these flat roof dwellings, shingled roofs were the rule in the residential section. The three-flat house is usually covered with tar and gravel.

In the region where the conflagration started there were a large number of tanneries and leather-working establishments of fairly large size of frame construction, and from one to five stories in height. They were grouped so closely that with their wooden construction a fire of magnitude quickly spread from one to the other.

Some were equipped with automatic sprinklers, but depended almost entirely for their supply on the city water, and as the city pressure soon dropped below an effective point, the protection in these cases did not amount to much (Fig. 4). Initially, the lowering of the city pressure was undoubtedly due to water wasted from broken mill service and domestic connections in the buildings not

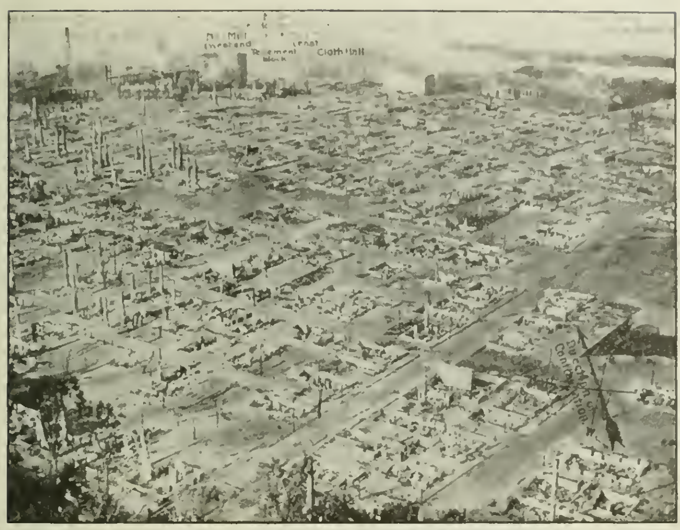

Fig. 1. Birdseye view of burned area.

Fig. 2. Three-story frame flat buildings.

Fig 3. Frame tannery buildings.

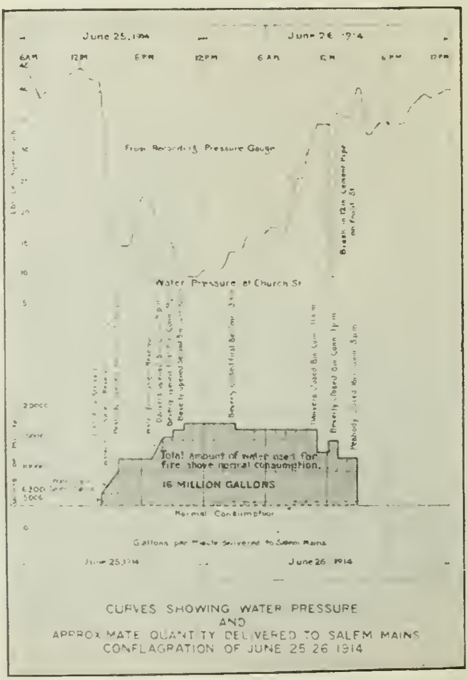

Fig. 4. Pressure Record.

having sprinklers, which were on fire, together with the draft imposed on the system by the fire department. Later broken sprinkler connections, of course, contributed.

The building laws were lax. Under certain restrictions wooden construction was permitted within the fire limits. Outside fire limits heights and areas of joisted construction were practically unrestricted except in dwelling or lodging houses, which were limited in height to 48 feet.

In the fire-swept zone there were but two examples of non-combustible construction—the concrete storehouse of the Naumkeag Steam Cotton Co. and the power plant of the Salem Electric Co. (Figs. 5 and 6).

The water works are owned by the city. The supply is pumped

Fig. 5. Concrete storehouse of the Naumkeag Steam Cotton Co.

from Wenham Lake by two 5,000,000-gallon pumps directly into the mains or to a distributing reservoir with the usual pressure of about 50 lbs., but during the fire pumping was directly into the mains against check valves at the reservoir. From the pumping station six miles north of Salem there are two large mains which reach the city by independent routes. The surrounding towns of Beverly, Danvers, Peabody and Marblehead have connections from their water works to Salem for mutual assistance, and these were all opened during the fire, affecting the Salem supply as shown by the accompanying diagram (Fig. 4). The Marblehead connection, however, had to be almost immediately closed to conserve the water in the Marblehead standpipe, as their pump is operated by electricity from Salem, and was soon obliged to shut down for lack of power.

Approximately 40 per cent of the Salem distribution system is cement-lined pipe. This fortunately did not give trouble during the fire, but there was some hesitancy about turning in the higher pressures from surrounding towns until it was apparent that there was sufficient draft from the Salem mains so that the pressure would not build up.

The Salem fire department has four steam fire engines with a small force of permanent men. The fire department was short-handed at the start, which was one reason for the spread of fire from the building in which it started, so that it soon assumed conflagration proportion. The shorthandedness of the fire department, however, was doubtless no worse than conditions which exist in many towns of similar size throughout the country.

Help was asked and promptly given from surrounding cities and towns and a total of twenty-four steam fire engines or automobile fire engines lent their assistance before the conflagration was over. The speed of the automobile engine in responding and the facility with which it could change its location after arrival were noteworthy.

Fig. 6. Salem Electric Light Plant.

The wind velocity was 15 miles per hour, temperature 94 degrees at the start of the fire. A spell of hot dry weather had preceded.

The fire originated at 1:37 P. M. at the corner of Proctor and Boston streets, where there was a group of four-story frame buildings with attached sheds occupied for the manufacture of shoe stock, heels, counters, etc. One of the tenants used celluloid scrap with inflammable solvents to cut it in the goods he manufactured. There was an explosion on his premises, the cause of which is not definitely known, that carried the fire throughout the building in an incredibly short time.

The fire spread to a large three-story tenement on one side and to a frame leather factory on the other, and the conflagration had started. The local fire department was powerless from the first. Some difficulty was experienced with a chuck hydrant, so that there was delay about getting water on the fire. The moderate wind blowing carried the flames through the district, already dry as tinder, where nearly all the buildings were of frame constructioin. Burning brands carried ahead of the main conflagration spread the fire on the east side of the railroad tracks and aided its sweep toward the waterfront.

At about 6 P. M. the wind shifted a little to the south, blowing directly toward the property of the Naumkeag Steam Cotton Co. The intervening district of three- and four-story wooden flat dwellings furnished fuel to intensify the conflagration. After the destruction of the mill buildings, the fire carried across South River, burn ing lumber yards and coal pockets in that section, and was finally stopped on Derby street, where a fighting chance was given by some buildings of good construction and the open spaces of the cemetery and the public square. The fire fighters, strengthened by help from neighboring cities and towns, massed themselves at this point, and by concentrating their efforts, stopped the fire.

In the path of the conflagration there was practically nothing of a combustible nature left unburned. The granite curbing and paving blocks spalled and crumbled. Toward the border of the fire zone some buildings possessing automatic sprinkler protection, or some special feature of construction calculated to act as a fire stop, escaped total destruction.

With the greater part of the construction that existed in Salem, it was the expected which happened when it burned completely, but it was little thought that a property like the Naumkeag Steam Cotton Co., of good construction, thoroughly equipped with automatic sprinklers and supplied with fire pumps and other means for its own protection, would yield so quickly and completely to the attack of a conflagration. To students of fire protection, the effects of the fire on this property, on its concrete storehouse, and on the plant of the Salem Electric Light Co., have some valuable lessons.

The main manufacturing buildings of the Naumkeag Steam Cotton Co. were five stories high, of good standard mill construction, with brick walls and with stair, elevator and other openings through floors properly safeguarded. There was a one-story Weave Shed with sawtooth roof, likewise of plank and timber construction, a four-story reinforced concrete storehouse for finished goods, some frame cotton houses and a frame building occupied as Cloth Hall These wooden buildings being directly in the path of the conflagration were an element of weakness, as the burning of the Cloth Hall spread the fire to No. 1 Mill.

The mill yard was surrounded by water on three sides, while on the other the rapidly-growing tenement district constituted an increasing exposure. To guard against this the west side of the Weave Shed had been quipped with open sprinklers and wired glass windows, and inside shutters of wood, tin-clad, had been provided at the concrete storehouse.

The property was completely sprinklered and the yard pipe system had recently been strengthened and was modern and ample. The primary supply was from two 12-in. city mains fed from a 20-in. main about 1,000 ft. distant. The normal pressure was about 50 lbs., which is below what is desirable for a property of this magnitude.

The secondary supply was from two Underwriter steam fire pumps with a capacity of 1,000 gallons per minute each, drafting from salt water and discharging into the private mains supplying sprinklers and yard hydrants.

The oncoming conflagration attacked this property on its exposed side. A line of 1,500 ft. had to be defended by the mill fire brigade without any assistance from the public department. As the fire advanced hose streams were applied on the exposing property and then upon the wooden cotton houses, which first took fire, but the intense heat drove the men back and it overcame the protection afforded by the outside sprinklers on the Weave Shed, being sufficient to turn the water into steam as it was discharged. The city pressure at this time was less than 10 lbs., but the fire pumps maintained from 100 to 125 lbs. on the mill system.

After about three hours' run, one of the pumps developed a loose crosshead and had to be shut down for about 15 minutes while repairs were being made. This was the vital moment. The strong pressure previously maintained fell off as the pump remaining in service could not furnish water enough to prevent the burning of the wooden cloth hall building, which carried the fire into No. 1 Mill. By the time both pumps were again in service a sufficient number of sprinklers had opened, so that in spite of their combined efforts, the pressure continued to fall, although practically all the hose streams were cut off from the hydrants to conserve the supply for the sprinklers.

As rapidly as possible sectional controlling valves were closed, shutting off the supply to some of the buildings that were doomed, to keep pressure on the balance of the property, but the increasing smoke and heat soon after made it impossible for men to stay by the pumps, and the men who remained to the last, including two representatives of the Factory Mutual Fire Insurance Companies, who were present, and assisted in fighting the fire, finally made their escape by boat from the water front.

The only buildings of this property that escaped destruction were the concrete storehouse and the No. 10 storehouse, the latter a low one-story building and probably not as severely exposed as the other buildings.

The main manufacturing buildings of mill construction were practically totally destroyed as the illustrations of the ruins show (Fig. 7 and 8).

The concrete storehouse (Fig. 5 and 9, however, had to withstand a direct attack, and although it was equipped with automatic sprinklers fusing at 155° F., not one of these opened, showing that at no time was the interior of the building very warm. The combustible contents, consisting of finished goods in cases, were undamaged.

The windows of the storehouse were small, glazed with wired glass set in metal sash, and, in addition, protected on the inside by hinged shutters held open by fusible links (Fig. 10). These links

Fig. 7. Ruins of mill buildings.

all melted and allowed the shutters to close, reinforcing the wired glass. Without the shutters the wired glass protection would have been insufficient, as some of the glass softened and bulged out of shape. Even where the glass held in place, the radiant heat transmitted was sufficient to distill the wooden cores of the shutters, and had it not been for these, the contents of the building would undoubtedly have been damaged or destroyed.

The building was 100 ft. long, 56 ft. wide and four stories high with stairs and elevators enclosed in towers. It was designed for a safe floor load of 200 lbs. per square ft., built of reinforced concrete, having trap rock aggregate. Plain round rods were used as reinforcement in columns, beams and side walls which were only 4 in. thick between columns, cast separately from the columns and

Fig. 8. Ruins of mill buildings.

Fig. 9. Sprinkler system in cotton warehouse.

the floor slabs, but tied to them. Scuppers were provided for draining the floors.

The only repairs required for this storehouse after the fire were the replacement of copper gutter on the west side, which was melted, the renewal of the wired glass in some of the windows, where softened or cracked, and slight repairs to the concrete in a few spots where there was a little superficial spalling.

The Salem Electric Light Company was housed in a high studded one-story building with brick walls and tile roof supported by unprotected steel trusses, with floor of concrete. Windows on the west and south sides were protected by wired glass in metal frames, on the east by wired glass windows with outside shutters, and on the north facing South River, unprotected.

Fig. 10. Wired glass windows in concrete storehouse.

There were several adjacent outbuildings of frame and brick construction which were destroyed, but the power house was left practically uninjured except that many of the wired glass windows were cracked, and some damage was done to the coal conveyor on the east side (Fig. 6). Three men remained in the building during the conflagration, and with a small hose line, kept what combustibles there were in the interior exposed to the heat radiating through the windows, from igniting, so that there was no material damage. The station was furnishing light and power on the day following the fire. It is probable that this plant was not subject to as heavy an exposure as the storehouse of the Naumkeag Steam Cotton Co. as the frame exposures were not as close to it.

As other examples illustrating the value of sprinklers and fire walls, where exposure conditions were not too severe, the three story wooden shoe factory of E. S. Woodbury Co. on Canal street may be noted (Fig. 11). The automatic sprinklers in this building were supplied by city water and a 11,000-gallon tank. The water supplies for the sprinklers failed, but the fire was stopped at the 12-inch brick parapeted wall which divided the building, with the assistance of the fire department.

The Wilkinson Counter Co. on Jefferson street was a three-story wooden shoe factory with walls covered with slate. The sprinkler equipment was supplied by city water and a 30,000-gallon tank (Fig. 12). The top story burned off after the tank water was exhausted, but the city pressure was sufficient to save the lower stories without assistance from the fire department.

This conflagration forcifully presented the following lessons:

1. The power of a conflagration is well nigh invincible as contrasted with the hazard of the usual immediate exposure, and

Fig. 11. Plant of E. S. Woodbury Co.

methods of defense suitable against the latter are in nowise sufficient to withstand the attack of a conflagration. Where a plant is particularly exposed it may be even advisable for the owners to purchase property on the exposed side, on which to erect buildings of non-combustible construction to serve as a barrier for existing buildings, which otherwise cannot be adequately protected without detriment to their value for manufacturing purposes.

2. A property must be physically able to withstand an intense heat, that is, the walls must be incombustible, of brick or concrete, with cornices and window casings of non-combustible construction. Granite trimmings are easily spalled by heat. Wooden cornices and window casings are easy points of attack. In this fire unprotected steel beams warped and twisted as usual, and in some cases the expansion of steel work pushed over brick walls.

3. Window openings must be protected. This is a difficult matter where the window area as in a manufacturing building, must be a large percentage of the wall surface and extend practically up to the under side of the floors, making shutters, as ordinarily constructed, practically impossible. Wired glass in metal frames, while sufficient for moderate exposure and a protection from sparks, will not alone withstand a severe exposure fire, as heat is easily transmitted through such windows. This matter of window protection offers a field for research, and it is hoped that some kind of curtain or shutter sufficiently staunch to protect against a severe outside exposure fire and capable of adaptation to existing windows will eventually be developed. Outside sprinklers may sometimes be a valuable aid, but they are not automatic in their action, and require large quantities of water to properly supply them, should the building be of considerable size.

Fig. 12. Plant of Wilkinson Counter Co.

4. A private fire-fighting equipment needs an abundant supply of water from at least two sources, one of which shall be independent of the city service. Conflagration conditions may so impair the city water as to render it of no avail. Duplication of the second supply, as, for example, the provision of more than one pump, may be necessary where the values are large and the exposure considerable.

5. Private fire apparatus must be manned by an organization large enough and sufficiently trained to efficiently handle their equipment in a real emergency. The public fire department under conflagration conditions will have so many demands upon their services that they cannot be counted upon for the defense of an individual plant.

6. The lesson for municipalities is the need for better building laws, which will prevent the erection of wooden buildings three

stories or more in height, making impossible combustible roof coverings, and the construction of any wooden buildings in districts likely to become congested. The wooden shingle again showed its dangerous character and the open balconies at the rear of three- and four-story wooden flat dwellings were easy points of attack for the flames. The proper authorities should also *be empowered to call for automatic sprinkler protection in any property whose construction or occupancy makes it extra hazardous to the community.*

Discussion.

Frank D. Chase, M. AM. SOC. C. E.: I am interested in fire protection, as most engineers and architects are, and I wish to express my pleasure in having had the opportunity to listen to this paper, which is an extremely clear presentation of some interesting facts.

There is at present before the Building Committee of the City Council an ordinance extending the fire limits. This brings out very clearly one fact which I wish might be impressed on every engineer and architect, and incidentally every member of the City Council, and that is this: the paper shows a plant which was as nearly perfect as a manufacturing plant can be made, from fire protection standpoint, and it was totally destroyed with the exception of one building, because of a conflagration which started and spread through an adjacent territory which was closely built up with cheap buildings. It is the intention of fire protection engineers that this city shall have an extension of its fire limits. In Chicago and elsewhere we build up a section of a square mile of cheap buildings, and when that district is pretty well built up, everybody agrees that we can extend the fire limits, and we build another section. The result is we now have a large territory in which a conflagration can spread, just as it did in the Salem fire. The city of Chicago and loop district is daily and hourly open to just exactly that hazard, and this whole city is in danger of again burning up. We are absolutely at the mercy of the elements, because we have no adequate fire limits.

I think this paper is the clearest exposition of that hazard which I have seen presented anywhere.

I wish there might be some way in which the Western Society of Engineers could go on record on this question of the extension of the fire limits in Chicago.

It has been proven that it costs a very little more—2 to 4 per cent more—for a brick house, with non-combustible roof construction, than a frame house with shingle roof. It seems to me there is no excuse for delaying the extension of the fire limits, because a few aldermen and some others, who may or may not be subsidized by certain interests, are opposing the ordinance. In my opinion, the fire limits should be coincident with the city limits, but it does not seem possible to get them. If a fire should occur on a winter night, when there is a strong wind and impassable streets, there is the possibility of the fire making such headway that the city would be destroyed.

In going outside of the city limits you will find brick buildings going up in preference to wood; slate roofs in preference to shingle. There will be no justification for the ordinance not passing, but I fear we will have a hard time putting it through the City Council. If any of those present know personally any of the aldermen, I think it is their duty to do what they can to influence the passing of the ordinance.

Douglas A. Graham, M. W. S. E.: There is another phase of the fire prevention question that seems to be overlooked a good deal and which, I think, is as important as the movement to enforce building restrictions. I refer to the necessity of protecting that most important part of the fire-fighting system, the waterworks. It is interesting to examine some of the waterworks plants to be found in the smaller cities throughout the country and it is almost unbelievable how little attention seems to be paid to protecting them from catching fire. When a downtown fire starts, the waterworks system is the most important agency for fighting the fire, and if anything happens to the waterworks, the fire-fighting apparatus is almost worthless.

Go out into the country and you will find many a waterworks plant where the boiler house is constructed with a low roof, unprotected wooden joists, the floors oil-soaked, etc. They have been that way for years, and all the attention seems to be directed to the visible parts of the fire protection system down town, and no attention is paid to the waterworks. I remember one striking example in a little town—a waterworks plant with a wooden tank. The tank was on a brick tower which housed the boilers; the engine room was of brick, with a slate roof, and apparently was well protected against fire. The smokestack was carried through the middle of the tank. It happened that in the middle of winter one night the engineer went to sleep and the tank ran dry, caught fire, dropped down on the station, and in about four hours there was no plant at all. No one paid any attention to protecting the waterworks from burning up.

I think if more attention is paid to building fireproof waterworks plants we will advance in the art of fire protection.

G. C. D. Lenth, M. W. S. E.: In going about the city one sees many brick buildings having the rear porches of wood. It seems to me unwise to have an expensive brick building with a wooden rear porch. Is there not some law to prevent that?

Mr. Chase: The width of a porch is limited to 8 to 12 ft., except in apartment buildings, where the width may be 10 ft. That amount of wood would not make a fire spread very far.

Albert Cone (Associate Editor American Lumberman): I have been much interested in some of the things said here, and was particularly impressed with the paper of the evening, because it is one of the most thorough and impartial accounts of what actually happened in Salem that has been called to my attention. I was very glad, also, to have Mr. Chase give the application which he did of the facts of the Salem fire to the conditions of Chicago, because that is just about what is usually done with those conflagrations

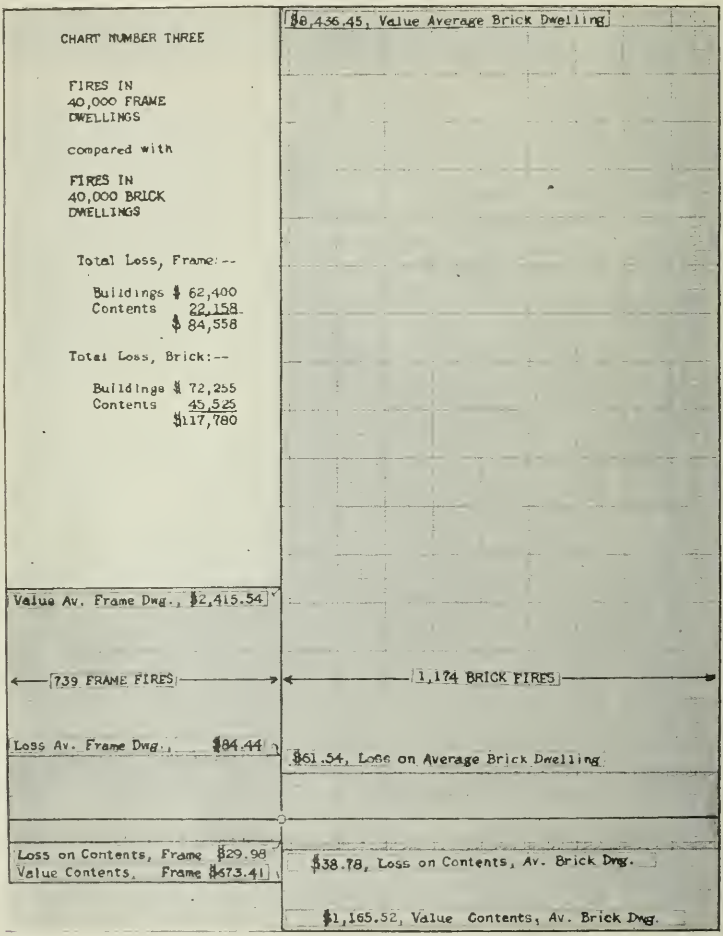

Chart I. Comparing losses in equal numbers of frame and brick buildings.

which occur here and there over the country and particularly where frame construction is involved. You do not hear much about San Francisco and Baltimore and their lessons, but you do hear much about Salem and Chelsea. This is an engineering body and we are accustomed to basing our conclusions on engineering data, and the things which happen in Chicago to frame buildings year in and year out are about as vital in their bearing upon our problem as what did happen down in Salem. Take our Health Department: they say our people ought to do certain things to conserve the health of our public and they have statistics to prove it, but when we come to talk about the death rate in buildings, nobody knows anything about it. The Fire Prevention Bureau does not; the Fire Department does not; they have figures, but they do not compile them in the proper way. I have been interesting myself a little on that particular subject, and went over the entire reports and made up a record of all the dwelling fires that occurred in the year 1913. I am not going to give you the bulk of the statistics, but there are a few pertinent facts which may be of interest to you. One of these is that in the dwelling fires, which were single fires, the loss on the average frame dwelling was $60.42 on the building and $24.41 on the contents. On the average frame building and communicated fire the loss was $339.88 on the building and $89.21 on the contents—five times as much loss. In brick dwellings, single fires, the average loss on the building was $42.93 and on the contents $31.93. Brick dwellings, communicated fires, average loss on building, $364.27 on the building, as compared with $339.88 on frame construction, and average loss on the contents of $150.07 as compared with $89.21 on the contents in connection with frame construction.

Here is Chart I, taking the single fires and communicated fires together, or the fires which happened to the dwellings in Chicago:

	Frame	Brick
Average loss, building.......	$ 84.44	$ 61.54
Average loss, contents.......	29.98	38.78
Total	$114.42	$100.32

Mr. Kelling, of the Building Department, estimates 90,000 frame dwellings and 30,000 brick dwellings in Chicago, but in order to be conservative I have used 80,000 and 40,000 as the relative figures, and in this chart have taken half the frame fires, representing 40,000 buildings, to compare with those which occurred among the 40,000 brick dwellings. The average loss in each class (vertical scale) multiplied by the number of fires (horizontal scale) gives a total loss of $84,558 in frame and $117,780 in brick, as you will see.

Now you are probably wondering why this is so. It is very largely because of the work which Mr. Chase and some of the other people have been doing, not only in Chicago but all over the country, emphasizing the need of doing away with frame construction. But they have got the people who live in brick dwellings to believe that they are safe, and that they can let the children play with matches. Here are some of the results:

	Frame	Brick
Fires caused by curtains	28	53
Fires caused by defective furnaces	19	41
Fires caused by carelessness with matches	157	183

The one thing which is much more severe in frame construction than brick is sparks from chimneys and defective flues, and those are both largely due to the defects of brick and mortar as material for building chimneys. If a chimney is properly built with smooth interior fire-clay lining it will do away with fires from defective chimneys, and also do away largely with the sparks from burning chimneys, because it prevents any large accumulation of soot.

These are some of the facts and I do not care to go into that to any further extent, but what I do wish to emphasize is this: if we are ever going to get anywhere in the problem of reducing our fire losses, we have got to have some intelligent analysis of what does happen in our fire experience, and we have got to get behind our fire department and get it to furnish more intelligent figures.

Take figures furnished by the Chicago Fire Department; the record I compiled showed 242 communicated fires and the fire department's figures showed 235 fires. In some months they skipped some. For others they show more fires than I found. I went back to the reports and verified my count. Their figures are full of mistakes. On page 94 they show 235 communicated fires, as I have just stated; pages 95 and 88 they show 458—a little discrepancy of 223. They do not give you the vital statistics. They do not tell you the number of occupants, exposure, kind of roof, or where the fire started.

In reporting fires the number of occupants is just as vital as the character of construction. It is obvious that if you double the size of house and number of occupants you probably double the likelihood of fire occurring. If you double the size of house without increasing number of occupants you do not greatly increase the probability of fire. Fires are caused by human activity. If you double the number of occupants without increasing the size of the building, you have come pretty close to doubling the likelihood of fire occurring.

F. J. Postel, M. W. S. E.: I would ask Mr. Cone whether, in accounting for the difference in the dollars loss per fire, both in the original and in the communicated fire, in comparing frame and brick buildings, the fact that the average frame building is not as expensive as a brick building and the contents not as valuable does not influence the ratio.

Mr. Cone: In regard to getting these averages, while 1,478 fires occurred in frame dwellings, there were 69 fires which were from burning chimneys, for which the fire department gave no figures whatever; they merely said there was a fire but that it was not of sufficient importance to put anything down. There were 545 fires on which they gave figures of value and insurance, but reported no loss or nominal loss. So that the fires in which actual loss occurred were 864 in frame and 783 in brick buildings, and there are at least two frame dwellings in Chicago for every brick dwelling. My own opinion is that there are at least three frame dwellings for every brick dwelling.

The City Manual gives, for 1910, all kinds of buildings, brick, 130,000; frame, 170,000.

Now if you will take my chart and divide the total loss by 40,000 buildings, you will find it amounts to $2.11 for frame and $2.94 for brick. Insurance rates on that average building, 80 per cent of value of building and contents, run from $6.67, 5-year term with approved roof, all the way up to $18.54 annual term with wooden roof, for frame; on the average brick dwelling and contents they range from $12.48 to $23.11. On dwellings in Chicago, therefore, we are losing to the insurance companies in excessive rates more than double our actual loss by fires; even conceding that for every dollar of fire loss they should have an additional dollar for their 25 per cent agents' commission and other expenses. That and not the actual fire loss is the great burden upon our homes.

Mr. Graham: Do not those figures bear out Mr. Postel's argument that the value in brick buildings is about 3½ times that in frame buildings? Your figures do not show nearly that difference in the losses, which would indicate that the percentage of loss in brick buildings is much lower than in the frame.

Mr. Cone: It is true that the average frame dwelling is worth $2,415 and the average brick dwelling $8,436. But how many people live in the two dwellings? The dwelling which costs 3½ times as much should not have a corresponding percentage of fires unless there are 3½ times as many occupants. Then, too, the value of contents is only about 50 per cent greater in the brick dwelling, and a large share of that represents increased quality of contents, not increased quantity. The average brick dwelling cannot be 350 per cent larger than the frame, or even 50 per cent larger. Its greater cost represents not greater size, but more expensive construction. Many mansions of the wealthy are included which might cost double or treble the cost of an ordinary brick dwelling of equal size; and that factor instead of increasing the liability to fires should diminish it. We cannot properly allow for these factors until we have arrived at some way of measuring them. I venture the guess that we would find the low loss ratio on brick dwellings largely a function of the size of the building rather than of the fact that its outer walls are of brick or stone.

Mr. Graham: If Mr. Cone presents these statistics for publication in the Society proceedings, it would be well for him to state exactly the lesson he wishes to teach. When considering a great mass of statistics, it is sometimes rather difficult for one to appreciate just what the statistics teach.

Mr. Cone: In regard to that, I will say that I have merely scratched the surface myself. I do not know much more about frame dwellings than I did before. You must realize that the average frame dwelling is not the average dwelling in such suburbs as Ravenswood or Beverly Hills. It takes in the poorest shacks as well as the best dwelling. These are not all equally desirable, from the fire-hazard standpoint. That is obvious. In order to know what kind of frame dwellings are desirable and otherwise, we must classify and sub-classify. That is being done along all other lines. At the present time we are dealing with our fires on the patent-medicine cure-all basis.

H. S. Baker, M. W. S. E.: I am much interested in Mr. Cone's figures and would like to ask him whether, from his study of the statistics, other things being equal, he would recommend a frame building as a better proposition, from a fire prevention standpoint, than a brick building.

Mr. Cone: If one were figuring on building a $3,000.00 house and someone should come along and tell him to build a brick house for 5 per cent more, that would be $3,150.00.

The kind of dwelling one can build out of brick nearly as cheap as frame is nothing but a box. When you come to figure on a frame dwelling with porches, it costs more to build it out of brick than frame, and that is the reason they put the porches on of wood. It is the most flexible construction. But it costs $150.00 more at 5 per cent to build your $3,000.00 house. That at 6 per cent would be $9.00 interest-earning. Your house would be little better than the average. Your share of fire loss would perhaps be less than half. Would you be willing to pay out $150.00 good money that would earn you $8.00 or $9.00 to save some small part of an annual fire loss of, say, $2.50? Eighty per cent of the dwellings are being built of frame construction in residence districts outside the fire limits.

Mr. Baker: I have always considered that a brick dwelling was superior to frame, for two or three reasons. Aside from fire protection, one does not have to pay out money for painting a brick house. The item of painting is a bigger one than the interest on the extra cost of the brick structure. Then, the insurance companies allow a better rate on a brick building than they do on a frame building. I live in a frame house, but I do not think we will have a fire there because we are careful. But I do feel that, other things being equal, a brick building is far superior to a frame building, from the standpoint of fire prevention.

Mr. Chase: The fire limit extension means putting in effect the building ordinance. The National Fire Protection Association, the engineers and architects of this city are not advocating brick and stone construction as opposed to frame, they are advocating the establishment of building ordinances for all classes of buildings. The ordinance does not refer primarily nor specifically to residences; we are endeavoring to protect lives in every building in which people are congregated. It is to the end of public protection in buildings of all types and the occupants, that the engineers and architects are fighting,—not for any one kind of veneering. Mr. Cone has argued from the wrong premise, and his conclusions have no bearing whatever on the subject before the City Council today.

Mr. Cone: As I understand the building ordinance, the construction of frame buildings is permitted only outside of the fire limits. I want to say, further, that in so far as the extension of the fire limits will do away with frame construction, 80% of that construction will be represented by the dwellings which I have been talking about. As far as other types are concerned, I have purposely avoided that, because I am not particularly interested. But I certainly am with Mr. Chase in making buildings more secure.

Mr. Cone: Chicago, February 12 (To the Editor): In the discussion of my remarks on Chicago fires, attention was directed to the difference in value between the average frame dwelling and average brick dwelling, and its effect upon the loss ratio. I stated some broad principles bearing upon that point, but had no definite facts.

In thinking over this matter it occurred to me that a sub-classification of the fires according to value of building might be of service; and while this involved a great deal of work I did it and secured the following separation:

	$5,000 value down		Over $5,000 value	
	Frame	Brick	Frame	Brick
Number of fires	1,375	473	33	648
Value, buildings	$3,313,175	$1,612,650	$257,000	$8,291,750
Contents	923,295	363,225	72,000	905,100
Total value	$4,236,470	$1,975,875	$329,000	$9,196,850
Loss, buildings	$ 110,245	$ 37,170	$ 14,555	$ 35,085
Contents	41,385	20,760	2,930	24,765
Total loss	$ 151,630	$ 57,930	$ 17,485	$ 59,850
Ratio of loss to value	3.579	2.933	5.315	0.651

A further subdivision for dwellings of $1,000 to $5,000 value is shown in Chart II. This showing covers all dwelling fires of Chicago in 1913.

I am glad to be able to give this more detailed reply to the questions for which I was not prepared at the moment. The loss on frame dwellings of $5,000 value and under is less than 3 per cent of the total fire loss; the loss ratio is below the average loss ratio of 3.6059 per cent. Obviously an exception in the fire limits ordinances permitting frame dwellings of approved construction, under

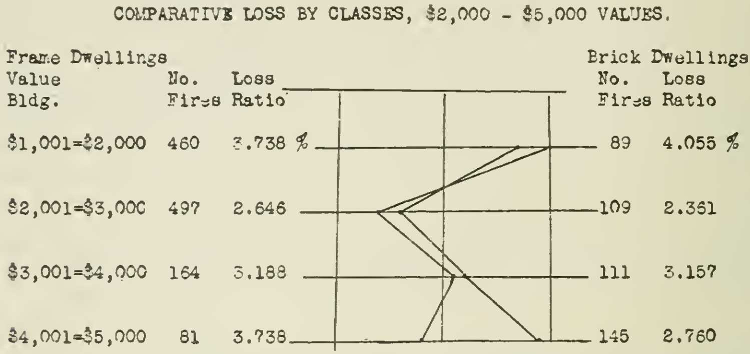

Chart II. Loss by classes.

$6,000 value, would not greatly affect the total fire loss one way or the other, while it would remove nine-tenths of the popular opposition to such legislation, and a corresponding share of the social injury worked by increasing the cost of owning a home.

Albert Cone.

IN MEMORIAM

BENEZETTE WILLIAMS, M.W.S.E.

Died June 22, 1914

Mr. Benezette Williams, Past President of the Western Society, died suddenly Monday, June 22nd, 1914, just as he was starting from his home at Western Springs, Ill., to Ann Arbor, Michigan, where he was to attend a reunion of his college class, and was to receive the honorary degree of Master of Engineering from the University of Michigan.

Mr. Williams, at the time of his death, was in his 70th year, and was the oldest living Past President, but one, of the Western Society of Engineers. He served as president for the year 1885, and was untiring in his efforts to increase the usefulness of the society when its membership was relatively small.

Mr. Williams was a noted Hydraulic and Sanitary Engineer, as well as an able economist. He had a wide acquaintance over this country and had a long and unique experience in many varied fields of usefulness. He was a man of strong mentality, a logical and analytical thinker, and a close student of technical and economic knowledge pertaining to his special line of endeavor. With a naturally rugged constitution, he was an indefatigable worker, even to an age when most men expect to relax their efforts. His investigations were always thorough and persevering, and no source of information was neglected and no stone left unturned in his effort to arrive at truth and fact when charged with responsible judgment in engineering investigations. This trait of character, combined with his rare common sense and good perspective, caused him to retain the confidence of a host of official and investing clients up to the very end of a long and useful career, covering a period of nearly a half century of activity in engineering study and achievement.

By nature, Mr. Williams was of a judicial turn of mind and his fairness and sense of justice, combined with the highest type of honor and intellectual honesty, caused him to be repeatedly entrusted with the appraisal of Public Utilities, as well as employed for expert testimony before the Courts and as an arbitrator in settling difficult questions of valuation.

His professional career has been long and distinguished. He was born in West Liberty, Logan County, Ohio, November 8th, 1844; his ancestors, who were natives of Eastern Pennsylvania, were of the Society of Friends. He graduated from the University of Michigan in Mechanical and Civil Engineering in 1869. Immediately thereafter he came to Chicago and entered the office of Mr. E. S. Chesbrough, then City Engineer of Chicago. Later he worked in the City Engineer's office at Milwaukee. In the spring of 1870, he became locating engineer of the old Milwaukee, Manitowoc and Green Bay Railroad in Wisconsin from Milwaukee to Appleton (now the Lake Shore line of the Chicago and Northwestern Railroad). At the conlusion of the preliminary work, in the latter part of 1870, he was Division Engineer on the Chicago, Burlington and Quincy Railroad, on the branch line from Mendota to Prophetstown. In the spring of 1871, he was again engaged on the Milwaukee, Manitowoc and Green Bay Railroad until early in 1872, when he again came to Chicago, and was engaged, under Mr. Chesbrough's direction, on the construction of the Fullerton Avenue Conduit and Pumping Station. Later he was Superintendent of Sewers. and in 1878 he was Acting City Engineer of Chicago.

In 1880 and 1881, as constructing engineer, he had charge of the building of the water works, and separate system of sewers and sewage disposal works at Pullman, Illinois, and for a number of years thereafter was Consulting Engineer there and elsewhere. During this time he made an important report on the Drainage and Sewerage of the Hyde Park district of Chicago, and was consulted on important trunk sewer construction in Lake View (now Chicago). In 1886, as contractor, he laid the gas mains of the Equitable Gas Company in Chicago. During 1887 he was one of the contractors on the Chicago, Santa Fe and California Railroad, and also had contracts on the Dixon Feeder of the Illinois and Mississippi (Hennepin) Canal.

He was a member of the Drainage and Water Supply Commission of Chicago, appointed by the Mayor, Carter H. Harrison, Sr., in 1886, to investigate the necessary solution of the Chicago Sanitary problem, and signed the report recommending the construction of the present Drainage Canal. Mr. Williams was Chief Engineer of the Chicago Sanitary District from January, 1892, to June, 1893, during which time the Main Channel was located between the Chicago River and Lockport.

Since that time Mr. Williams was in practice as a Consulting Engineer, designing, constructing and remodeling water works plants and building sewage and sanitary works. He was a member of a Commission which reported on an Improved Water Supply for the City of St. Louis, and was entrusted by the City of Seattle with the design of the Cedar River Water Supply of that City, which, in its later development, is in form as designed by him.

A recent editorial from the Seattle Daily Times (June 25th, 1914), noting his death, says:

> "He was the man whose ability and genius as an engineer made possible the splendid Water System which the people of Seattle enjoy today."

Mr. Williams was also called in consultation to the cities of Monterey, Zacatecas, and Tampico, Mexico, on Water Supply problems.

In 1899 he was appointed one of a board of appraisers on the Water Works Property at Dubuque, Iowa, one of the earliest valuations made in the West, and wrote a report in that proceeding, which was long regarded as a valuable contribution to the Art of Valuation. At that time he formulated the methods of computing the Going Value, substantially as they are in use today, and he was the first engineer to work out the principles of this difficult problem and give them public and recorded form. Later, in the Sheboygan Case, he called attention to the value of the sinking fund in computing depreciation and from this time forward his mind was much on these problems of Economics involved in the valuation of Public Utilities. In all of this earlier investigation he was a pioneer, whose work has always been of the greatest value. He was connected with a large number of appraisal proceedings, notably at Des Moines, Council Bluffs, Peoria, the New York Inter-Urban Water Company, and The Suburban Company of Philadelphia.

Mr. Williams early recognized the need for co-operation among engineers through their Societies, and for many years endeavored to bring about a union of the scattered Engineering Societies in this country. He was long on the board which published the proceedings of the Joint Engineering Societies, and hoped to see the day when Engineering would be represented by a strong, single society, comprising all the varied branches in one organization. This ideal was not realized.

He was married September 27th, 1871, to Lydia Jane Terrell of Mount Pleasant, Ohio; settled in Western Springs, a suburb of Chicago, in 1873, where he has resided for over forty years. His married and family life has been most happy. He is survived by his wife, a son and three daughters: Carl Benezette, a member of the Western Society of Engineers, who carries on his father's office practice: Edith C., Hester G., and Ellin T.

Mr. Williams was an active citizen of his home town, and for many years he was president of the Board of Trustees of the Lyons Township high school, and the new hall has been recently dedicated "Williams Hall." He was also for some years a trustee.

Mr. Williams became a member of this society in 1872, and was also a member of the American Water Works Association. He always had the best interest of his profession at heart and did what he could to elevate its standard and dignity.

John W. Alvord,
Lyman E. Cooley,
Ambrose V. Powell,
Committee.

February, 1915

SANITARY DISTRICT PROCEEDINGS,

June 25, 1914, Page 979-80.

WHEREAS BENEZETTE WILLIAMS, late Chief Engineer of the Sanitary District of Chicago, died suddenly at his home town, Western Springs, on June 22, 1914, and

WHEREAS, Mr. Williams was a man of recognized capacity in the profession of Civil Engineer, and of special achievement in the domain of Sanitary Engineering, and had been honored as President of the Western Society of Engineers, and by his Alma Mater as Master of his art.

His professional life of over forty years is identified with the upgrowth of the City of Chicago as Assistant City Engineer under the late Mr. E. S. Chesbrough, and at a later time in responsible charge of the sewerage system and other sanitary work of said City. In the year 1892 and 1893 he was Chief Engineer of the Sanitary District of Chicago. His latter practice has been in the country at large rather than locally.

Therefore, Be It Resolved:

That the Board of Trustees of the Sanitary District honors the memory of Mr. Benezette Williams as one of its efficient early chief officers, and expresses regret at his untimely taking off, while still in the active practice of his profession.

Resolved, That this Board extends to the wife and children of our late associate the assurance of its profound sympathy with them in their bereavement.

Resolved, That in recognition of his public service and his character as a man and servant, these resolutions be spread upon the records of the Board of Trustees of the Sanitary District of Chicago, and a copy thereof presented to his wife and family.

PROCEEDINGS OF THE SOCIETY

MINUTES OF MEETINGS.

Regular Meeting, February 1, 1915.

A regular meeting of the Society (No. 888) was called to order by President Jackson at 8 p. m., Monday, February 1st, with about 95 members and guests in attendance.

The Secretary read applications for membership from the following:

Harvey Arthur Anderson, 2115 Sherman avenue, Evanston.
Harvey J. Chilton, 1657 Monadnock block, Chicago.
William Frederic Kurfess, 16th and Rockwell streets, Chicago.
Ray Belmont Whitman, Box 66, Oak Park, Ill.
Walter Henry Allen, 111 West Monroe street, Chicago.
James Arthur Cook, R. 2004, 111 West Monroe street, Chicago.
Charles Henry Tylor, 4563 Oakenwald Avenue, Chicago.
Henry Missostow, 615 Lincoln Parkway, Chicago. Transfer.
David St. Pierre Gaillard, 2004 Harris Trust building, Chicago.
Harold P. Fisher, 221 South Ashland avenue, Chicago.
Frederick Lewis Faulkner, 5544 South Park avenue, Chicago.
Richard G. Miller, 1231 East 46th street, Chicago.
William Ralph Ourand, 2046 McCormick building, Chicago.

The Secretary read the following elections to membership:

William Alexander Casler, 3403 West 63rd place, Chicago.
Orville Hay Drought, 2435 Brown street, Milwaukee.
Peter M. Larson, 4254 North Lincoln street, Chicago.
Chas. F. W. Felt, 1033 Railway Exchange, Chicago.
Max Kushlan, 2046 Le Moyne street, Chicago.

Mr. Charles M. Denise, representing the McClintic-Marshall Construction Co., presented the Society with a beautiful gavel of lignum-vitae taken from a tie laid on the Panama Railroad in 1852. President Jackson in a speech of acceptance thanked the McClintic-Marshall Co. on behalf of the Society.

Mr. Claude M. Saner delighted the audience with two vocal selections.

The Secretary read a resolution regarding newspaper criticism of certain engineers of the Sanitary District. After discussion by Ernest McCullough, H. S. Baker, S. T. Smetters and F. E. Davidson the resolution was adopted with minor amendments.

President Jackson then introduced Director K. G. Smith of Iowa State College, Ames, Iowa, who read a paper on "Methods of Instruction in Engineering Extension." Discussion followed from Messrs. F. W. Kassebaum, Douglas Graham, Ernest McCullough, F. E. Davidson, Prof. S. N. Williams, Director Williams of the Illinois Mines and Mechanics Institute, Prof. P. B. Woodworth of Lewis Institute, F. H. Wright and Prof. Yoeman of Valparaiso University, with a closure by Mr. Smith.

After two more selections by Mr. Saner, the meeting adjourned for refreshments of cider, gingerbread, apples and a smoke.

The meeting was finally adjourned at 11:20 P. M.

Extra Meeting, February 8, 1915.

An extra meeting (No. 889) in the interests of the Bridge and Structural Section was held on Monday evening, February 8th. The meeting was called to order by Vice-Chairman Musham at 7:50 with 130 members and guests in attendance.

Ballots were then cast for members of the Executive Committee of the Section.

Vice-Chairman Musham introduced Mr. W. S. Lacher of the C., M. & St. P. Ry., who read his paper on "Retaining Walls on Soft Foundations."

At the close of the paper the results of the election for the Executive Committee of the section was read as follows:

For chairman:
H. C. Lothholz, 29.
F. W. Dencer, 24.

For vice-chairman:
W. S. Lacher, 40.

Member of committee (3 years):
N. M. Stineman, 27.
T. L. D. Hadwen, 9:
O. F. Dalstrom, 13.

This committee now stands as follows:

Chairman, H. C. Lothholz.
Vice-chairman, W. S. Lacher.
Members, E. N. Layfield, I. F. Stern, N. M. Stineman.

Chairman Musham then called for discussion of the paper of the evening. Messrs. Vent, Wright, Pearl, Vey, McCullough, Morrow, Baker, Ford and Leisner responded. The Secretary read a discussion prepared by Mr. Onward Bates.

Mr. Ernest McCullough then took the chair and introduced the work of the Legislative Committee which has prepared a bill for the Illinois Legislature which provides for the licensing of Structural Engineers. The purpose and meaning of the bill was explained and some of the principal points discussed by Messrs. Schwarz, Hansen, Stineman, Lowell, Leisner, Davidson, Gaiver, Hoyt and Allen, with answers and explanations by McCullough.

Meeting adjourned at 10:20 p. m.

Extra Meeting, February 15, 1915.

An extra meeting (No. 890) in the interest of the Hydraulic, Sanitary and Municipal Section was called to order by Mr. G. C. D. Lenth at 8 p. m. Monday, February 15th, following music and songs by Mr. R. P. Hogan. About one hundred and seventy-five members and guests were in attendance.

Mr. W. W. DeBerard read a resolution authorizing the appointment of a committee to investigate the possibilities of cooperation with the United States Army Engineers, by which the Society might aid the government. On motion of Mr. H. S. Baker the resolution was referred to the Board of Direction.

Mr. Lenth then introduced Mr. Lewis R. Ferguson, Assistant Secretary of the Association of American Portland Cement Manufacturers, who gave an illustrated talk on "The Edison Fire." At the close of the paper Mr. T. L. Condron, Consulting Engineer in charge of the repair work at the Edison Plant, was called upon for a few remarks.

Moving pictures of the fire were then thrown upon the screen. The discussion was continued by Messrs. Humphrey, President the Concrete Institute; Fire Chief McDonnell, F. E. Davidson, H. P. Weaver and Ernest McCullough.

After two reels of comic moving pictures and some announcements by Mr. Lenth, the meeting adjourned at 10:15 p. m. for refreshments.

Extra Meeting, February 23, 1915.

An extra meeting (No. 891), a joint meeting of the Electrical Section of the Society and the Chicago Section of the American Institute of Electrical Engineers, was called to order at 8:00 p. m. Tuesday, February 23, 1915, with 210 members and guests in attendance. Mr. H. M. Wheeler, Chairman of the Electrical Section, was in the chair.

Mr. Wheeler announced the meeting for March 1st, and called upon President Wm. B. Jackson, who introduced Mr. Edward Schildauer. Mr. Schildauer gave a very interesting talk on the Mechanical and Electrical equipment of the Locks of the Panama Canal, illustrated by many beautiful lantern slides and two reels of motion pictures.

A discussion followed in which Messrs. Allen, Wheeler, Beattys and Mabbs took part.

The meeting was adjourned for refreshments at 9:50 p. m.

J. H. WARDER, Secretary.

BOOK REVIEWS

THE BOOKS REVIEWED ARE IN THE LIBRARY OF THIS SOCIETY.

STRUCTURAL ENGINEERING. By J. E. Kirkham, Professor of Structural Engineering, Iowa State College. The Myron C. Clark Publishing Company, Chicago, 1914. 670 pages, 452 figures and drawings, 13 tables and an index. Green cloth, 6 in. by 9 in. Price $5.00.

The author states in the preface that "This book is intended as a text book for college students and as a self-explanatory manual of structural engineering for practical men," and the book in many ways is adapted to these purposes. The book is marred to some extent by peculiarities of expression not usual in technical writing, though this does not necessarily detract greatly from its value for study and reference.

The author states, for example, that it fell to his lot "to break in students from most all of our engineering schools," that "the student must bear in mind that he is not at liberty to use just any section therein* that he happens to pick out," that "rivets are simple bits of metal in themselves. but indirectly are the source of a great deal of trouble," and that "templets are taken to the laying-off shop, where they are clamped to the material for which they were made to lay-off." It is also stated that "Drawings 18x24 inches is a very convenient size in some cases," "measuring forces is the same as measuring any other thing," and "We cannot conceive of the force being transmitted to the surface other than that each infinitesimal area receives a small amount of the same force."

These expressions, as well as numerous similar ones, occur in the preface and the first three chapters, and indicate a lack of care in the use of the English language.

The index of three pages, single column, does not seem to be very complete for a reference book of this character.

Notwithstanding these blemishes, the book is a valuable one and has a vast amount of information, which will be useful to students and to engineers engaged in practical work.

The actual processes of designing steel bridges and buildings are gone through in great detail and in a manner that indicates the practical experience of the author.

With reference to those portions of the book on structural mechanics, the author states in the preface that "he has no apology to offer for the elementary mechanics given in this volume, as he is convinced that no matter how thorough the course in mathematics and theoretical mechanics may be, it is quite desirable that students have a short review of the materialistic phase of mechanics at the beginning of the subject of structures to whet their appetites for the work."

It is somewhat doubtful that that particular purpose will be served, but the portions treating of structural mechanics will be useful, of course, for review and reference.

*In the tables

The scope of the book is indicated by the titles of the chapters, which are as follows:

Preliminary; Structural Drafting; Fundamental Elements of Structural Mechanics; Theoretical Treatment of Beams; Theoretical Treatment of Columns; Rivets, Pins, Rollers and Shafting; Maximum Reactions, Shears and Bending Moments on Beams and Trusses and Stresses in Trusses; Graphic Statics; Influence Lines; Design of I-Beam and Plate Girders; Design of Simple Railroad Bridges; Design of Simple Highway Bridges; Skew Bridges, Bridges on Curves, Economic Height, and Length of Trusses and Stresses in Portals; and Design of Buildings. E. N. L.

American Sewerage Practice, Vol. II. Construction of Sewers. By Leonard Metcalf and Harrison P. Eddy, Consulting Engineers, Boston, Mass. McGraw-Hill Book Co., New York and London, 1915. Cloth, 6½x9 in., 564 pages with index, 180 figures and illustrations. Price $4.00 net.

This is the second of a series of three volumes on American Sewerage Practice by Metcalf and Eddy, Consulting Engineers of Boston. The first volume treats of the design of sewers, and the third volume, which has not yet been published, will deal with the subject of sewage disposal. This volume is a worthy addition to the first book, and engineers who were delighted with the multiplicity of valuable tables and the detailed and exact information regarding the design of sewers as was found there, will have no cause for disappointment after looking over this second book.

Chapter 1 treats of Preliminary Investigations, Chapter 2 of Engineering Work and Inspection During Construction, and the succeeding chapters follow the construction of the sewer through its various stages to final completion, Chapter 18 dealing with the Operation and Maintenance of Sewerage Systems.

Sewer construction through rock is treated quite fully, two chapters being given over to this discussion. Costs and rates of progress are given their proper share of attention, many valuable tables being inserted to show the costs of different kinds of sewers built under different conditions. The book discusses brick, block and concrete sewers and accompanies the discussion with complete cost data. There are two chapters devoted to contracts, specifications, and drawings which should prove of special interest to the student as well as to the engineer. Chapter 9 discusses the sheeting and bracing of trenches and tunnels and Chapter 10 gives complete information necessary for the proper design of sheeting, hangers and bracing.

Perhaps the best idea of the value of the book as a whole may be gained from a statement of the authors. As soon as the book was compiled, the tables and data therein were used in all construction work superintended by the authors. This actual use of the book for a guide on construction work soon demonstrated its strong and weak points with the result that many additions were made, which added greatly to the value of the book.

F. G. G.

Land Drainage. By J. L. Parsons, Associate Member of the Western Society of Engineers. Myron C. Clark Publishing Company, Chicago. Cloth, 6 by 9 ins., 165 pages with index, 22 tables and 36 illustrations. Price $1.50.

In taking up this work the author undertook to write a book that would be equally valuable to the young and inexperienced drainage engineer, the experienced engineer, the drainage contractor, land owners and drainage offcials, and the manner in which this purpose had been carried out within the narrow limits of the volume is its greatest feature.

Mr. Parsons has not divided the book into several parts, each of which might appeal to but one of the above named classes, but has written the book with such clearness as to make it readily intelligible to all, at the same time technical enough to be valuable to the expert.

The book has four departments, in which most of our technical books are woefully lacking, namely, Plans and Reports, Costs and Estimates, Specifications, and Inspection. The four subjects have been exceptionally well handled, not by long, uninteresting pages of tabulated data, but rather by methods of preparation and application which have been based on experience and experiment. Especially well treated are the first and third named subjects.

The careful attention given these subjects does not outweigh the treatment of preliminary surveys, design, construction and maintenance. Under these headings the author has used his efforts in telling how to accomplish the various steps, rather than what steps to attempt.

The tables are very useful and complete, being arranged in such form as to be readily applicable to the conditions for which they were intended. Much time of computation can be saved by their use.

The illustrations are line drawings and sketches, the latter of which are far below the general standard of the book. If good halftones had been used, the appearance of the book would have have been greatly helped.

An appendix, which is a copy of the instructions to the jury in the trial of a drainage damage case, lucidly sets forth the basis upon which damages for open drains should be allowed under the Iowa state drainage laws. While not identical in detail, the main elements would be approximately the same were the method of procedure under any other state law. The expenditure of ten pages of small type to accommodate this matter is somewhat doubtful as to justification.

The index is very complete and usable.

LIBRARY NOTES

The Library Committee desires to return thanks for donations to the library. Since the last publication of the list of such gifts the following publications have been received:

NEW BOOKS.

McGraw-Hill Book Co.:

Construction of Masonry Dams, Chester W. Smith. Cloth.
Uses of Water in Irrigation, Samuel Fortier. Cloth.
American Sewerage Practice, Metcalf & Eddy, Vol. II. Cloth.
Elements of Hydraulics, S. E. Slocum. Cloth.

Myron C. Clark Publishing Co:

Structural Engineering, J. E. Kirkham. Cloth.

MISCELLANEOUS GIFTS.

General Education Board:

An Account of Its Activities, 1902-1914. Cloth.

Sanitary District of Chicago:

Report on Industrial Wastes from the Stock Yards and Packingtown in Chicago. Cloth.

D. W. Mead, M.W.S.E.:

Report of Board of Engineers on the Huai River Conservancy Project in Provinces of Kiangau and Anhui, China. Paper.

Illinois Rivers & Lakes Commission:

Annual Report, 1914. Cloth.

Wyoming State Engineer:

Biennial Report, 1913-1914. Pam.

E. E. R. Tratman, M.W.S.E.:

Proceedings, American Wood Preservers' Association, 1914. Paper.

Alvord & Burdick:

Progress Report to Commission on Down-Town Municipal Improvements on Relief for Sub-Surface Congestion in Down-Town Chicago Streets. Paper.

Colorado Bureau of Mines:

Thirteenth Biennial Report, 1913-1914. Cloth.

EXCHANGES.

American Institute of Mining Engineers:

Transactions, Vol. XLVI, 1913. Paper.

Lake Superior Mining Institute:

Proceedings, 1914. Paper.

American Society for Testing Materials:

Proceedings, Seventeenth Annual Meeting, Part II. Paper.

American Society of Heating and Ventilating Engineers:

Proceedings, 1913-1914. 2 cloth.

Iowa Board of Railroad Commissioners:

Thirty-sixth Annual Report, 1913. Cloth.

Canada Department of Mines:

The Production of Coal and Coke in Canada in 1913. Pam.
Gypsum in Canada. Paper.

Oklahoma Geological Survey:
Bulletins Nos. 13, 18, 21, 22. Pams.

Institution of Civil Engineers:
Minutes of Proceedings, Vol. 197, 1914. Paper.

Alabama Geological Survey:
Bulletin No. 15, Statistics of the Mineral Production of Alabama. Pam.

North Carolina Geological Survey:
Proceedings of the Good Roads Institute, 1914. Pam.

GOVERNMENT PUBLICATIONS.

Isthmian Canal Commission:
Annual Report for the Year Ending June 30, 1914. Paper.
Canal Record, Vol. 7, 1913-14. Cloth.

Interstate Commerce Commission:
Twenty-eighth Annual Report, 1914, Part I. Cloth.

Library of Congress:
Report of Librarian of Congress, June 30, 1914. Cloth.

U. S. Public Health Service:
Report of Surgeon General for the Year Ending June 30, 1914. Cloth.

U. S. Bureau of Mines:
Fourth Annual Report of the Director, 1914. Paper.

U. S. Department of Commerce and Labor:
Annual Reports 1903-1912. 5 cloth; 2 pams.

Chief of Enginers, U. S. Army:
Annual Report, 1914. 3 cloth.

Smithsonian Institution:
Annual Report, 1913. Cloth.

U. S. Coast and Geodetic Survey:
Description of Its Work, Methods and Organization. Paper.

U. S. Geological Survey:
Thirty-fifth Annual Report of the Director for Year Ending June 30, 1914. Paper.

RULES FOR ESTABLISHMENT OF BRANCH ASSOCIATIONS OF THE WESTERN SOCIETY OF ENGINEERS.

(1) Branch Associations of the Western Society of Engineers may be established by the adoption of a Constitution, which shall be approved by the Board of Direction, and by organization of the proposed Branch Association thereunder.

(2) Said Constitution shall provide:

(a) That all members of the Branch Association shall be members, in good standing, of the parent body.

(b) That all fees and dues assessed by the Branch Association against its members shall be in addition to regular fees and dues required by and paid to the parent body.

(3) A copy of the minutes and proceedings of each meeting of the Branch Association shall be filed with the Secretary of the Western Society of Engineers within ten days after the meeting.

(4) The Western Society of Engineers may publish in the Journal such proceedings of the Branch Association as shall be approved by the Publication Committee.

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VOL. XX MARCH, 1915 No. 3

ECONOMIES IN POWER CONSUMPTION IN ELECTRIC RAILWAYS

By N. W. Storer.*

Presented January 25, 1915.

In April, 1912, in a paper before the A. I. E. E. at its New York meeting, Sanuel Insull presented a very strong and convincing argument in favor of large Central Power Stations as against a number of isolated plants. One of his strongest arguments was the enormous saving in fuel that would result on account of the higher efficiency and better load factor with the larger plant. - Taken in the aggregate, the figures given were startling and have shown not merely an immense saving in dollars and cents, but a long step towards the conservation of our nation's fuel supply. He estimated that if this system of power generation were adopted for the entire country, it would result in a saving of over 200,000,000 tons of coal per annum—a most stupendous amount. Mr. Insull pointed out that the electric railways in any community would not require more than 15% to 20% of the total power used, but where figures such as that are involved, it is well worth while to try to save even a small part of that percentage; for instance, it is probable that not far from 1,000,000 tons of coal will be burned in Chicago this year to furnish power for the electric railways. Chicago has good reason to be proud of her electric railways, yet I do not doubt that if an entirely new equipment of cars were to be installed with all of the economies that can be introduced with our present knowledge, not less than 40% and possibly 50% of that 1,000,000 tons of coal could be saved every year. Since some of the cars that have been installed on the Chicago surface lines in the last two years have cut the power consumption per car mile by reduction in weight, field control, etc., to less than 67% of that of older cars of the same capacity, it can be seen at once that the above statement is not as wild as it looks.

It is the purpose of this paper to show how some of the sav-

*With the Westinghouse Electric and Manufacturing Co., East Pittsburgh, Pa.

ings have been effected and to explain in some detail the possibilities of further economies, especially from the standpoint of the electrical equipment.

A large part of the energy now consumed, considered in the light of the present knowledge and the best modern practice, is wasted, but on account of the large amount of money invested it will continue to be wasted until the older cars and equipments are worn out. In fact, a great deal of power is still wasted, even in the most modern equipments, if the possibilities are considered.

In taking up the question, there are two things to consider:

1st—The weight to be handled.
2nd—The efficiency of the equipment for handling it.

There is one idea that has been drilled into electric railway men in this country in the last few years to such an extent that it has become second nature to many of them; namely, that every pound of weight on a street car costs the company 5 cents per annum to carry it around. I shall not discuss the correctness of this idea except to remark that the next result of its promulgation has been a nation-wide campaign to cut down weights of cars and equipments. It has, on the whole, produced wonderful results.

A great deal has been done in this respect in Chicago, where the weight of the cars on the surface lines, by careful and scientific design, was cut about 25%. A part of this reduction lies in the use of two motor equipments with maximum tractions instead of four motor equipments. This change would, of course, save a great deal of weight if the same total motor capacity were necessary. A reduction in weight of the entire equipment, however, made it possible to use two 50 H. P. motors where four 40's had been used on the older cars. Moreover, the modern 50 H. P. motor weighs no more than the old 40, so that the two motors on the new cars weigh only half as much as the four motors on the old cars. It is beyond my province to tell how the trucks and car bodies were lightened except to say that it was done by a design that made every pound of material in them perform some necessary function.

After all useless weight had been eliminated, we may turn our attention to the amount of energy required to carry the remaining weight around, how it is all used, and what becomes of it. In other words, we will consider the efficiency of the equipment. The energy consumed by an electric car or locomotive is practically all dissipated in the following ways:

(1) In overcoming train resistance.
(2) In ascending grades.
(3) In motor losses.
(4) In gears and motor axle bearings.
(5) In rheostats.
(6) In auxiliaries.
(7) In brakes.

TRAIN RESISTANCE.

Under this heading is classed all friction due to the motion of the train. It includes friction of the main journals, thrust collars, wheel flanges, rolling resistance on track, air resistance and friction, and in periods of coasting, the friction of motors, gears and axle bearings. It is usually expressed in pounds per ton of train. The importance of train resistance may be judged from the simple formula for power consumption necessary to overcome it. Twice the train resistance in pounds per ton divided by the motor efficiency equals watt hours per ton mile. The train resistance of a street car probably varies on account of local conditions between the limits of 10 and 20 pounds per ton, so that, assuming 80% average efficiency for the motor, the energy required to overcome train resistance varies from 25 to 50 watt hours per ton mile. The total power consumption for street cars usually varies from 120 to 180 watt hours per ton mile, so that probably not more than 25% is used in overcoming train resistance. For elevated and subway service, where runs are longer and many curves encountered, the power required for train resistance is a larger proportion, especially where the speed becomes so high as to give a high air resistance. It can be seen, therefore, that train resistance plays a very important part in the power requirements for an electric railway, and anything that can be done to decrease it is worth while.

Journal friction is one element that can be greatly reduced. This amounts to probably not more than six pounds per ton in average service, but can be practically eliminated by the use of ball or roller bearings. A considerable amount of experimenting is being done and many service tests are being made at the present time with these bearings, and it is probable that before long some form of frictionless bearing will be standardized for main car journals. This will save anywhere from 6 to 15 watt hours per ton mile, and possibly more.

In high speed railroading, the question of air resistance becomes one of considerable magnitude. The resistance offered by the air is due not only to the pressure at the front end but to friction on the sides. The shape of the front end of a high speed car or locomotive has a great deal to do with this train resistance. The front end of a high speed car should be designed to make a hole in the atmosphere through which the car or train could pass without other disturbances of the air than that caused by friction along the smooth lines. Of course it is understood that a car designer has to meet other requirements than that of low air resistance, but this is deserving of much more serious attention than it has yet received in this country. The head resistance of an ordinary car at a speed of 60 m.p.h. amounts to 800 to 1,000 pounds and requires from 110 to 150 kw. to overcome it. Every projection on the car that creates an eddy in the atmosphere increases this amount.

Other elements contributing to high train resistance are bad curves, defective tramming of trucks, unequal diameters of wheels, and any other cause tending to make the wheel hug one rail, producing flange friction. Rapid flange wear is a sure indication of excessive friction on the rail head and an investigation should be made immediately to eliminate the causes of it.

GRADES.

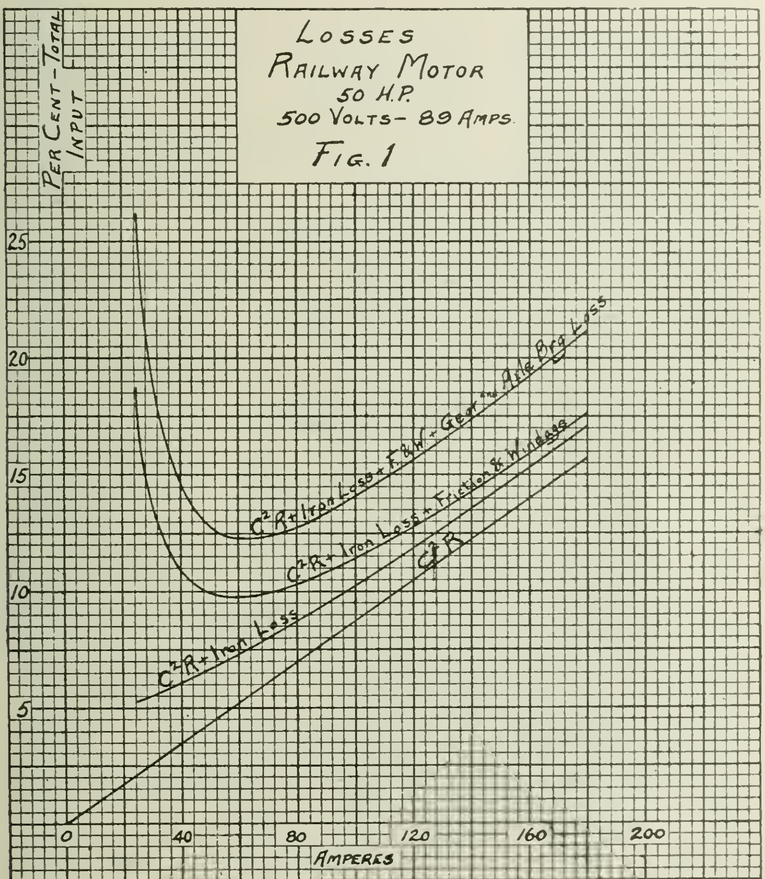
The power required in ascending grades can be decreased only by reducing the weight.. It is sometimes possible, however, to save the power stored in the train in descending one grade to help it up the next one. This is seldom done in street car work, but is quite common with lines where long runs are made. Short grades of 1% or 2% on an interurban or elevated line add very little to the power consumption.

MOTOR LOSSES.

The efficiency of a railway motor varies from 80% to 90%, small motors ordinarly used in city service having a maximum efficiency, including gears and axle bearings, of 85% to 86%, while large motors run 2% to 3% higher. The motor losses consist of the I^2R losses in the armature, field windings and brushes; the core loss or loss in armature iron, and pole faces; eddy current losses in bands and armature windings due to rotation in the magnetic field; and friction losses in bearings, brushes and windage. Figures 1 and 2 show the loss curves for two typical railway motors that are used in large numbers. They are standard commutating pole type motors.

Other things being equal, the capacity of a given size of motor is practically dependent upon its efficiency, since the amount of loss determines both the efficiency and temperature rise and the temperature rise determines the capacity. It is therefore pretty certain that the efficiency of railway motors is as high as the state of the art will permit with the present commercial conditions. In any case an increase in efficiency is sure to be accomplished by a heavier and more expensive motor and the increase would be so small as to effect only a minor reduction in the total power consumption. Therefore a full discussion of the matter will not be entered into in this paper. It is desirable, however, to consider briefly the losses due to friction and windage. To show their relative importance I have translated them from watts to train resistance. A motor of 40 to 50 H. P. with ordinary speed characteristics will have approximatety 400 watts friction loss at a car speed of 10 miles per hour; this power translated into train resistance is equivalent to 20 pounds. A two motor equipment would then add 40 pounds to the total train resistance. With a car weighing 20 tons loaded, the armature friction and windage then amounts to 2 pounds per ton. In the same way the axle bearing losses may be translated into train resistance, but owing to the reduced speed of the axle they would probably not amount to more than one-half as much. There are very few data available from which gear and axle bearing losses can be determined, but it is hoped that in the near future further tests will be made which will enable the Standardization Committee of the A. I. E. E. to give more definite figures for the efficiency of axle bearings and gears.

It is possible to use some form of frictionless bearing for arma-

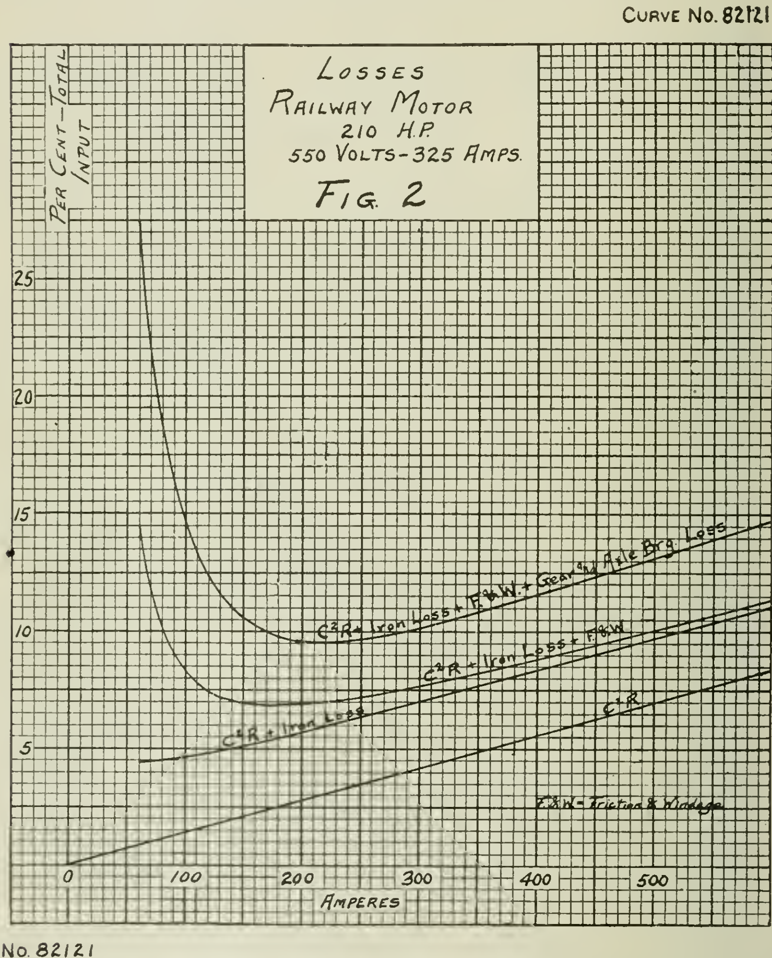


tures, but such bearings, as yet, have not had sufficient test under heavy service conditions to justify their adoption, especially as the cost is considerably higher than that of the ordinary sleeve bearing.

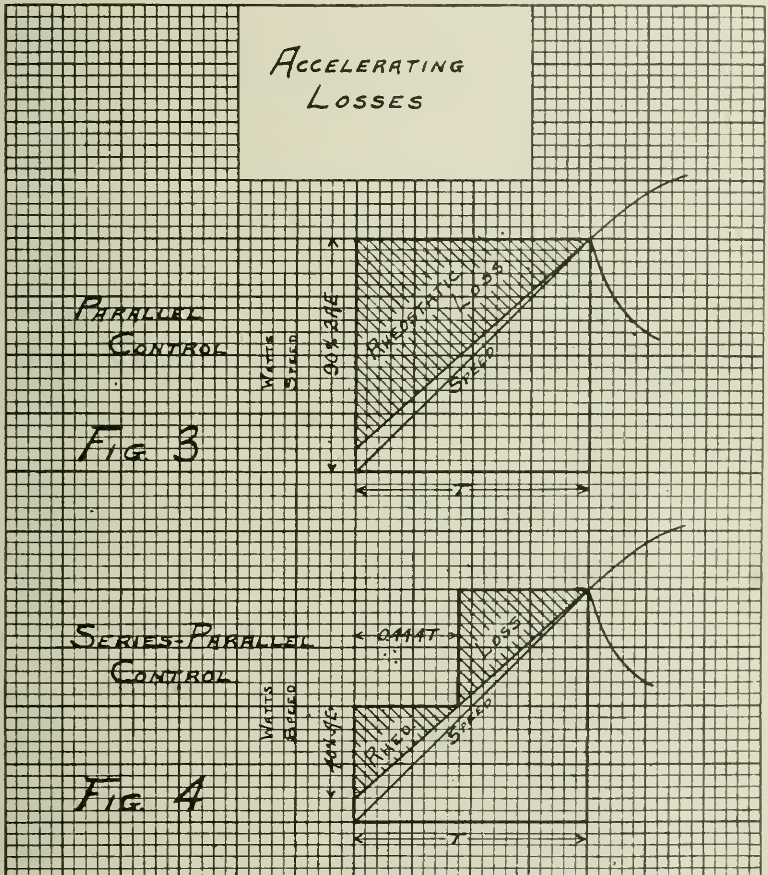
RHEOSTATIC LOSSES.

Everyone deplores the fact that it is necessary to dissipate so much energy in rheostats, but with a constant potential line and commercial motor it is impossible to avoid them altogether. There are various methods, however, by which we can reduce these losses to a much lower amount than has ordinarily been the practice.

Series parallel control was the first great improvement in this respect. Figs. 3 and 4 show the relative value of rheostatic losses for straight parallel control and for series parallel respectively. Assume two motors accelerating with a current that will give 10%



drop in voltage in the internal resistance of each motor, then in Fig. 3, 90% of the voltage will be lost in the rheostat at the instant of starting and an average of 45% during the time the rheostat is in circuit. During the entire time of acceleration double motor current will be taken from the line. With series parallel control as shown in Fig. 4, the rheostatic loss at starting will be 80% of the line voltage with single motor current, or an average of 40% of the line voltage multiplied by single motor current during the time the car is accelerating in series. The total time will be divided between series and parallel in the ratios of the counter e.m.f's. after the resistance is cut out. In this case it will be in the ratio of 40 to 90 or 44.4% of the time will be spent in series and 55.6%



in parallel up to the time the motor curve is reached. When the motors are connected in parallel, the voltage applied to the motor terminals is only 50% of the line voltage, consequently the remainder of the line voltage, or 50%, is lost in the rheostat. The average drop in the rhesostat will be 25% for 55.6% of the time. The rheostatic loss for straight parallel control shown in Fig. 3 may be illustrated in the following formula where *A* is the current for one motor, T the time to reach the motor curve, and E the line voltage; *Rheostatic loss* $= 2A \times .45E \times T = .90\ AET$. The total power taken from the line during this acceleration is $2\ AET$, and 45% is therefore lost in the rheostat.

In series parallel the rheostatic loss $= A \times .40E \times .444T + 2A \times .25E \times .556T = .456\ AET$.

The total power from the line in this case is $AE \times .444T + 2AE \times .556T = 1.556\ AET$.

The rheostatic loss is thus cut almost in half by using series parallel instead of parallel control, and the total power during acceleration on resistance was reduced by this means over 22%.

The use of four motor equipments makes it possible to go still further and use full series, series parallel and parallel control. This is shown in Fig. 5. The rheostatic loss in this case is the same as in Fig. 4, except for the rectangle cut out by full series operation, the area of which is $.083\ AET$. The total rheostatic loss is thus $(.456 - .083\ AET)$, or $.373\ AET$, a decrease of 18.3% below Fig. 4. The power taken from the line during the time on rheostat is $(1.556 - .083)\ AE = 1.473\ AET$, a reduction of 5.3%. Since the rheostatic loss in ordinary city service is only 12% to 20% of the total power used, it will be seen that the saving resulting from starting with four motors in series will scarcely exceed 2.5% of the total power used, unless there is a great deal of operation at extremely low speeds.

One system which has recently been exploited combines operation with four motors starting all in series, series parallel and parallel with intermediate steps using three motors and a limited amount of rheostatic operation. A portion of the rheostatic losses are eliminated through unequal loading of the motors, due to doubling the voltage on one motor at a time, thus heavily overloading it without a serious surge in the acceleration. A saving of 8% to 10% in power is thus effected.

An inspection of Figs. 3 and 4 soon brings out the fact that the rheostatic loss (other things being equal) varies as the square of the speed at which the motor curve is reached in acceleration. This being true, the characteristics of the motors themselves, and also the rate of acceleration must have a great deal to do with the rheostatic loss. For example, a motor with a steep speed characteristic, geared for a certain schedule speed, will reach the motor curve at a lower speed than one with a flat speed curve geared to the same speed and will therefore have less rheostatic loss. A higher rate of acceleration will also reach the motor curve at a lower speed, especially with an unsaturated motor. This reduces the rheostatic loss in the same way.

The shape of the speed curve has been too often left out of consideration because the unsaturated motor (the one with the steep speed curve) is usually slightly heavier than the saturated motor of the same rating and armature speed, and stress has been laid on the reduction in weight of the motor at the expense of efficient operation. It of course saves power to lighten the car equipment, but if it is lightened at the expense of efficiency the net result may be worse than with a heavier equipment.

Another method of decreasing rheostatic losses is one which was introduced in the early statges of the street railway motor and

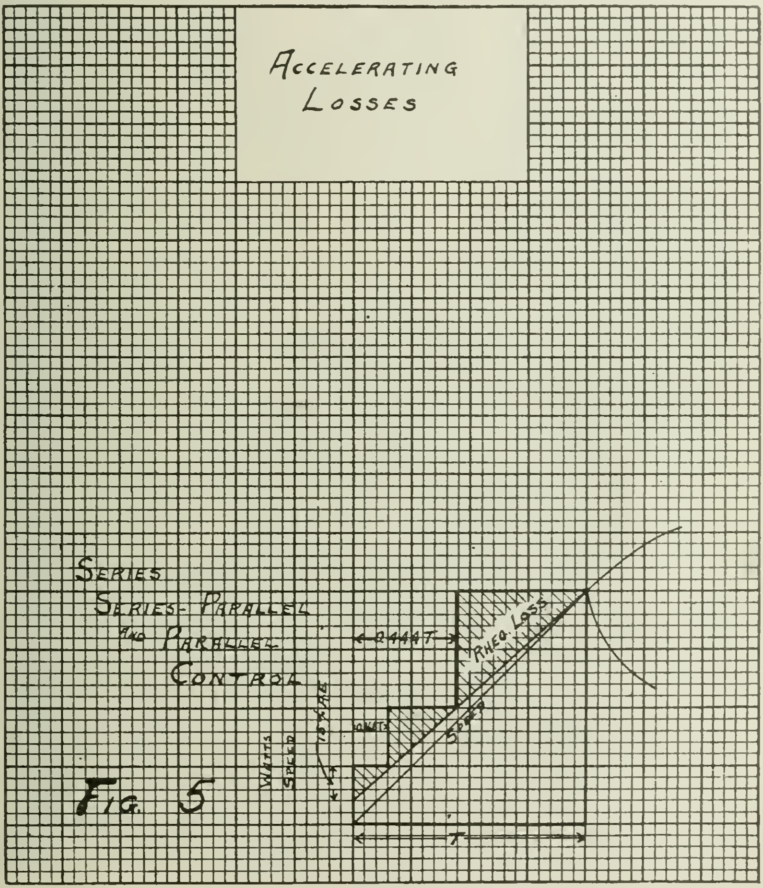
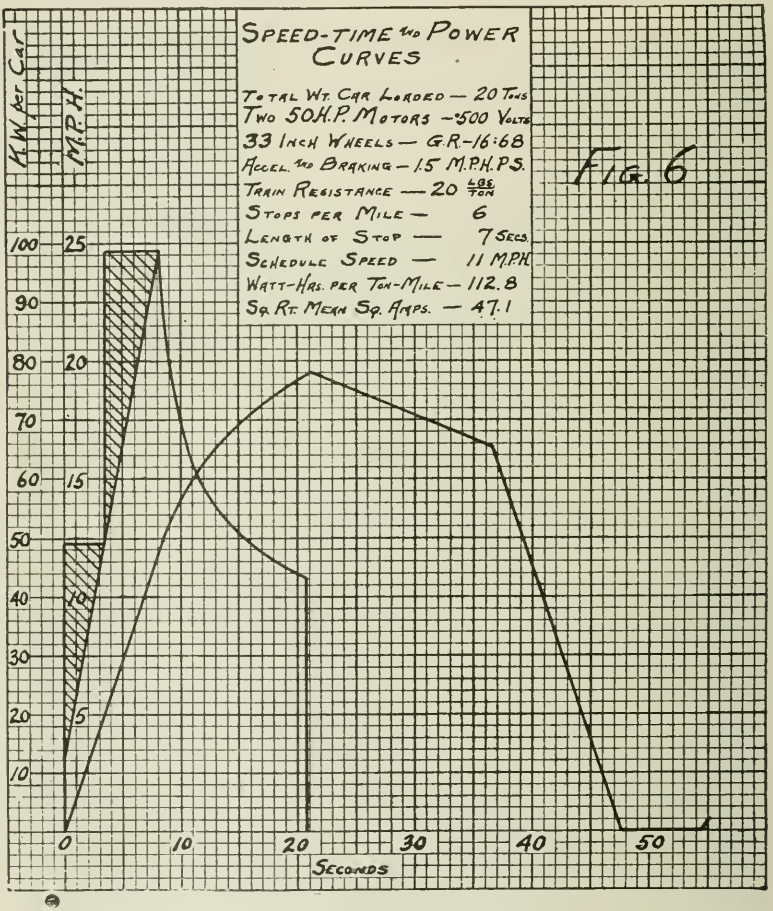


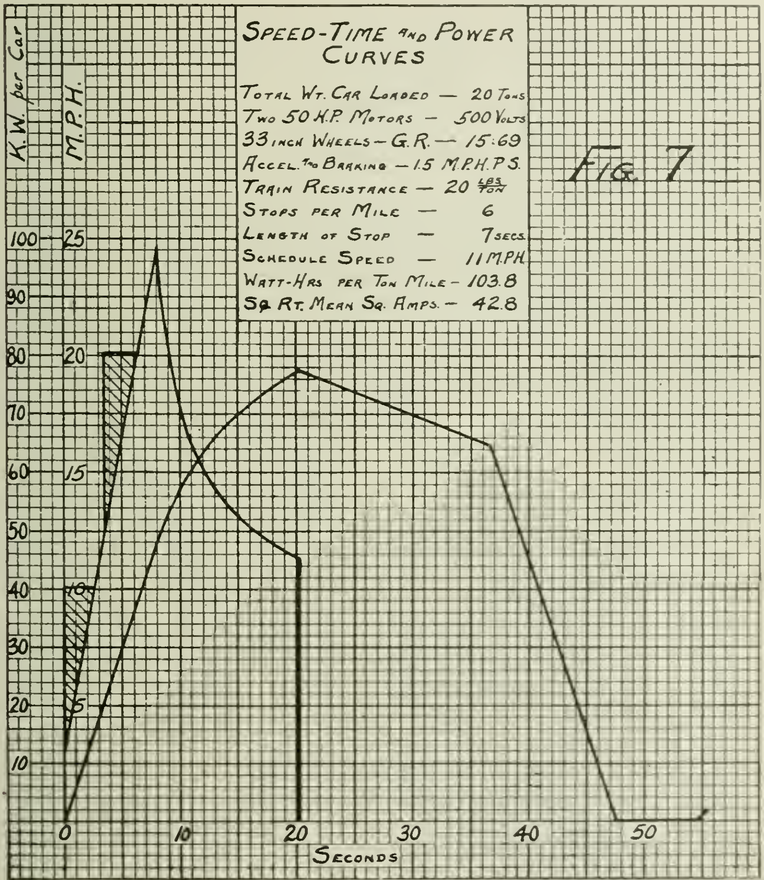
Fig. 5

used extensively with double reduction motors to secure additional running notches on the controllers, which were all of the straight parallel type.

After the series parallel controller and the single reduction motor were introduced, this control of the field as a means of effecting economical speed variation and reduction of rheostatic losses was dropped because of the trouble from poor commutation and from overloading motors. The commutating pole motor and a better understanding of the application of railway motors to a given service have led to a revival of field control, and it is now used in all classes of service. The use of field control will usually effect a saving of not less than 10% and sometimes as much as 20% in the power consumption. To get the best results the motor

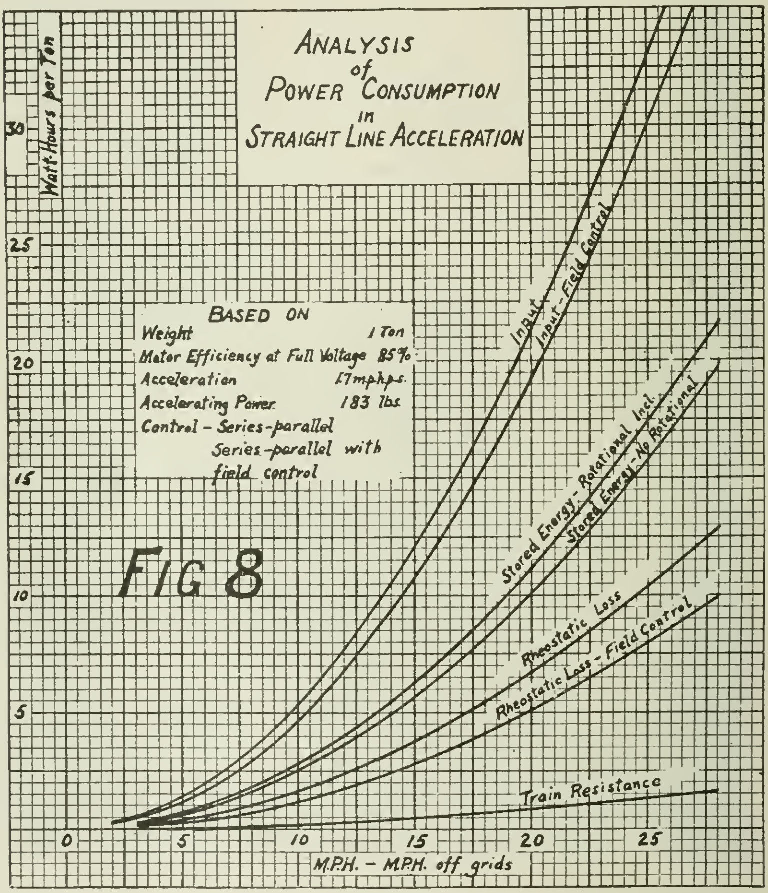


should be geared to give the highest speed desired with the short or permanent field. The full field speed curve should be 20% to 25%, or more if possible, lower than the short field speed curve at the accelerating tractive effort. Referring to Fig. 4 and assuming that the full speed of the motor at the accelerating tractive effort is 20% below that of the short field, and that the same rate of acceleration is maintained, a field control equipment would perform the service indicated in Fig. 4, with approximately one-half the rheostatic loss. Where the balancing speed on short field is higher than that of the non-field control equipment, a still further saving in power consumption will result on account of the more rapid acceleration on the motor curve permitting a longer coasting period and consequently a lower speed at the time the brakes are applied and less loss in them. Where stops are frequent the use of field



control thus effects a very substantial saving in power consumption. Figs. 6 and 7 show speed time curves of typical conditions of service on street railways. Fig. 6 shows the typical run with standard motor without field control, and Fig. 7 shows the same run under identical conditions of load and speed, but with field control. The difference in rheostatic losses is clearly shown.

Fig. 8 shows a set of general curves that may be applied to almost any condition of acceleration on electric railways with reasonable accuracy. The curves are intended primarily to show the rheostatic losses entailed in accelerating one ton under certain conditions of motor efficiency, train resistance and rate of acceleration with and without field control. With these curves are included others showing watt hours input and output or energy used in overcoming train resistance, all plotted in terms of speed at which the motor curve is reached.



For instance, take the speed time curve in Fig. 6. The energy stored in train at the time brakes are applied is all lost, either in brakes or in overcoming train resistance during braking. The brakes were applied at 16.3 miles per hour. Reference to stored energy curve in Fig. 8 shows that at this speed 7.5 watt-hours per ton are stored. Part of this (4 watt-hours) was stored while accelerating on resistance at an efficiency of 56% (approx.); the remainder (3.5 watt-hours) with motors accelerating on motor curve at an efficiency of about 83%. The first portion, 4 watt-hours at 56% efficiency takes 7.15 from line. The second portion, 3.5 at 83% efficiency takes 4.22 from line, or a total of 11.37 for each stop, or 68.22 watt-hours per ton-mile. The train resistance of 20 pounds per ton would normally require with average efficiency of 80%, 50 watt-hours per ton-mile, but since we have already included the braking period, that distance, or 13.5%, must be deducted, leaving 43.25. The total per ton-mile then is 68.22 + 43.25 = 111.47 as compared to 112.8 given on Fig. 5.

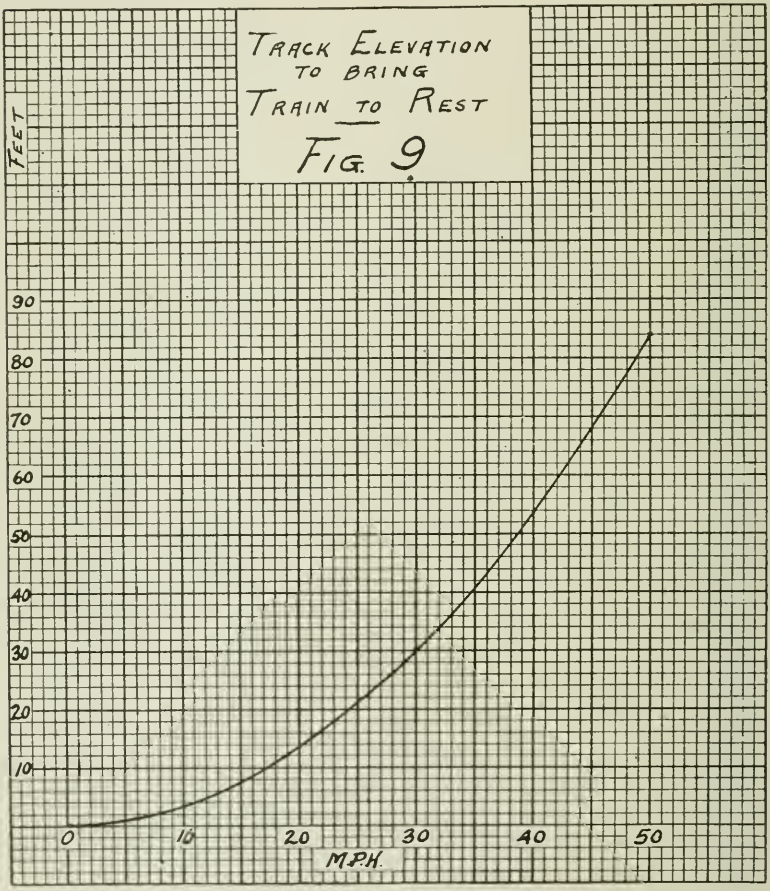
The ratio between the sum of the curves of stored energy and friction to the curve of input is the efficiency of the equipment during acceleration to the motor curve. With the conditions of motor efficiency, train resistance, etc., assumed here, this efficiency is found to be approximately 56%. It will hold approximately constant regardless of the time of acceleration, or whether on level or grade. The rheostatic loss with a given tractive effort is inversely proportional to the rate of acceleration; in other words, if the car were starting on a grade that would cut out the rate of acceleration in half, the time on the rheostat would be doubled and the rheostatic loss double that shown on the curve. This is a very convenient curve to have, since everything is plotted in terms of watt-hours per ton. It is a good check on speed time curves.

There are various other means for saving rheostatic losses, notably one system by which the voltage on the motors is varied by means of a motor generator set, the motor of which takes power from or gives power to the line. Such a system is in operation in Paris and is reported to be giving very economical results. We understand that it is also operated so as to vary the voltage applied to the motor during the braking period and consequently regenerate the stored energy of the train and return it to the line, thus performing a double function. Such a system, however, must require a relatively large capacity of motor generator set on the car, and as it would require a shunt or compound field winding, not only on the M. G. set, but on the main motors in order to return energy to the line, we would expect a very sensitive machine when operating at the usual variable voltages that are found on the third-rail system. Further, the cost of the M. G. set and the extra cost of motors and control would be considerable, and the additional weight to be carried around and the losses in the M. G. set will go a long way toward absorbing any savings that might be made.

LOSSES IN BRAKES AND REGENERATIVE CONTROL.

Regenerative control and regenerative braking are popular names for any system of control that permits the energy that is usually lost in brakes in descending grades or in stopping trains, to be regenerated or converted into electrical energy that may be used by other cars or trains. This portion of the energy used by electric railways is usually a large part of the total and is in most cases entirely wasted. How to prevent this waste of energy, which not infrequently amounts to 40% or 50% of the total used by the car, has been a regular will-o'-the-wisp to a great many engineers. The amount of energy is so large that it is of far greater moment than any other single portion of the total energy used and is worthy of the most serious attention.

One of the schemes for saving this energy is that of elevating



TRACK ELEVATION TO BRING TRAIN TO REST

FIG. 9

the station tracks above those between stations, thus changing the kinetic energy of the moving train to the potential energy of the train on an elevation. This is theoretically the most efficient method that can be devised, but a little consideration of it will show why it has not been more often used. In order to convey to the mind quickly an idea of the requirements for such a system, I have shown in Fig. 9 a curve showing the heights to which station tracks would have to be elevated in order to change all of the kinetic to potential energy for various speeds. The speed time curve in Fig. 6 shows the brakes applied at a speed of 16.3 miles per hour. Assuming that the rotational energy of the train is sufficient to balance the train resistance, it would be necessary to elevate the track at every stopping place 8.9 feet in order to save the energy that is dissipated in brakes on this typical run. This is, of course, out of the question for a street railway. A train stopping from a speed of 25 miles per hour, which corresponds to elevated railway service, would require station tracks elevated 21 feet in order to store the energy lost in stopping. A train running at a speed of 40 miles per hour would climb to an elevation of over 50 feet before coming to a stop. These figures are sufficient to show the impracticability of this method of saving the kinetic energy in a train for any class of service except subway and elevated railways, where the number and location of stops are quite definite. Even in such service the scheme is open to the following objections which make it impracticable.

1. It would greatly increase the cost of any construction.
2. Elevated railway stations would be so high as to require elevators to take passengers to and from the streets.
3. It is possible only for very short trains. At a rate of braking of 2 miles per hour per sec., which is a fair average for heavy electric trains, a train stopping from a speed of 25 miles per hour moves a distance of approximately 228 feet. A single car, if short, could save most of the stored energy by climbing a grade of 9% for a distance of 200 feet, tapering off to a level of both bottom and top of the grade and giving a total rise of about 20 feet. With two or more cars in a train the average rate of braking would be decreased, due to the fact that only a part of the train is on the grade at one time. To keep up the rate of 2 miles per hour for braking, it would be necessary to dissipate more and more energy in brakes as the length of train increases, and the elevation must be proportionately decreased. Even then it is very difficult to save any considerable portion of the energy, for the entire train should mount the grade during the stopping period, which is manifestly impossible with long trains. About all that can be done with such trains is to mount a long, low grade before braking actually begins and ending so that the entire train can be on level track at the station. This grade would have to be mounted during the coasting period, which would slow down the schedule unless the motors were geared for higher speed.

Without pursuing the matter further it is apparent that practical operating conditions would be very seriously interfered with by such a scheme and that it is adaptable only under certain special conditions of operation.

The use of the electric driving motors as generators returning energy to the line during braking periods was one of the earliest arguments in favor of electric traction. It has been realized only to a very limited extent in actual service. The three-phase railways in Italy and Switzerland were the first to use this plan in extensive commercial service. It is well known that an induction motor driven above synchronous speed will act as a generator and will supply power to the system from which it derives its magnetizing current. A locomotive driven by induction motors will, when connected to the line, therefore maintain a practically constant speed regardless of whether it is going up hill or down. In the former case it takes power from the line; in the latter, feeds power into the line. This system is now used with marked success on the Italian State Railways and is also used on the split-phase locomotives that will shortly be put in service on the Norfolk & Western Railway. The operation of the latter locomotives is exactly the same as that of three-phase locomotives, both in running and in regenerating. The advantage of being able to hold a heavy train without the use of brakes when descending a mountain grade is of far greater importance than the mere saving of power would indicate. The wear and tear on brakes on these heavy grades is enormous and there is a continual danger from accidents, all of which are overcome by the use of regenerative control. The locomotives have been a perfect revelation to the operating men on the Norfolk & Western in this respect.

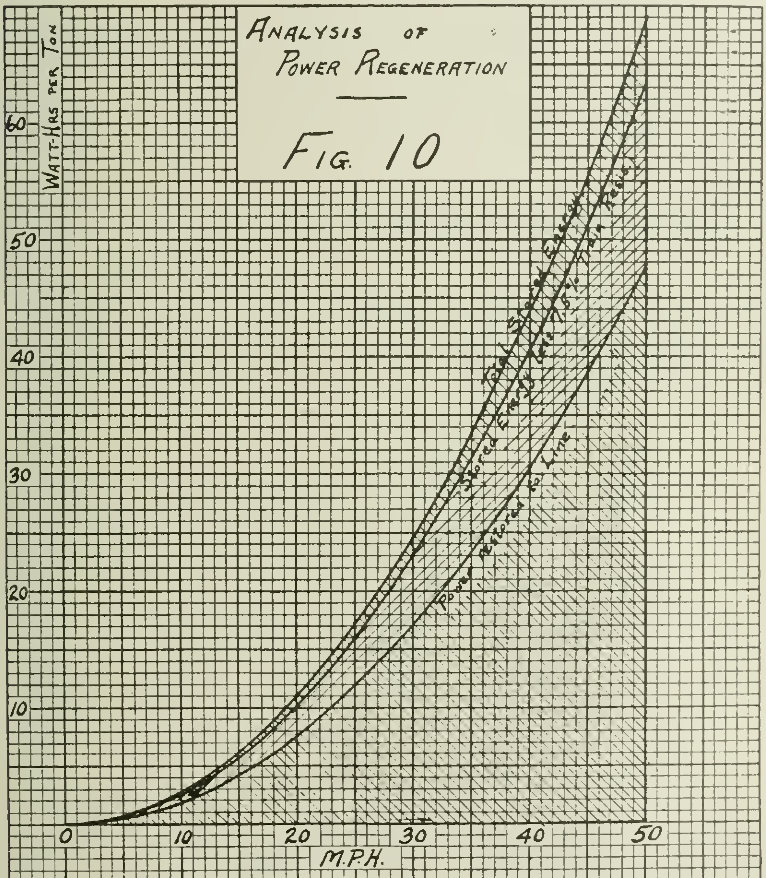
Induction motors can be used to some extent for stopping trains that are running above the minimum synchronous speed, by changing the motors from the high speed to the lower speed combination and gradually reducing the speed by means of the resistance in the secondaries of the motor. They are, however, not particularly efficient for such work on account of the rheostatic loss and the fact that the minimum speed that can be reached in braking is the lowest synchronous speed.

With direct current on the line, regeneration has been accomplished by the use of shunt motors, but these have been used only to a very limited extent and chiefly in Europe. Shunt motors are similar to induction motors in being inherently constant speed machines. The shunt motor, however, has the advantage of a wide range of speeds which are secured by changes in the field strength. For this reason, it is much more efficient for stopping trains than the induction motor. It has the disadvantage of not being suitable for railway operation on account of its liability to flash under sudden changes of voltage which are bound to occur on any railway line. The shunt motor is also necessarily larger and more expensive than the ordinary series motor, is less foolproof and requires a more complicated control system. These reasons appear to have been ample thus far to prevent its extensive use.

Another scheme for regenerative control is the one which has already been mentioned under rheostatic losses, consisting of the motor generator scheme which is in use in Paris. The lack of more published data on this scheme would seem to indicate that it has not been so successful as to be of a revolutionary character.

A great many other schemes have been proposed, most of which have never gone farther than the Patent Office, but it is hoped that some plan will be developed that will prevent this enormous

CURVE No. 82131.



No. 82131

destruction of energy that at present costs a great deal simply to destroy.

In order to show the possibility of regenerative braking for stopping trains, Fig. 10 is given. This shows the stored energy in terms of watt-hours per ton and speed in miles per hour, the portion of this that would be required for overcoming train resistance assumed to be 15 pounds per ton with a braking rate of 2 miles per hour per sec., and the portion that could be regenerated, assuming that the train could be brought to rest by regeneration with an average efficiency of 75%. This is as much as can reasonably be hoped for in the present stage of the art, but shows plainly the great stake for which to work. The speed-time curve shown in Fig. 6 shows the brakes applied at a speed of 16.3 miles per hour. Even with the high train resistance of 20 pounds per ton and the low braking rate of 1.5 miles per hour per sec. assumed for this typical run, 27.5 watt-hours per ton-mile, or approximately 25% of the total power used by the car could be returned to the line if it were possible to regenerate at 75% efficiency until the car could be brought to a standstill. Even with an efficiency of only 50%, 18 watt-hours per ton-mile, or over 16% of the energy would be saved.

In the opinion of the writer, the essentials of an equipment for regenerative braking with direct current motors are the use of the standard series wound motors and a control equipment that would add but little weight and complication to that used without regeneration, since every bit of additional weight and complication would mean additional first cost, additional cost of maintenance and additional power to carry it around. The point would soon be reached where the extra cost would balance the saving.

CONCLUSION.

The foregoing by no means covers the ground for possible saving in power consumption. Nothing has been said directly concerning the importance of correct gear ratio or the correct operation of equipments so as to take advantage of the benefits of rapid acceleration, long coasting, quick braking and short stops; of the saving in power required for lighting by the use of highly efficient lamps now on the market, and the best distribution of the light, or of the latest methods of heating cars by circulating heated air by means of fans. Neither has anything been said in regard to line loss and its relation to the reduction in peak loads by means of field control and proper gear ratio.

These point have all been discussed as, indeed, have most of the points in the paper many times before. It is confidently believed that without considering the possible saving in power consumed by auxiliaries or in line loss enough has been said to fully substantiate the claim made at the beginning of this paper. The reduction of dead weight per passenger, the adoption of frictionless bearings and the widest use of field control with motors of steep speed characteristics and efficient handling of cars will alone be sufficient to save more than 40% of the power now used on a great many roads. Any saving that can be accomplished by the development of a successful scheme for regenerating the power now lost in brakes would be so much clear gain.

DISCUSSION.

Harry H. Adams, ASSOC.A.I.E.E.: The author of the paper has certainly touched on a question of deepest interest to everyone in railway work—the matter of economy in our equipment. I have been particularly interested in it and have seen a great many steps taken to bring about the results that we are getting today. I remember that in one of the experiments we carried on we had under consideration the question of going into the higher gear ratio by the use of 3½-pitch gearing. We thought we were going to get the real answer there, but found that that gearing was rather noisy and we experienced difficulties which we did not have with 3-pitch gearing. The last equipments that we have been getting, which combine the interpole with the field control, seem to give the economies we have been looking for, and although I do not say that we want to stop there, we have made great advancement in the direction of effecting economy. The equipment itself is very interesting from the standpoint which Mr. Storer has outlined in the economies in the rheostatic losses.

There is another feature about the use of the slow-speed armature and the short field, it gives a very smooth acceleration. We can get a high acceleration and at the same time a smooth one. I like the expression used by the manufacturer's representatives in describing the accelerating, that is, the equipment has lots of "rubber" in it. We experimented by taking the controller handle and slamming it the way round, this resulting in no apparent jerks in the acceleration. It makes an exceedingly practical equipment for service such as we have in Chicago, and the equipment seems to stand most any test to which we put it. We have a few tunnels in this city, and the question that was frequently asked was, "Well, will it go through the tunnels?" We answered, "Yes." We tried it and it went through and operated on the grades just as well as any of the other equipment running there today. We stopped and started on the grades without difficulty.

The economies represented in the development of the electrical equipment for surface work Mr. Storer has pointed out. We get the 33% he mentions. There is no question about that, because many of us have seen the four motor equipment where we average about 4 kw. per car-mile, and with the new two motor equipment this has been reduced to 2½ kw.-hr. per car-mile. Some tests were made with this equipment. We found the watt-hours per ton-mile down as low as 119, showing that we are getting good economy out of the field control. In these tests we carried out some rather interesting work. We had a set of instruments that told us almost everything that we wanted to know. In the first place, we had an instrument that gave us the time we had the current on. Then we had a coasting clock; we rigged up an ingenious scheme to give us the time of braking, and the only time we had to take was the time to stop. The scheme for determining the time for braking was simply a combination of tapping into the brake cylinder and leading an air pipe up to the board holding the instruments, and at this point an electrical switch was actuated by the air pressure, this switch operated an electrical circuit in connection with a current clock which recorded the time of the brake application. We were compelled to allow for the lost motion in the brake application, but this was taken care of by a definite amount of lag in the application of the switch. The motorman was instructed to release his brake just as soon as he had actually made his stop, so as not to get any longer interval on the recording clock than the time for application of the brake. The accelerating speed we obtained with this equipment in our test ran as high as two miles per hour per second.

In connection with the apparatus used for the test, there was one particular piece of apparatus that we used which was exceedingly interesting, although I am not going to describe it. I will ask Mr. Storer to describe this, if he feels like doing it.

H. A. Johnson: After the able paper by Mr. Storer and Mr. Adams' discussion, I feel a little backward about taking up much of your time. Possibly one or two of the problems which have come to our attention may be of interest.

In the first part of his paper Mr. Storer makes a statement which appeared to me at first as a little bit rash, but he made a very good effort at substantiating the statement. The statement to which I refer is that "not less than 40% and possibly 50% of that 1,000,000 tons of coal used for furnishing power could be saved every year." As I listened to the paper I understood that the 40% or 50% comprises all of the various items which Mr. Storer took up, and some which have not been worked out and made a commercial proposition, so that at the present time if we were to scrap or throw away all of our present equipment and put into service equipment which has been sufficiently tested out, any operating company would take chances on operating it, and there would be nothing like a 40% or 50% saving in power.

Reduction of weight is a very interesting subject and a very important one from the standpoint of the equipment and power engineers. Mr. Adams has had a great deal to do with the reduction of weight in surface cars. The statement that it costs 5 cents per pound per year to carry excess weight was made at the convention of the American Electric Railway Association in Denver, 1909. That statement was accepted immediately, without condition, and many of the people who accepted it did not fully realize the circumstances and conditions surrounding it. However, it has spurred all of us to the point of looking to the reduction of weight. As an example of what this has done, I might tell you that in 1904 the Metropolitan Elevated Railway designed and built a steel car which was the first steel car built for subway or elevated traffic. That car is still being run on the West Side line, but only during the rush hours as an emergency equipment. The reason is that the car weighs so much we cannot afford to run it except when absolutely necessary. That car is not insulated in any way, We have now put in service a large number of steel cars, and by careful consideration of the weights and experience gained since the first steel car was built, we have been able to put into service steel cars thoroughly insulated which weigh no more than our wooden equipment. The weight of cars may determine whether a railroad is operating on a paying basis or should be in the hands of a receiver. My attention was called to a railroad on which the operating conditions were such that it was necessary to put on the lightest possible car which would carry people. They had put up to the car builders the proposition of building a car which would not weigh over 12,000 pounds total weight. They figured that by operating such a car they could operate satisfactorily under the conditions. If they had to put in operation a heavy car, there was not traffic enough to pay to run the car. It might be well for some of the interurban roads to look into this phase of the problem. Many roads are running large cars where a smaller car would answer the purpose nine-tenths of the time. The other tenth could be handled by an additional car operating with multiple unit control.

We can also add to the experience of the surface lines relative to interpole field control motors. We first put interpole motors in service in 1908. Our experience was so satisfactory that when the field control feature was brought out we were the first to adopt it for elevated or subway work. We put the first field control motors into service somewhat over a year ago. These equipments have operated entirely satisfactorily up to the present time. Our experience previous to putting the field control motors into the service was that the heavy currents which are handled during acceleration were very exacting on our control equipment. We had some cases where control equipment, carrying heavy current, was giving us considerable trouble, while the same control equipment installed with smaller motors carrying less current gave no trouble whatever. The fact that we could put on a field control motor and reduce the maximum current was a very important feature to us. You will readily realize that with the heavy equipment of the large motors, the current handled is a much more serious problem than on the surface lines. The equipments on the elevated roads, where we have multiple unit operation with automatic acceleration, have become very complicated. In fact, they are getting so complicated we have some difficulty in teaching men to properly inspect and repair the equipment. In the past year, we are glad to say, there has been a tendency to simplify the equipment, and I am also glad to see that the field control feature has been added with practically no complication.

I am much interested in that part of the paper referring to regenerative control, or returning part of the power to the line.

No doubt many of you have noticed the rise in the track at many of the South Side stations. This varies from 3 to 5 feet at all stations between Twelfth street and Indiana avenue. I have often been asked the question if the structure was so built with the idea of saving power when stopping at the stations. We are frank to admit that it was not. That feature came when the third track was put in. There was a condition of clearances which made it necessary to raise the structure at the different stations. However, we are obtaining the benefit of that rise, which is clearly shown on equipment operating on the South Side road in comparison with equipment operating on the other roads. It is my opinion that in working up any system of regenerative control it must be worked up without adding undue complication to the present equipment. If that can be done I am very sure that the railroads will be ready to take it up after it has been thoroughly tested out.

W. Thorn (Asst. Engr. Board of Supervising Engineers): I would like to ask a question in connection with the loss curves. In regard to the motor losses, the curve shows that the minimum point was reached at about 70% of full load. Why is that?

In regard to the saving in energy in watt-hours per ton-mile, brought about by the field-control equipment, some tests have been made from time to time which indicate that the saving runs about as shown in Mr. Storer's curve, namely, about 9%. It may be interesting to compare that with the total cost of operation. Taking this at 26 cents per car-mile, including interest on the investment, and with 3½ cents per car-mile for power, which is roughly correct, for the old equipment, we have about 13% of the total cost of operation for power under old conditions. Under new conditions, assuming the power saving above indicated, the total cost of operation would be reduced about 4%. In other words, it would be equivalent to an increase in net earnings per car-mile of about 25% (under the assumption of gross earnings of 30 cents per car-mile)—a very gratifying result.

E. J. Blair: In looking at the savings from a power point of view, ten per cent, for instance, as applied to the power requirements for the elevated railroads or surface lines, is an enormous saving and we try very hard to get even 2% or 3%. I might say that on both the surface and elevated lines an effort has been made —a very determined effort—to school the motormen themselves in saving power, and recent strenuous attempts on the elevated lines have resulted quite satisfactorily. That is to say, a 4% or 5% saving can be accomplished with an ordinary amount of schooling of the average man with the equipment in hand. Since power is such a large item in railroad work I feel that the power engineer and the equipment engineers will have to dig in very hard and cut these power losses down. Mr. Storer's paper is somewhat of a revelation to me in that line. I would ask him if satisfactory results have been attained with the Johnson-Lundell regenerative control system. I presume that is the system to which he refers as in use in Europe.

President Jackson: I feel that we should be very grateful to Mr. Storer for giving us this paper, because we hear from a man who speaks with knowledge and authority, and we can rest assured that his statements can be relied upon.

In 1909 when the "five-cents per pound saving" might be considered to have become a slogan it was quite proper that it should have become such. At that time our traction people thought that the light car was almost useless for heavy traction service and they were going to atrocious excesses in the matter of heavy cars.

In connection with the regenerative systems used in Europe, my observations lead me to the conclusion that the European operating and maintenance men will operate and take care of equipment which it would be impracticable to introduce in America.

Another point touched upon by Mr. Storer, is the beautiful effect of the braking obtained by the regenerative control. For instance, the cascade motor control on some of the Italian railroads, if such braking is well worked out, is something we hardly know of in America. In those trains, instead of having the slap-bang effect that we have on many of our trains, they have such a perfect braking effect that it is practically impossible for one to tell when the braking actually begins except for a slight throwing back if one happens to be standing in the middle of the car.

J. W. Mabbs, M. W. S. E. I am particularly interested in this paper tonight, not because I am interested in any ordinary traction line, but because I am interested in a traction proposition where the requirements are much more severe than anything which has been presented tonight. The grade percentage is infinity and the stops, instead of being four or five to the mile, run from 100 to 400 per mile. We experimented on field control, and also on returning current to the line. These features have been worked out in this traction line for ten or twelve years, and I might say that we have a kilowatt consumption of 3½ kw. per car-mile. When you take into consideration the *number of stops* and the *grade,* the figures mentioned in the paper are cast somewhat into the shade. I refer to an electric elevator.

Mr. Adams: Mr. Blair's remarks about the saving reached in connection with their motors reminded me of a similar experience in New York City. It was during the wave of "coasting" that went over the country; we decided we would test out the 34th Street line, which is a heavy cross-town line. We had the line metered, and observed it for a week, taking the equipment and passenger load and reducing everything down to watt hours per ton mile. No instructions were given to any of the men during this week, and in fact the men did not know that any observations were being made on the line. Then the next week we instructed those men particularly in the art of coasting. The third week we observed the line again, with the result that we had a clear 10% saving as the result of the instruction. So we can accomplish a great deal along the line of instruction, even without the use of instruments.

T. Milton, M. W. S. E. I would ask if, among the regenerative control schemes, the shunt motor scheme has been tried with any great success in railway work, and whether the author thinks there are any great possibilities with that scheme.

W. E. Symons, M. W. S. E. Although I am not an electrical engineer, there are one or two questions along the line of electric transportation, or the cost to produce transportation, particularly in local service, on which I would be glad to hear the author's views.

The first question is with respect to the length of time, expressed in minutes and seconds, required to stop trains of different weights and at various speeds, the elements entering this calculation to include the following:

(a) Period of time in decelerating the train from running speed to complete stop at station.

(b) Period of time standing at station.

(c) Period of time accelerating train from zero to running speed again.

Total of a, b and c to constitute actual time to make stop.

The second question is with respect to the cost to stop trains of different weights and at different rates of speed. The elements entering into this item would embrace the following:

(d) Wear of brake shoes and car wheels.

(e) Wear and tear of couplers and draft gear.

(f) Electric current expended in making stop.

(g) Electric current expended in accelerating train to normal speed again.

(h) Any expense to electric equipment or cars incident to the stop that would not have been necessary if stop had not been made.

Total of d, e, f, g and h to be considered actual cost to stop trains.

In considering questions similar in character to the foregoing in connection with steam railway operation, these points are being followed very closely by the State Railway Commissions, the courts and all others who have to do with the question of the cost to produce transportation of various kinds, and while the electric railways are not, as a rule, handling a very large volume of through passenger or freight business, they do handle a very large volume of local or suburban passenger business, which is of a character generally similar to the suburban business of the steam railways. Therefore, in my opinion, the foregoing information with respect to the length of time required to stop electric trains and the cost of making these stops would not only be interesting information, but would be quite valuable in considering similar statistics with respect to steam surface railways, and I feel quite confident that the author of the paper of the evening is well able to give us detailed and reliable information on the points mentioned.

Closure

The Author:—In Mr. Adams' remarks, he called attention to a certain instrument that was used in making tests on some of his equipments. This is an instrument which was manufactured by the Westinghouse Company and is designed to measure the root-mean-square currents. As is well known, the copper loss in a series motor varies as the square of the current, so that, in testing an equipment by the old method of taking 5 or 10-second readings, it was necessary to square the readings, take the sum of the squares, and obtain from that the square root of the mean square current, or the R. M. S. current, as it is usually spoken of. This current is the one which determines the average $C^2 R$ loss in the motor. The instrument which Mr. Adams spoke of is a very simple affair, consisting primarily of a thermos bottle containing a small resistance and a certain amount of water. The resistance is put in parallel with a shunt in the motor circuit, and therefore, receives a current that is always proportional to the current passing through the motor. The loss in the resistance will be proportional to the square of the current and is measured by the rise in the temperature of the water in the bottle. Having such an instrument properly calibrated, it can be connected into the motor circuit, and the rise in temperature at the end of any period will enable one to read directly from calibration curve, the root-mean-square current in the motors directing that period. It is an extremely simple instrument, and will probably be on the market before long. It is something which should be in the possession of every electric railway, as it is a very definite and opposite measure of the work that the motors are called upon to perform, and will save an enormous amount of labor.

I knew that the electric railways, both surface and elevated, in Chicago had engineers who were thoroughly up to date, but I did not know that to the Chicago engineers belong the credit for the first steel car. I have known, however, that they are always the first to adopt the up-to-date electrical equipments, as is shown by their adoption of the commutating pole motors and the field control.

Mr. Thorn asked why the minimum point in the percentage of motor losses is located at about 70% of full load. That is largely because 70% of the full load is more nearly the average load applied to the motor and is therefore the proper place for the maximum efficiency.

In the paper which I have presented this evening, I did not discuss the saving in power which can be made by proper training of motormen. I am fully aware of the enormous savings that can be brought about in this manner, but it is a question of operation, and the paper tonight is confined more to equipments. It is an old story that rapid acceleration, long coast and a quick stop gives the most efficient cycle of operation as far as energy is concerned. If the maximum speed could be attained in an instance with the efficiency of acceleration, as is now obtained, the minimum energy consumption would be realized. The nearest that we can come to that ideal cycle is to make the quickest possible acceleration, cut off power at the earliest moment, coast as long as possible, and then make a very quick stop. Accelerations up to a maximum of 2½ miles per hour per second, and braking at like rates, can be secured with perfect comfort to the passengers if the rates of acceleration and braking are approached gradually so that there is no sudden change.

In this connection must be mentioned the coasting time clocks and other instruments which have been introduced as a check on the motormen, to obtain efficient operation. If properly handled, such instruments will undoubtedly save any company a great deal of money, as a saving in power saves also in the wear and tear on the motor equipment.

Considerable savings can be accomplished by simply training the motormen to know that coasting is one of the things that can save a great deal of power, and if I had included all of such items, I would have had to put the total saving up to 70% instead of 50%. In my paper, I have assumed that the cars are now operated with the maximum efficiency.

A question was asked about the results from regeneration in Europe. I am not sure just what system is in use there, but believe the Raworth system is in use to a limited extent on small street car equipments in England. I have very little information as to the results. The scheme in Paris seems to resemble more the Ward-Leonard system than it does Johnson-Lundell.

Before discussing the infinite per cent grade proposition which Mr. Mabbs mentioned, I want to say that the mere fact that he has operated with 2½ kw hours per car mile, is very indefinite information. It is absolutely necessary to have the weight of the car and the number of stops in order to make any sort of comparison with the equipments which we have been discussing.

Mr. Mabbs: It was two tons.

The Author: A 2-ton car operating with 3½ kw hours per car mile is 1.75 kw hours per ton mile, which is about 14 times the amount originally used by the street car, and it would seem that this could be reduced still more, especially as the elevator, which this car is, has counter weights.

I have not much hope for the possibilities of shunt motors for regenerative control in railway service. Shunt motors are not at all satisfactory for operation on any line that is subject to rapid fluctuations in voltage. Fluctuations in voltage produce enormous rushes of current and are very apt to make them flash. There is very little possibility of such motors coming into general use.

Mr. Symons has asked a question which involves a great many variables, and to which, therefore, no complete answer can be given. The time to stop a train varies both inversely as the rate of braking, and directly as the speed from which it is stopped. I am not prepared to give any figures as to the wear on brake shoes, car wheels, couplers and draft gear, in stopping a train, but the amount of energy consumed on account of making an extra stop on a train is comparatively easy to calculate. A simple example will show how the problem may be approached. A train running at 40 miles per hr. has approx. 40 watt hours per ton stored in it. Assuming that this is stored with an efficiency of 75%, which is probably as high as the average, about 53 watt hr. per train would be required to once more bring the speed of the train to 40 miles per hr. A train weighing 500 tons total would therefore require about 26.5 kw-hr. additional energy on account of the stop. At 1.5c per kw-hr. at the car, this would cost about 40c. The additional loss due to wear and tear on the brakes, tires, etc., would have to be added to this figure. A further increase should be made in case the train is required to make up the time lost in stopping, this amount depending, of course, upon the distance in which it is to be made up. The amount of time lost will depend entirely upon the speed and the rates of braking and acceleration. For steam trains, it is probable that a rate of braking of 1.25 miles per hr. per sec. is about the maximum to be assumed for braking and 0.4 is all that could be expected from fairly rapid acceleration. Electric trains will brake at a higher rate and the initial acceleration, at least, is very much higher. It is very difficult to give any general figures which will be even approximately correct.

RETAINING WALLS ON SOFT FOUNDATIONS

Walter S. Lacher, Assoc. W. S. E.

Presented February 8, 1915, before the Bridge and Structural Section.

In view of the vast amount of material which has been written on the subject of retaining walls, the writer rather hesitates to burden the profession with anything further. His excuse for presenting this paper is that it deals with walls built under unfavorable conditions, where rules of thumb were of no use whatever, and well-known theoretical treatments presented definite limitations. The solutions of the problems also lead to some rather novel designs.

The Chicago, Milwaukee & St. Paul Railway Company is now engaged in elevating its tracks in the city of Milwaukee on what is known as the South Side, between the Kinnickinnic and Menomonee Rivers, a distance of about a mile and a half. When this portion of the railroad was built in 1871, about two-thirds of the stretch now to be elevated was placed upon a pile bridge, because the ground surface at that time was but a little above the level of Lake Michigan, and virtually a marsh. In the years since that time, this trestle has been entirely filled in. This is true also of the surrounding ground, much of which has been improved with buildings of various kinds. Marked settlement of the tracks has, of course, taken place since the fill was made, but additional material has been placed under the tracks from time to time so that the total settlement which has taken place is not apparent. Many of the buildings in the vicinity, however, show evidence of unusual settlement.

Because of the uncertain conditions, foundation investigations were made at various points within the limits of the track elevation work, which included test piles driven to a depth of 80 ft. and test borings carried to a depth of over 100 ft. The results of these investigations may be summed up briefly as follows: Immediately below the surface to a depth of 10 to 15 ft., there is a deposit of filled material varying from gravel and sand under the main tracks to refuse of various kinds under side tracks and unoccupied portions of the right-of-way. Below this to a depth approaching 80 ft. below the ground surface there are numerous, though rather poorly defined strata, of wet, slimy clay and fine sand, the several strata varying in position and thickness at various points along the line. Below this soft material is a bed of coarse sand and gravel of an unknown depth. The pile driving and loading tests proved beyond any question that piles would have to be driven into this gravelly material to be at all reliable. Owing to a lack of a sufficient number of drivers with leads long enough to handle 75 ft. and 80 ft. piles, it was evident that many piles would have to be driven in two sections, connected by a splice; and taking into consideration the results of the pile tests, the great length of the piles, and the presence of a splice, it was concluded to limit the load per pile to 15 tons.

A wall on pile foundations such as is shown in Fig. 1 would prove very expensive under such conditions, so much so as to lead naturally to speculation as to the possible use of walls on natural foundation. Many types of wall in mass and reinforced concrete were investigated, but most of them offered little encouragement, being eliminated either because they gave too great a variation in the toe and heel pressure under the various cases of loading, or else were not capable of the large settlement anticipated without possibility of serious damage to them. The only common design that seemed to approach the solution was the mass wall in Fig. 2a, or its equivalent in reinforced concrete in Fig. 2b; the advantage in cost apparently being with the former.

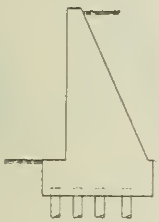


Fig 1

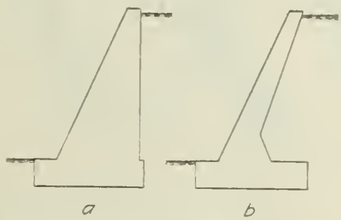


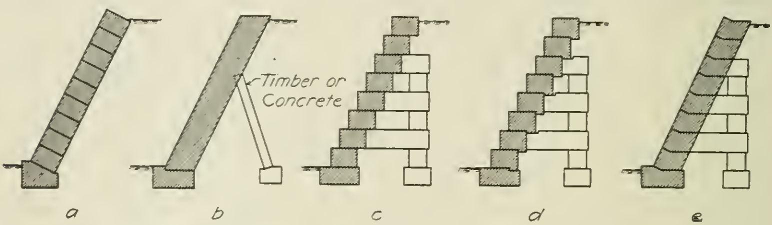
Fig 2

As a possible source of a solution, Mr. Loweth, Chief Engineer, suggested that studies be made as to the feasibility of adapting either the timber crib or dry stone wall to plain or reinforced concrete. The dry wall was the first to be studied, and a number of different forms suggested themselves, as shown in Fig. 3. The idea of the dry wall is to incline the wall at such a slope that the resistance line will at all points in the height of the wall fall at the center line of the wall or behind it. If this was carried out exactly, the analysis would result in an ideal design which consists of a slab of concrete with a curved front face similar to that obtained on a high gravity type masonry dam.

Naturally, the most primitive design for such a wall would be as shown by *a* in Fig. 3. This imitates the dry stone wall very closely and has the joints placed very nearly at right angles to the resistance line. Obviously such a wall would involve difficulties in construction which would make it prohibitive.

A modification of this design would be the wall *b*, which is simply a slab of concrete leaning against the embankment. This slab could be built in place or cast in short sections and erected when convenient. In either event it would be necessary to provide struts of timber or concrete to support the wall until the embankment could be placed.

In the wall *c* we have a design which is intended primarily to get cheap construction. It consists simply of a tier of blocks with horizontal beds stepped back to give the desired slope. To avoid the necessity for erecting these walls piece-meal during the placing of the embankment, they are provided at intervals of about 9 ft. with ribs extending back into the fill, composed of headers interspaced with small blocks. This portion of the wall serves simply as a support until the embankment has been placed, and is not intended in any way to add to the stability of the wall against lateral pressures. The weakness of the design "*c*" is that the resultant at each joint is inclined at rather an oblique angle with the horizontal



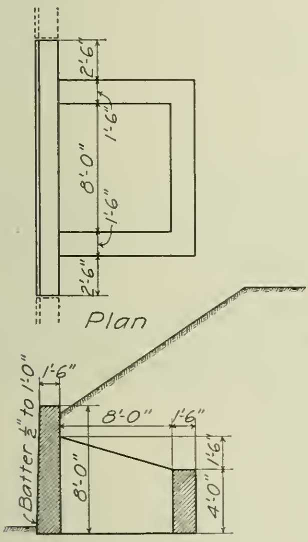
Various schemes for application of the dry wall idea to concrete construction i e concrete block wall

Fig. 3

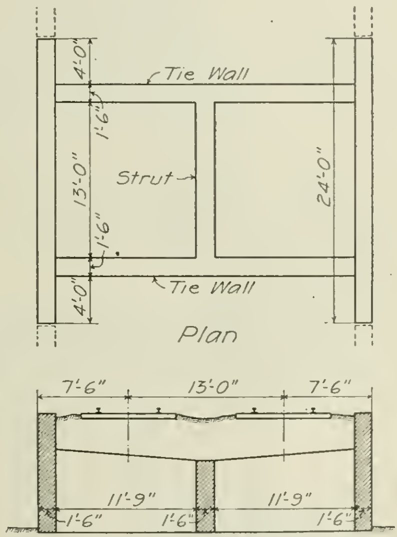
beds of the blocks, an angle which approaches much too closely to the angle of friction of concrete upon concrete. This naturally suggests the use of a mechanical lock or bond between the various blocks; for example, the surfaces of the blocks may be corrugated by casting them in forms lined with corrugated iron, or a lug may be cast on the bottom of each block as shown in *d*.

The scheme *e* is a composite of *a* and *c* in that part of the joint is horizontal, while the forward portion is inclined at an angle even greater than that of a plane perpendicular to the resistance line. By this means the desired resistance to sliding is obtained without sacrificing anything as to ease of erection. The forms are somewhat more complicated, but this is not of great importance if any considerable number of the blocks are to be cast.

The reinforced concrete equivalent of a timber crib is not, as might seem at first thought, a combination of various shaped concrete sticks dove-tailed or dowelled together. Instead, it is a box or series of boxes of reinforced concrete built with not less than one cell complete in one piece. The walls are made of such a thickness as will compromise considerations of the strength, economy and ease of construction. Concrete cribs have been used for some time by the War Department in the construction of breakwaters on the Great Lakes. In this adaption they do not act as retaining walls but as receptacles for stone. A concrete crib for use as a retaining wall is shown in Fig. 4. It is simply a bottomless box, which depends for its stability upon its own weight and the weight of embankment superimposed on the portion buried in the fill, and is not hard to analyze. This type of wall has a large factor of safety in the passive resistance of the earth on the inside face of the rear wall, which becomes effective as soon as the wall starts to move forward. The wall also affords great frictional resistance to overturning. Neither



Section
Cellular Retaining Wall
Unsymmetrical Type
Fig. 4



Section
Cellular Retaining Wall
Symmetrical Type
Fig. 5

of these elements, however, ought to be considered in making an analysis for design.

For a narrow right-of-way a natural modification from the crib wall described above is that shown in Fig. 5. This is in reality an application of the reinforced concrete filled **U** abutment. The lateral forces are taken care of entirely within the structure itself and only the vertical loads are transmitted to the foundation.

Before attempting to analyze any of the types of walls described above, it was necessary to investigate the applicability of the theory and constants commonly used in dealing with the lateral pressure of earth. A question arose in particular as to the proper value for the ratio k of lateral to vertical pressures, and the correct application of the surcharged live load.

Considering the first of these, we find that two solutions are given for the value of k for a wall which overhangs the embankment, as in Fig. 6, where angle θ is less than 90 degrees. Ketchum gives under what he calls, "Rankine's Theory Modified," the formulæ

$$k' = jk \sec (\lambda - \lambda_1)$$
$$j = (1 - \cot \theta \tan. \phi)^2, \cos \phi \sec \lambda_1 \cos (\theta - \lambda_1)$$

Cain's application of Coulomb's theory results in the formula

$$P = \tfrac{1}{2} wh^2 \left(\frac{\sin (\theta - \phi)}{(n+1) \sin \theta}\right)^2 \frac{1}{\sin (\phi' + \theta)}$$

where $n = \sqrt{\dfrac{\sin (\phi + \phi' \sin (\phi - \delta)}{\sin (\phi' + \theta \sin (\theta - \delta)}}$

These formulae seem rather elaborate but are readily represented in workable diagrams, and for such cases as occur in common practices, results obtained by the two methods agree very closely. The reader is referred to Ketchum's "Walls, Bins and Grain Elevators."

In the case of a wall with an appreciable backward inclination, the above formulae give a considerable reduction of the value of k. For a wall with a level top embankment, and a value of ϕ, the angle of repose taken at 33°—42′, we find that

when $\theta = 81°$, $k = 0.2$.
when $\theta = 70°$, $k = 0.12$.

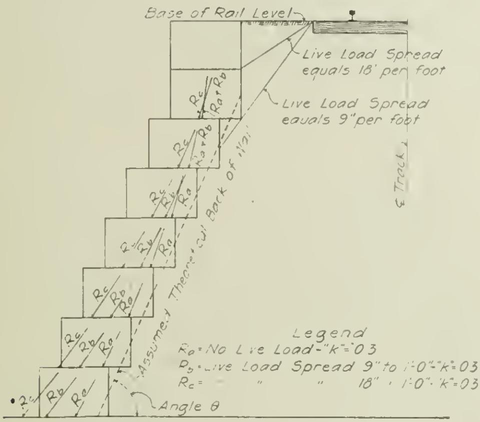
The effect of a live load upon an embankment is generally represented by a surcharge of additional embankment of equal weight. The practice of the Engineering Department of the C. M. &. St. P. Ry. is to make use of the theory of the live load spread. Referring to Fig. 6, a live load of 11,000 lb. per lineal foot of track is considered as distributed over a width of 8 ft. at the level of the base of rail, and spreading through the embankment in such a manner that at any given level, the live load would be uniformly distributed over a width defined by two planes spreading symmetrically from the center line of track. This is, of course, at variance with the actual conditions, but is surely much closer to the truth than the equivalent earth surcharge.

The formula for live load spread is simple,

$$P = \frac{11,000}{8 + 2hx}.$$

where P = vertical live load pressure at a depth of h feet, and x = the inclination of the spread planes, in fractions of a foot per foot of depth.

Upon analyzing trial designs of the block wall, it was discovered that small variations in the factors explained above resulted in great variations in the position of the resistance line. This is shown in Fig. 6, where widely different positions of the resultants are shown for different assumptions as to live-load spread. From this it was clear that more definite knowledge concerning the questioned points were necessary before a really intelligent analysis was possible. To this end, authority was obtained to build and test a model wall of the concrete block type.



Position of the resultant on each joint of a block wall under three assumed conditions of loading
Fig 6

The wall as shown in Fig. 7 was one-fourth as high as a full size wall for a 17 ft. embankment; it was made 12 ft. long between bulkheads and backed with a sand embankment. The live load was pig iron piled on wooden cross ties 2 ft. long.

The question arises as to the correctness of results obtained with a small sized model, particularly when dealing with earth pressures. A very simple demonstration, which cannot be given space here, will prove that the ratio of the weight of wall to the total lateral earth pressure will be the same in the model as in the full size wall; hence, since the walls are similar, the factors of safety against overturning and sliding will be the same. To maintain this relation for the live loading, the load per square foot must be one-fourth as much, and therefore since the ties are one-fourth as long, the load per lineal foot must be one-sixteenth as much. Actually the load used in the test was just double this, 1375 lb. per lineal foot.

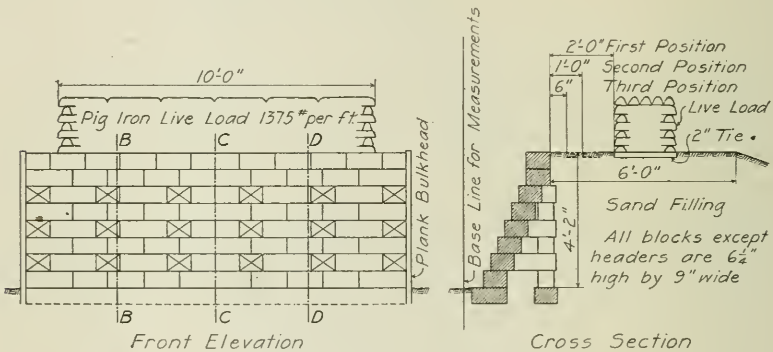
When we come to foundation bearing pressure, the value of the test wall is nil. The pressures are just one-fourth those for the full size wall and therefore of no value.

The program for making the test was as follows:

After the wall is erected, take levels in the planes *BB, CC,* and *DD* (Fig. 7) on the toe of the front wall footing and on the front edge of each course of blocks. With a transit set on the base line, and a level rod held horizontally in the above planes against the front top and bottom edge of each course of blocks, measure the distances from the plane of the base line.

Place fill behind the wall, the fill to be well tamped, using plenty of water and to be level with the top of the wall for a distance back of 6 ft.

Take levels and base line measurements twice at intervals of four days at each point where they were originally taken before the wall was filled.



Arrangement of Test Wall

Fig. 7

After completion of the eight-day test of the wall under earth load only, lay 2 in. by 4 in. ties 2 ft. long and 5 in. center to center, the ends of the ties to be 2 ft. from back of top block. Load the middle 10 ft. of the wall with a uniformly-distributed load on the ties of 1375 lb. per lineal foot of wall. Take levels and base line measurements twice at intervals of two days at all points where they were previously taken.

After completion of this step, move the live load to the second position, 1 ft. nearer to the wall and repeat all measurements in the same manner. Then move the load to the third position 6 in. closer to the wall, and repeat measurements. Then increase the live load by 50% in the same position and repeat measurements.

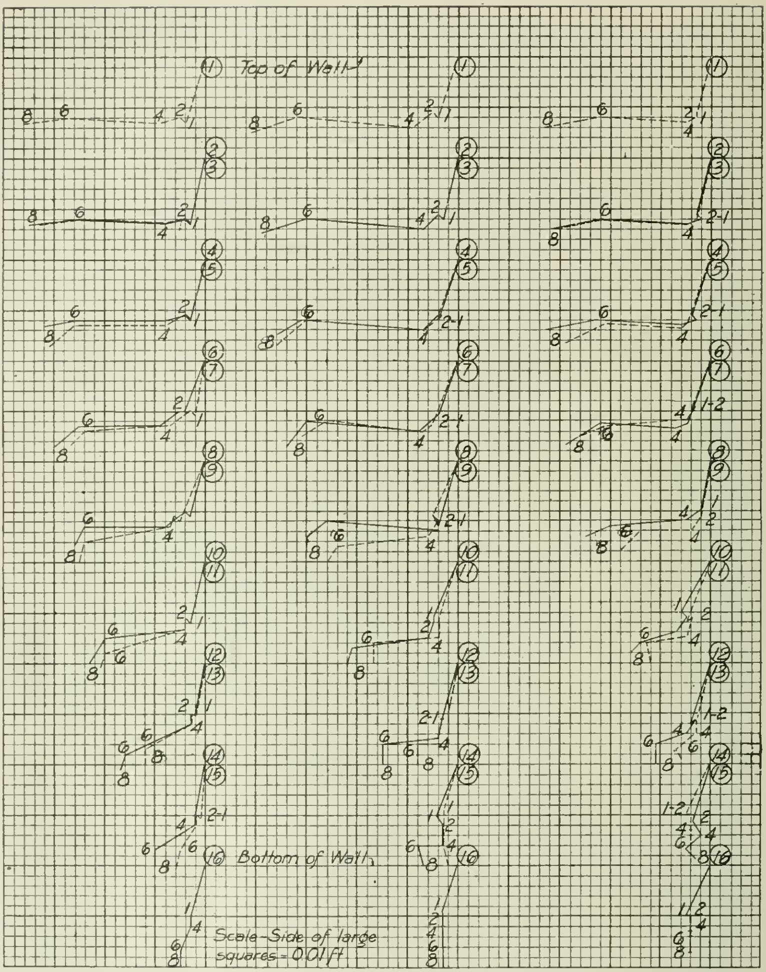
The blocks were made with a rough sanded surface without any mechanical bond. Thus the wall was weaker in resistance to sliding than overturning; this resistance to sliding was then used as a measure of the lateral pressures obtained, as will be shown. As a check on the sliding resistance, tests were made to determine the coefficient of friction for concrete surfaces like those on the blocks, which gave values varying from 0.53 to 0.75 with a mean for dry surfaces of about 0.66 and for wet surfaces about 0.63.

As anticipated, the test wall failed by sliding on the several joints between the blocks. Complete destruction was dispensed with as a matter of no consequence. The test was discontinued after placing the 50% additional load in position, as a sudden and general sliding caused a settlement of the embankment which tipped over the live load.

The results of the measurements taken after each loading of the wall are shown in the diagrams in Fig. 8. These show to an exaggerated scale, the movement of the top and bottom of each tier of blocks in three different planes, the dotted lines for the tops of the blocks, and the full lines for the bottoms. All lines are referred to the same vertical base line for convenience, upon which are represented the initial positions of all points. That is, the top front corner of the lower block and the bottom front corner of the upper block at each joint, are shown as coincident on the base line. The figures 0-1-2-4-6-8 are the measurement numbers. The difference in position of two measurement numbers on a given line indicates the amount which that point has moved between the dates of the two measurements. Difference in position, horizontally, of any pair of lines at a given measurement, indicates the amount which the surfaces represented have slipped relative to each other since the beginning of the test. Vertical separation of the lines similarly shows vertical separation of the surfaces. These measurements were read and recorded to 1/1000 of a foot—too fine for the degree of accuracy possible. For this reason the large scale used in Fig. 8 brings out some rather erratic results. These have been adjusted where it could be done with the exercise of any discretion, but a number of unavoidable inconsistencies still appear.

A careful study was made of Fig. 8 to determine at what stages of the test the slips took place, and the amount of each. This is shown for an average for the three planes of measurement in Table I. The figures in the blocks show the amount of slip in decimals of a foot which has taken place since the last preceding measurement. Thus, the diagram shows that the load applied previous to measurement No. 4 caused sliding at joints 10-11, and possibly at 12-13; that the load applied previous to measurement No. 6 caused sliding at joints 8-9, 10-11, 12-13 and 14-15.

If we assume a value for the coefficient of friction between the blocks at 0.63, by computing the weights of all the blocks above any given joint, we can determine the sliding resistance of the joint and thus have a measure of the pressure behind the blocks above this joint necessary to cause sliding. This, then, may be compared with curves representing the theoretical pressure as obtained according to various assumptions.



Movement in Plane BB — Movement in Plane CC — Movement in Plane DD

Diagram showing movement of top and bottom edge of each tier of blocks in wall. Measurement taken in three planes perpendicular to face of wall. Figures circled thus (10)/(11) indicates position of edge, see diagram. Full line in each case is for lower edge of block. Dash line is for top of block. Figures on the line indicate measurement number.

Table of Measurements

No. 1 - 2 days after placing fill.
No 2 - 7 days after placing fill.
No. 4 - 3 days after placing live load in 1st position.
No. 6 - 2 days after placing live load in 2nd position.
No. 8 - 3 days after placing live load in 3rd position.

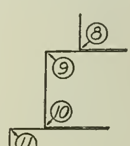


Fig. 8

First, let us consider Fig. 9, which illustrates the effect of modifying the assumption as to the live-load spread. The portion of the figure on the right shows the outline of the model wall in relation to spread of the live loading according to various inclinations of the limiting planes. The portion of the figure to the left is a diagram which shows the intensity of the vertical live load pressures for the various spreads at various depths, in relation to the blocks making up the wall. By applying the proper coefficient "*k*" we obtain from these the lateral pressures, which, when combined with the lateral pressures due to the weight of the embankment alone, give us the total unit pressures, it being understood, of course, that there is no live-load pressure on the wall above the point where the given live-load spread line intersects the back of the wall.

Joints	Measurement Numbers				
	1	2	4	6	8
2 - 3					
4 - 5					
6 - 7				0.0013	0.0017
8 - 9				0.0023	0.0013
10 - 11				?	0.0020
12 - 13			0.0020	0.0030	?
14 - 15			?	0.0030	?

The table shows the average amount of slip between each tier of blocks, the amount given for each measurement number and joint, indicating the slip in decimals of a foot since the last previous measurement. No entry has been made unless the slip was more than 0.001 ft

Table I

From Fig. 9 we have constructed the diagrams of Fig. 10, one for each position of the live load, during the test. The curves give values of *P*, the total lateral pressure obtained between the given ordinate and the top of the wall. Ordinates indicate distance from top of the wall by blocks.

On these same diagrams have been shown the values of the sliding resistance for each joint in the wall based on the weight of the blocks above each joint and a coefficient of friction of 0.63. The joints at which slipping was recorded under the particular loading have been marked with an arrowhead.

If our assumptions as to live-load spread, and coefficient *k* are correct (accepting ordinary theory as to earth pressure), the curve for values of *P* should intersect the heavy black lines of the sliding resistance for all joints where no slipping occurred, and fail to intersect, i. e., pass to the right of ends of all the black lines for joints where slipping did occur.

The curves for P given in Fig. 10 were selected after a number of trials; the value k is 0.29 while curves for live-load spread are given for values carrying from 6 in. to 1 ft. 0 in., to 18 in. to 1 ft. 0 in. Examination of diagrams will show that the curves for spreads of 12 in. to 1 ft. 0 in. and 18 in. to 1 ft. 0 in. seem to conform best to the proposition outlined above. The absence of any sliding at joint 7 for loads in positions one and three is contradictory, and no satisfactory explanation has been suggested. No data on sliding at joint 8 were taken.

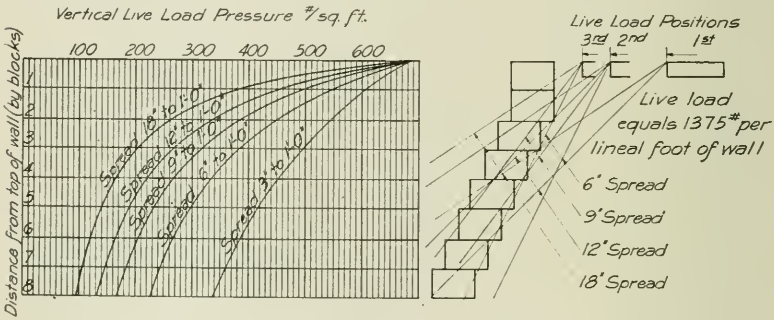


Diagram shows intensity of live load pressures on a horizontal plane, for various depths of fill and various assumptions as to spread. Figure shows relation between the model wall and lines representing live load spread.

Fig. 9

Conclusions to be drawn from this test must be made with a knowledge of a somewhat unfortunate circumstance. Through a misunderstanding of instructions, the amount of water applied to the filling after the placing of each load was excessive, so much so as to make conditions much more severe than could be obtained under ordinary actual conditions. This has been compensated for, in part, by taking the weight of the filling at 124 lb. per cu. ft., determined by test. According to Ketchum and Cain, the value for "k" should have been about 0.12 for an assumed value of the coefficient of internal friction of the material of 0.67 (1½ to 1 slope). The fact that the test points to a much higher value does not conflict with the theoretical results, but indicates that the material had a much lower coefficient of internal friction due to the use of too much water.

Owing to these circumstances, the results of the test are rather disappointing. They indicate that the live-load spread is much greater than had been supposed. Beyond this, the results are qualitative rather than quantitative. It is believed that the test will prove of value in pointing out a field for extensive investigation and in suggesting a simple means for making a test.

As to the design of a block wall, the test proves clearly that horizontal beds without a form of bond or lock give the wall a low efficiency, as failure by sliding will take place at loads much below those required to cause overturning. With a properly designed joint such as is shown in *e* in Fig. 3, the block wall presents advantages under certain circumstances that justify its serious consideration.

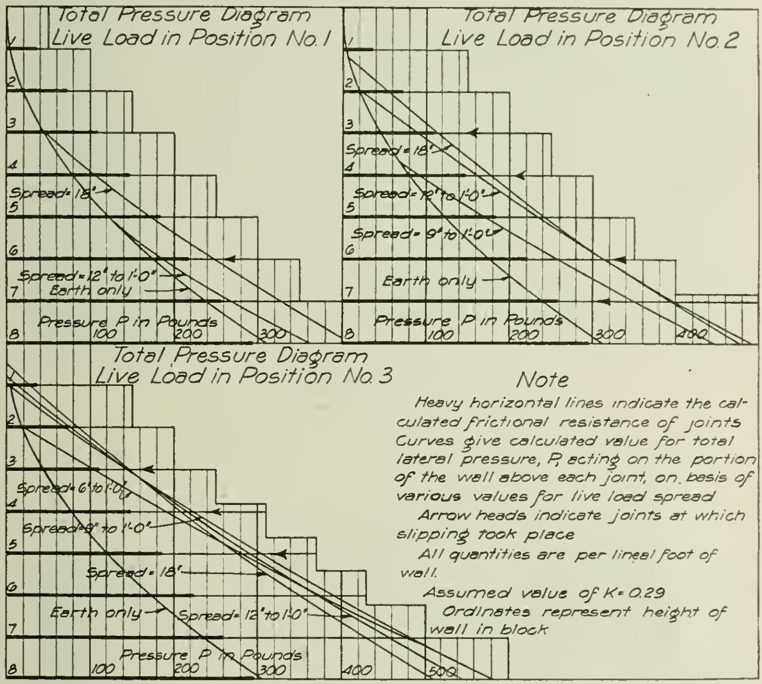
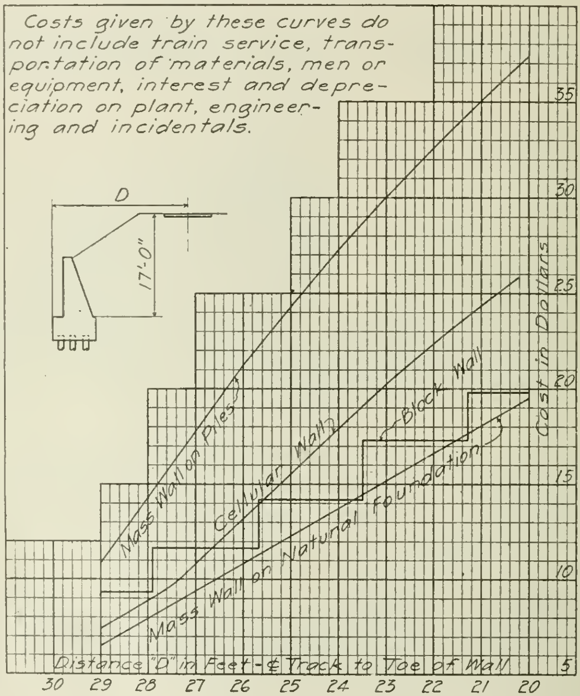


Fig. 10

In Fig. 11 are shown diagrammatically the relative costs of the heavy front batter mass wall on natural foundation, the block wall, the cellular wall, and the mass wall on piles. This comparison is based on the assumption of very expensive piles such as are required on the work at Milwaukee. The relative economy of the several types, excluding all other considerations, is directly in the order named above.

In conclusion, the following advantages and disadvantages are listed for the several types:

Advantages of the block wall: It is economical; settlement in an irregular manner will not be conspicuous; it may be constructed in several stages; it does not occupy much space before filling. Disadvantages: The heavy front batter causes a waste of property which will encourage encroachments, and unless built with a smooth front batter will encourage trespassing. Because of its loose-jointed nature, the block wall does not, under some circumstances, possess as much of a potential factor of safety against the unforeseen contingency as a monolithic structure.



Curves Showing Comparative Cost
of Different Types of Walls

Fig. 11

The heavy batter mass wall is economical but will cause criticism if it settles or tips appreciably, and is subject to the same objections as the block wall on account of the heavy front batter.

Advantages of the cellular wall: It occupies the right-of-way in such a way as to afford little opportunity for encroachment. It may settle considerably, but offers great resistance to overturning or sliding. It permits of ready driving of a pile trestle directly over it. Disadvantages: It occupies considerable space before filling and may thus interfere with the use of tracks. Settlement may also give an unpleasing appearance.

The mass wall on piles gives maximum security, but is expen-

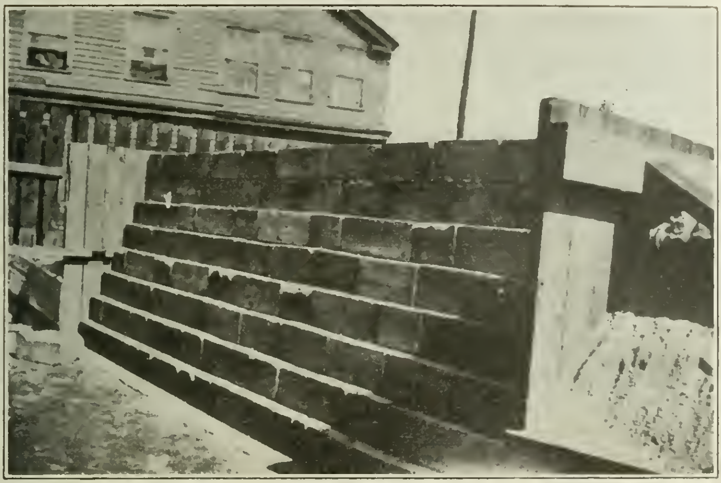


Fig. 12. Test Wall; Front View.

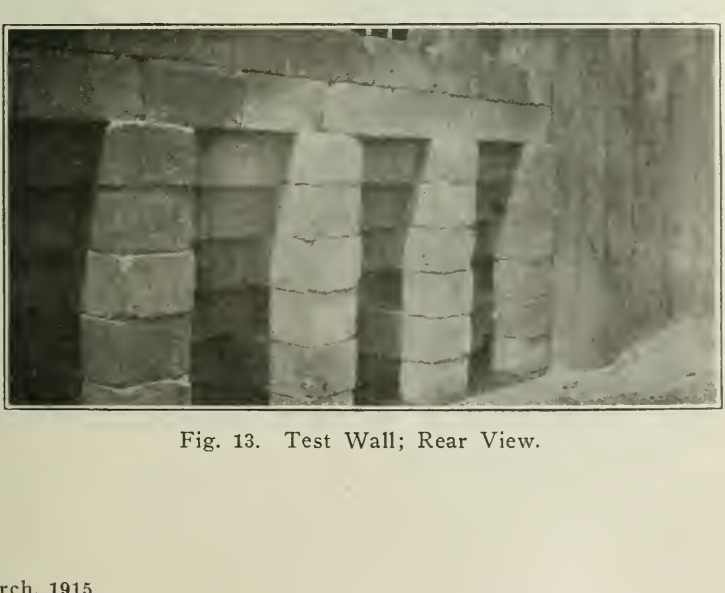


Fig. 13. Test Wall; Rear View.

Fig. 14. Block Retaining Wall; Rear View.

Fig. 15. Block Retaining Wall, Showing Detail of Joints.

sive and may lead to difficulties, because of possible damage, which the pile driving may do to adjacent buildings on insecure foundation, a consideration which was given much weight in the search for a substitute for the structure on piles.

Up to the present, one block wall with corrugated horizontal beds, and two cell walls, have been built at Milwaukee. Plans for the use of the cell wall at a number of other places on the work have been made. The cell wall has been favored on account of the fuller utilization of the right-of-way, and also in a number of cases because of the necessity for driving a pile trestle for an adjacent industry track directly over the wall.

DISCUSSION

Onward Bates, M.W.S.E. (Read at the meeting.) This paper is of much interest to me, because it indicates a practice in building retaining walls which I think will grow, and will result in a large saving in the cost of such walls. If we examine the cross section of an ordinary retaining wall built of massive masonry we cannot fail to observe what a great portion of the cost of such a wall is buried under the ground. All of the wall lying below the base of the embankment which the wall is intended to support is of no value except to prevent the wall proper from overturning, or from sliding out sideways when subjected to the thrust of the embankment. When the retaining wall is supported by piles, the proportion of cost of the wall below the surface of the ground is emphasized.

All builders of retaining walls recognize the facts stated above, but engineers have gone on building them with immense and costly foundations, apparently under the belief that it is the only thing for them to do. A railroad engineer who would build such a costly retaining wall when he had room to support the embankment by the natural slope taken by the material of which the embankment is composed would be considered crazy. Obviously, in the case of an ordinary railway embankment, the retaining wall has no other purpose to serve than to take the place of the natural slope, which holds the prism of embankment upon which the railway track is laid, in a stable and permanent condition.

In making this statement I discard minor objections to an embankment with a slope, such as the liability of trespassers to reach the railway tracks. In this case, we may hope as we become more civilized that the State will protect railway tracks against trespassers; if not on the ground that railway property is entitled to protection, then for the reason that the public's safety requires trespassers to keep off the tracks. An instance of this phase is to be found in a recent report of the coroner of Cook county in which he advocates a law to prevent trespassing on railway tracks, on the ground of safety to the public, and being very careful to say that it is not the intention of any such law to afford the railways protection, but the people should be protected, because, naturally, if they walk on the tracks in front of approaching trains they might become injured.

I do not suppose any engineer will dispute the statement that a massive retaining wall is the most stable support for a railway embankment, but recognizing the great cost of such walls there have been many attempts to substitute some other form of wall. Some of these substitutions are shown in Mr. Lacher's paper in Figures 2b, and 3a, b, c, d and e. These are to be commended as efforts in the right direction, but all of them are more or less open to criticism.

Taking Figure 2b, the author raises the objection that as compared with the massive wall the advantage in cost is in favor of the latter, and this, when it is considered that the massive is the most reliable, would lead to its adoption. There are various objections which can be raised to the sections of walls in Figures 2 and 3, one of which, in cases where land is of high value, is that, while the wall does not occupy the space of a natural earth slope, it is still sloping enough to occupy much valuable land, and might easily, in the case of a railway in a city, reduce the number of tracks by one. The cellular retaining walls shown in Figures 4 and 5 have commendable features, and I am surprised that they are not more often used.

Limiting the consideration of retaining walls to such a case as that described by the author, where the underlying soil is insecure and the whole of the railway company's right-of-way is valuable, let us consider the functions of the retaining walls.

First: The walls should retain the railway embankment laterally.

Second: They should be vertical, or nearly so, to avoid reducing the width of the right-of-way.

These are the two main purposes to be served by the retaining walls.

In designing walls we may properly consider the possibility and methods of their failures. I remember reading at least thirty-five years ago the statement of that great engineer, Benjamin Baker, that no engineer could claim to be an authority on retaining walls until he had built some which failed. It is strange that we have made so little progress since the date of that statement. A retaining wall may fail by overturning. In overturning it must partially revolve about an axis which is horizontal or nearly so. If a retaining wall is built on a solid rock foundation, and its base is not of sufficient width, it will naturally revolve outward around its outside lower corner. If the foundation is unstable, failure will be hastened by a settlement under the lower outside corner of the wall section. In the case of a pile foundation the wall will revolve about an axis lying on the top of the outside row of piles, unless these piles settle, in which case the next row will take a part of the load, and so on. Pile foundations for retaining walls are subject to criticism, in the respect that to get a sufficient number of piles under the wall they cannot all be placed where they will do the most good. For instance, examine Figure 1, which shows four longitudinal lines of piles. It would almost seem from looking at the cross section that the two inner rows of piles are unnecessary, and certainly one row of piles, if it could be advantageously interpolated with the others at the outer edge of the wall section, would be worth the two inner rows as shown.

Now, if the two walls could be held together, as shown in the author's Figure 5, there is no occasion for any special foundation. Any natural foundation which will support the embankment will support the walls as well. In this case the embankment is confined between longitudinal walls. If these walls are tied together at top and bottom, they can only fail by bulging out laterally between the top and bottom ties, and if additional ties are placed intermediately and of sufficient strength to resist the lateral outward pressure of the embankment the wall need only be strong enough to carry the thrust from one tie to another. Comparing Figure 5 with Figures 1 and 2a, it will be observed that in the former case no foundations are required and that a less amount of material is used above the ground. An objection to Figure 5 is a lack of flexibility in the walls, which are difficult to arrange for expansion in the concrete, swelling of embankment by freezing, and the settling of the ground upon which they rest. In this respect Figures 3c, d and e show a decided advantage.

Is it not possible that theoretical designs have stood in the way of economic designs for retaining walls? To ascertain this, let us look aside from the author's paper and see what others have done as the result of experience rather than of theory. Take for example some of the coal yards in this city where large piles of lump anthracite coal are stored. This coal is graded into lumps of approximately uniform size. It is a hard material, and if cast into a pile without lateral support will invariably take its own natural slope. It is similar to sand, except that the units are larger and of less density. Observe how the coal dealer piles his coal up to perhaps twenty feet in height with a steep slope, by a skillful use of planks laid horizontally running into the coal pile and acting as ties, and other planks set on edge and making the wall to confine the coal. For years I have never observed one of these coal piles without wondering why it was that the engineers did not use the same principle in at least some cases of embankment. As a matter of fact, they have followed a similar practice by cribbing with old cross ties, and I call the attention of our members to the admirable manner in which cross ties have been used for this purpose at the 79th street crossing of the Rock Island and Western Indiana roads in this city. This work at 79th street seems so notable that the engineer in charge should be encouraged to give the Society a photograph and description of it for our transactions.

Why, then, if common wooden planks can be used in small amounts and at small cost to do away with the necessity of a retaining wall to hold anthracite coal, and if important railway embankments can be retained in place by the use of old, rotten and misshapen cross ties eight feet in length, cannot we engineers get a lesson from these examples and devise retaining walls that will be permanent and will answer all practical purposes, at a cost very much less than is usually incurred? This is a problem which I suggest be taken up by reinforced concrete experts. They do all sorts of things with reinforced concrete, and claim to be able to justify them by calculations. If this is so, they should be able to make concrete planks and concrete cross ties, certainly as good as those which are usually used for cribbing embankments.

I have tried to interest engineers in this matter, but so far without success. I consider this a problem for the young engineer, and there is ample opportunity for practical experiment with it. Almost every railroad engineer has the opportunity to make these experiments at small cost. It is not to be assumed that an engineer will in his first attempt get the best results. But if he learns by starting with concrete planks in much the same manner that the coal dealer uses wooden planks, he can from a small beginning improve until the best results are obtained.

There are some special convenient and economic advantages in the use of concrete as proposed, especially in the case of raising the grade of an existing railway. For example:

First: The wall can be built up as the work proceeds.

Second: It will require no form work at the location of the wall.

Third: There will be very much less form work, because the slabs, ties and sills can all be moulded at some convenient place, and the same moulds can be used over and over again.

Fourth: The material can be delivered at the site of the wall just as it is required for use, no storage at the site being required.

Fifth: The wall will be adjustable to settlement, expansion and shrinkage.

Sixth: There will be no foundation pits to be dug and no space required for an outside toe to the wall, so that for ordinary heights of embankments in cities the full width of right-of-way may be occupied by railway tracks.

Objection may be raised that the concrete planks will break under the settling of the material, both during and after the embankment is placed. This is not a serious objection, because the planks should have sufficient reinforcement to hold them together longitudinally, and if they do break and become deformed, no special damage is done. For the ties; that is, the members which hold the front of the wall from bulging out, iron rods may be used in preference to concrete. Rods of circular section present the least area for rusting, and will last a long time. If the objection is raised that pieces may break and need replacement and will be difficult to replace, the answer is, do not make the mistake which is usually made in building something new; that is, to make it too cheap at the start. It will be better to spend more than is necessary in the first attempt, and in future work, to reduce as indicated by experience, rather than to build the work too light at the outset, which would require its replacement.

I hope Mr. Lacher's paper will spur engineers to a continuance of experiments with the class of walls that he describes, and I will be glad if some of the active young members of our Society will consider the question of concrete planks and see what can be done with them. In either event, I look to an improvement in the practice of building retaining walls in many cases where the practice has heretofore been unduly expensive.

Ernest McCullough, M. W. S. E.: Mr. Bates, in his discussion, refers to a statement made by Sir Benjamin Baker, "that no engineer could claim to be an authority on retaining walls until he had built some which failed." That paper was read before the Institution of Civil Engineers and published in Van Nostrand's Magazine about thirty years ago. One of the illustrations referred to the way coal dealers piled coal in their yards, from which it was thought some valuable suggestions might be obtained.

I know of a wall built in California to a height of 24 ft., in just the way the coal dealer builds walls to hold his coal. The wall was of rubble, anchored with reinforced concrete planks. The idea was to cover it with vines, giving a pleasing effect. We found quite a difference between coal and earth, for earth had a tendency to run through crevices. The wall stood about eleven months until we had a tremendous rainstorm, which made mud of the earth and the wall fell. We discovered that in addition to having blocks piled up, we should have used considerable mortar and not supported the stone on a slope with ties, this construction being good only for rather low walls. Since that experience I have been a believer in retaining walls of the usual type.

F. E. Morrow, M. W. S. E.: The Chicago & Western Indiana Railroad has been trying out the method suggested by Mr. Bates, with reinforced concrete slabs which approximate the general dimensions of cross ties, using tie rods of the same material, which extend back into the embankment. The tie rods are sloped back and the face of the wall built with a batter, so that in pushing out, the wall will have to raise somewhat as well as to slide out.

Of course, it is a very short time since we began our experiment, but the appearances so far are very good, and we feel that it is a good scheme for low walls. I am inclined to think that perhaps up to a height of 7 or 8 feet, where the surcharge is not very great, it may work very successfully. I am not prepared to advocate anything of that kind, however, to any great height. It is in walls 7 or 8 feet high where you get most of the expense under the ground, because you have to go 4 to 4½ feet below the ground with the footings to get below the frost line. In a wall of that height, or less, a large part of the materials are under the ground.

It is possible that we may do more of that kind of wall building in connection with low walls. We find we can put up a wall 7 or 8 feet high at about one-sixth or one-seventh of the cost of a mass wall of the same height. We constructed it at a cost of 20c to 25c per square foot of face, which, on an 8-foot wall, would be only $2.00 per lineal foot.

I mention this as it is along the line suggested by Mr. Bates and I am inclined to think there is something in it to take the place of low mass walls, but I do not advocate it for a very great height.

F. G. Vent, M. W. S. E.: I made some of the preliminary calculations for the retaining walls used on the Rock Island track elevation and will state that I considered the use of a wall composed of concrete struts, placing them in such a manner as we so often see old ties used in coal yards for retaining piles of coal, but discarded the scheme as it would probably cost as much as a reinforced concrete retaining wall for a wall of any considerable height, due to various elements taken into consideration in the designs of the walls, if such a wall were to be built to meet all the requirements which might possibly be imposed upon an ordinary gravity or reinforced concrete retaining wall.

The struts would have to be reinforced probably as much as a reinforced concrete pile to insure against possible breakage and would be correspondingly expensive to manufacture. Furthermore, the transverse struts or "dead men" would increase very rapidly with the height of the wall; increasing both in length and in number per superficial face area of wall for the lower ones.

I heartily agree, however, with Mr. Morrow that such a wall might be economical for a low wall, say up to 7 or 8 feet high, on account of the relatively great proportion of footing to neat wall ordinarily required for walls of low heights; but for a 30 foot wall, I have doubts as to the feasibility of a concrete strut retaining wall.

We have all observed coal piled up behind a timber wall of old ties or other timber, as long back as we can remember; but in all my observations of such walls, I have never seen a case where the coal has been left piled up for any great length of time. I believe this is true of us all, as the coal piles are always found to be low with the approach of Spring, and hence we have had little opportunity of observing results where such a wall has acted for any great length of time and naturally would be skeptical as to how much such a wall would lean under severe conditions of loading.

Walls made of old ties 8 feet long and placed in this manner, were used in the preliminary construction on the original Rock Island track elevation back in about 1898, and this method was also adopted upon their track elevation south of 76th street during the last year or more and were simply of a temporary character. I believe Mr. Ford is here tonight and will bear me out in the statement that these walls bulged considerably.

Even if this bulging or leaning was not great, we cannot learn much from these walls, because they were in service but a season and saw probably very little or no service under train loads, as it will be noted that the track just east of the timber wall was the construction track which was on piles and the live load from the south bound main track would never spread to reach the wall unless possibly the very bottom of it.

We built a wall on the C. M. & St. P. Ry. in 1897 that has often reminded me of the type of wall Mr. Lacher has shown us this evening. It was located at Chestnut street, St. Paul, on the Short Line between St. Paul and Minneapolis, and was 250 ft. long by 56 ft. in height. It had a batter of about 1 horizontal to 2 vertical. The wall in one way would probably give us valuable information, and in another way would not. The wall was 56 ft. high. The lower 30 ft. was sandstone, and above that was 11 ft. of limestone rock; and above that 15 ft. of loose sand, gravel, and bowlders. The wall was not over 2½ ft. thick on the average, and probably the top portion is acting as a retaining wall to this day.

H. S. Baker, M. W. S. E.: I am very much interested in Mr. Bates' discussion. I recall a wall which I saw five years ago on the C. B. & Q. R. R., designed by Mr. F. L. Stone, who was at that time engineer of the track elevation of the road, and who is a member of this Society. At that time it was the first wall of the kind I had seen. It was modeled after the cross tie retaining wall used for a good many years. He built the blocks out of reinforced concrete about the size of ties, and he built a tie to go back into the embankment of about the same size, with a dove-tailed joint to make it hold. They built some walls of that kind on the Sixteenth Street Line out near the International Harvester Company. As I remember, those walls were 8 or 10 ft. high, and I think they are still there. As far as I know, that was the first time such walls were used in Chicago.

R. H. Ford: Before entering into this discussion, I would like to correct a statement made by the former speaker, Mr. Vent, who spoke of the movement of some walls recently built by this company on its track elevation at Chicago. The speaker undoubtedly referred to the temporary timber walls or cribs. He is in error, however, as a careful weekly inspection, continued over a number of months, has failed to indicate any appreciable movement on these walls, or in fact on any other type of walls which have been built.

As these timber walls, or cribbing, have been the source of considerable interest to engineers and others on account of their height and close proximity to the operating tracks, over which a large volume of business is done, perhaps a brief description will be of interest at this time.

The walls were constructed during the past year, parallel to and from 8 to 10 ft. from the center of the operating tracks, their purpose being to hold the slope of the heavy gravel fill on the easterly portion of the right-of-way, which was first elevated. These walls are from 4 to 20 feet high, and extend for about a mile and a half. They were constructed of old ties, with a header in the length of each tie, one end being spiked to the ties below and the other to the second line of ties placed one tie length back of the face ties, thus

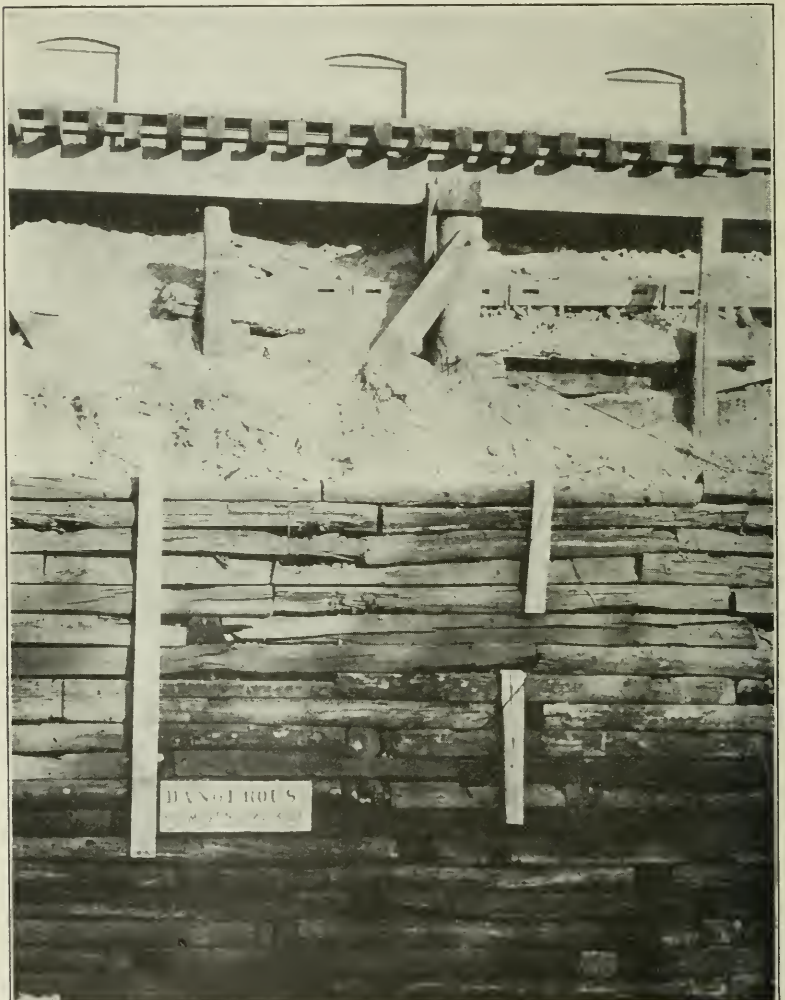
Retaining Wall Showing Use of Old Ties. C., R. I. & P. R. R. at 79th Street, Chicago.

making a cellular timber retaining wall. The cribs were then filled with coarse sand and gravel, and an occasional tie spiked on top to catch the larger stones as they rolled from the cars during the filling. The new road bed and slopes were continually soaked with water during construction, both for the purpose of obtaining the minimum settlement, and to test the efficiency of the walls before regular main line traffic was placed on the elevated portion. The walls have successfully retained the load imposed upon them for three main tracks, the nearest of which is 19 ft., center to center from the track below, and over which traffic was also maintained. In some places there

Retaining Wall Showing Use of Old Ties. C., R. I. & P. R. R. at 79th Street, Chicago.

is a difference of 37 ft. in elevation between the high and low tracks. This wall has served its purpose admirably, at a very slight cost over what would have been the case had other means been resorted to. The labor cost of the wall averaged 20c per running foot. A concrete retaining wall 30 ft. high, supported on piles, averages to cost $115,000 per lineal foot; a wall 18 ft. high without piles (the usual height for track elevation) costs $32.00 per foot.

For some years the speaker has given considerable study to the



Retaining Wall Showing Use of Old Ties. C., R. I. & P. R. R. at 79th Street, Chicago.

problems involving the use of high retaining walls, as well as the general practice in their design and construction, and for a long time has been unable to escape the conclusion that in a great many instances there seems to be something fundamentally wrong between the application of the theory of design and actual requirements. On a number of occasions, he has had to deal with cases where timber retaining walls have been built or tied in to the slope. These have successfully served the purpose. Had retaining walls, designed along the general accepted lines, been substituted, the cost would have been multiplied many times. The application of the principle of design in the first instance seems to be so different from what it is in the other, although the desired result is the same, that it seems remarkable that there is not more attention paid to such cases.

Some of the questions that have suggested themselves to me are: has this problem of design and requirement kept pace with each other? Are we not designing too much work of this character, with a too incomplete knowledge of actual conditions or requirements? Are we giving sufficient study to the question of the expenditure incurred in the adoption of designs, which may be out of all proportion with what is actually necessary?

It is not my purpose at this time to enter into any general discussion of this subject, but rather to call attention to some of these tendencies as they appeal to me. I do not wish to be understood as advocating the use of timber retaining walls, when stone or concrete are required, but I am sure there is a link somewhere between the action of the two types of walls described, which perhaps we may have lost sight of. I think that we should get away from that much abused term a "standard design of retaining walls," and provide sufficient latitude to enable the engineer to extend his investigations in an effort to get a more real relation between design and requirement. When this is done, there will be much less money spent on unnecessary construction. In general, there seems to be too many assumptions made in relation to wall design, which increases the cost. Many of these might be eliminated, or minimized, if the walls were designed and built to suit the local conditions; for example, the author of the paper under discussion has just shown by diagram he has drawn on the blackboard that there was a doubt in his mind as to the angle of repose for the material which his wall must support. Is not this feature as important relatively as some of the other elements considered? Often times a comparatively slight investigation will go a long ways towards assisting in the determination of such factors,—and unless better knowledge is at hand, it simply means another assumption to add to the other assumptions, which are so often taken in this question of design. The practical result, to my mind, is a sort of combination of assumptions, mathematical facts resting on assumptions, with a few actual well determined realities,—and from this, the wall is designed.

It is, of course, true that on account of the present status of engineering data, we are not possessed of sufficient information to eliminate some of the assumptions which must be made, and we can only resort to accepted practice, but the speaker is inclined to believe that it is none the less true that a large part can be materially reduced by investigation, similar to what the author of this paper has been doing in the walls under discussion. The speaker strongly endorses all that has been said by Mr. Onward Bates on this subject. Engineers are as a rule too sensitive to criticism, and I think are inclined to confuse custom, conservatism and good practice. A departure from the first two, and a careful independent study, backed up by local investigation, may some times show that in a great many instances the engineer is warranted in adopting a course which is not along the well worn path "good practice," especially when large sums of money are involved.

Mr. Lacher is to be congratulated upon the study he has made of the problem before him; and whatever his results, it indicates that progress is being made along the right line.

F. G. Vent, M. W. S. E.: The author said the load curve in Fig. 10 should intersect the heavy black lines of the sliding resistance for all joints, where no slipping occurred, and also that the heavy black lines represented the friction at the joints due to the dead load. I would like to ask if he neglected the live load upon the joints in figuring the frictional resistance. Realizing, of course, that the live load may distribute laterally much less than the assumptions would indicate, it might not enter at all into the thrust line of Fig. 6, and therefore not into frictional resistance in Fig. 10. On the other hand, should the live load spread sufficiently to come upon the wall, it would increase the frictional resistance of the joints and be a factor in preventing sliding, due to its own action.

Mr. Lacher: This friction is simply a function of the dead load on the joint and the coefficient of the concrete upon concrete. We assumed there was nothing resting on the joint except the block.

Mr. Vent: That would be doubtful as the live load might fall inside.

F. H. Wright, M. W. S. E. You figure the assumed lateral pressure working back from your friction between the blocks. In arriving at the friction that you have between the blocks, does that assume that the weight of the blocks alone is transmitted vertically? I notice in the diagram that the lower block seems to move more to the left and further away from the upper block.

Mr. Lacher: In some cases it is below and in others it is above. I might add that those figures in the diagram are drawn to a very large scale. The movement at the top of the wall is only 0.036 ft.—a little over 3/8 in.—so that the bulge in the wall is only 3/8 in. The diagram does not show the position of the wall at the final test, the time that the load tipped off. The reason for that is that the movement was so much more that it could not be shown to this scale. The appearance of the wall, after the final test, would indicate what Mr. Wright said, so that the settlement of the wall in the three planes was very nearly uniform. There was little difference between the elevation of the top of the wall at the center and at the ends.

J. W. Pearl, M. W. S. E.: I judge from the paper that the friction of the earth on the back of the wall was neglected in determining your coefficient 0.29. Is that the case?

Mr. Lacher: Yes.

Mr. Pearl: How do you account for the top course settling only about half as much as the bottom course? These diagrams show that the bottom blocks settled about twice as much as the top blocks. I can see nothing that would keep the upper blocks up unless they were partially supported by the earth. If that support was sufficient to hold the blocks up, it would release the weight on the lower blocks and destroy your assumption in regard to coefficient of friction. You would not know what part was resting on the blocks and what part was carried on earth.

Mr. Lacher: It is probable that the pressures were higher and conditions not the same as we would expect under ordinary circumstances. It may be that some sand worked into these joints, and for that reason they would be opened, as Mr. Pearl suggests.

Mr. Pearl: If the weight of the blocks was partially taken on the embankment, you could not determine the friction between the blocks, because an unknown part of the weight was supported there.

Some experiments have been made by Mr. F. P. McKibben on the coefficient of friction between concrete blocks, which correspond closely to those given in the paper—60% to 74% is reported by him in the Engineering Record of December 28, 1912. With the coefficient of friction used, if the sand did get in between those blocks, it would not materially change results. Mr. McKibben also made experiments on concrete blocks with layers of red clay and loam between them. In that condition the friction was greatly reduced.

The effect of partial saturation of sand would increase instead of reduce your angle of repose. Some experiments I have made on sand operated in that way, and to get the lowest coefficient of friction sand should be dry. This experiment was made with ordinary lake sand. If thoroughly dry it would stand at an angle of 1.545 horizontal to 1 vertical; damp sand, 0.75 horizontal to 1 vertical; saturated, 2 horizontal to 1 vertical; and when quietly deposited in water it would take an angle 3.69 horizontal to 1 vertical. So for all conditions of damp sand you would have a higher angle of repose. I believe one of those photographs (Fig. 12) shows a rather high angle of repose. The internal friction and angle of repose seldom coincide, and I believe it is the angle of internal friction that should be used in all calculations rather than the angle of repose.

Mr. Lacher: One reason for believing that the blocks have not separated enough to reduce the coefficient of friction very materially, is that on the whole this movement which we are discussing is very small, as is shown by the maximum movement of 0.003 feet in Fig. 10. If there was a separation such as Mr. Pearl suggests, we would expect sudden and very apparent movements as the friction was withdrawn. As to the angle of repose of this material, we are all familiar with the angle of repose of molding sand, which is frequently 180°. We did not have the condition of molding sand in this test. I think there was no doubt but that the sand was semi-saturated, a condition not obtained in molding sand.

F. E. Vey, ASSOC., W. S. E.: In reading over Mr. Lacher's paper the main point that occurred to me was that if the proposed block wall idea is sound, then our previous notion of massive requirement in retaining walls is wrong and it seems to me that the engineers in general will have a hard time saving their faces if they find that after all these years of designing they have been wasting money in their walls. An immense amount is spent for retaining walls each year and even a small percentage of saving would make a respectable sum in most any project undertaken.

I believe it to be a fact that we can insure a large project against loss of money through extravagant design just as well as insuring this same project against loss through accident to its workmen. In the first case the premiums are paid out in the way of tests either on models or better still on full sized units. The work need not be held up awaiting the results of these tests as the project can be begun along the old conservative lines and the tests can be carried out during the construction. If something to advantage is found, the construction details can then be changed. The costs of such tests would only be a small percentage of the cost of the entire project.

This is the first instance I have come across of walls being tested and we have built miles and miles of them and sunk millions upon millions of dollars in them and we have never tested out a wall to find where we stand.

I believe that the tests on Mr. Lacher's wall should have been carried to destruction so that we would know what factor of safety was obtainable. It would be interesting to know whether this factor was 1¼ or 3. I am inclined to think that it has a small factor; as to me it represents the case of a riprapped embankment on a steep slope. I have seen a number of such embankments fail.

F. H. Drury, M. W. S. E. It would seem to me that this discussion has developed into a series of guesswork.

I was of the opinion that the country had gotten to the point where permanence is to be considered rather than cheapness.

It seems to me the advance made in reinforced concrete and the use to which it is being put is such that that ought to be the solution for retaining walls. I understand that the C., B. & Q. has been spending millions of dollars during the past year or two in retaining walls and that they have used reinforced concrete walls almost entirely.

Unless land adjoining the railroad is worth nothing, and it becomes simply a matter of building a wall 3 or 4 ft. high to hold the embankment, it would seem to me they ought to build accurately, and having a knowledge of the compressive strength of concrete and the tensile strength of steel, there should be no necessity for guessing. It has become pretty nearly an exact science and the walls should be built to last forever and to save the land.

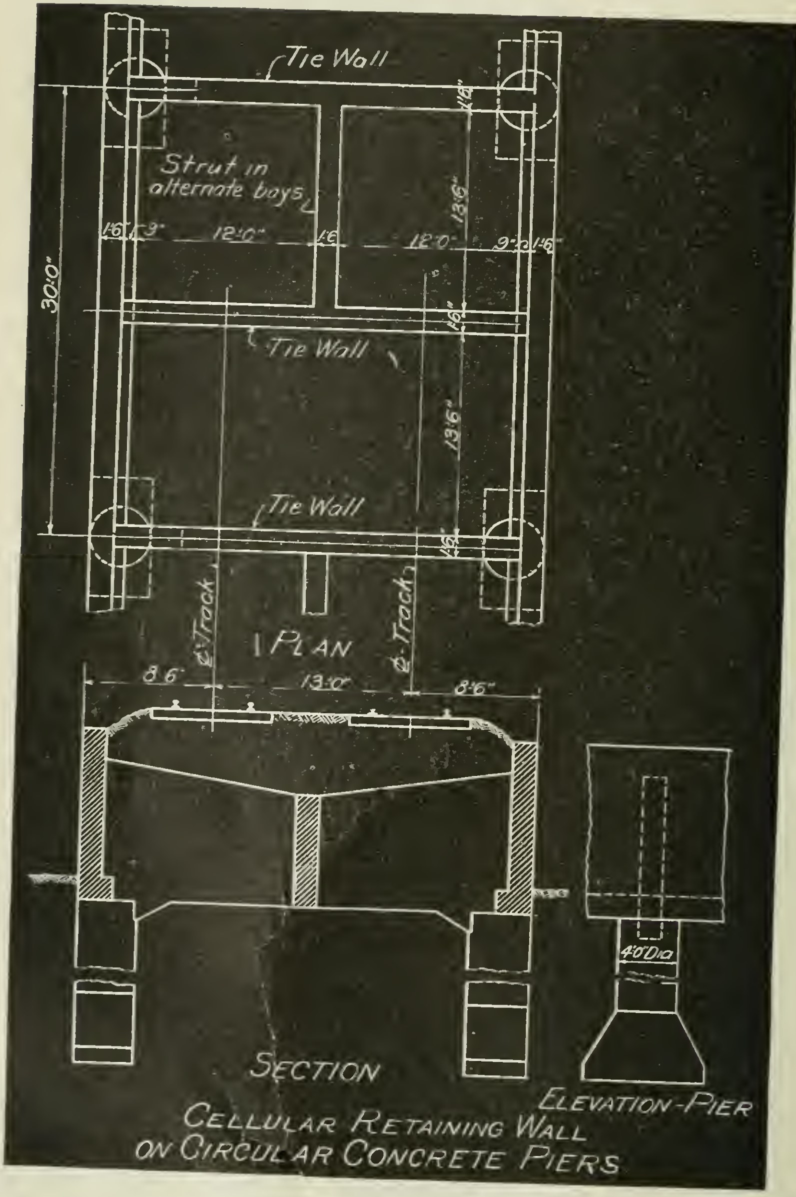
A. M. Wolf and A. W. Hoffmann: The writers have read with much interest Mr. Lacher's paper which is unquestionably a very valuable addition to the field of retaining wall literature. Mr. Lacher has fully succeeded in presenting his study of retaining walls from an entirely new viewpoint, and in opening up a portion of the field which has heretofore not been given the study it rightfully deserves.

The tests made for the purpose of determining the spread of a live load surcharge through the fill will unquestionably lead to further studies and investigations, by which many questions such as the following will be cleared up: the influence of the rate of movement of the live load, the influence of different kinds of filling material and also of the moisture of the filling material, upon the live load thrust. Mr. Lacher deserves much credit for making a start in the right direction, and for making the details and results of his investigations accessible to the engineering profession which has long waited for tests on this subject.

Aside from the tests which were incidental to the main question of design, it is apparent from the paper that studies were made of all types of retaining walls and all foundation methods that might possibly offer a good solution of the problem of designing a structure which could be carried on a very soft soil under which a good foundation was to be found only at a depth of approximately 80 ft. below the surface.

The author mentions that "marked" settlement of the track has taken place since the fill was orignally made and that additional material has been placed under the tracks from time to time. It must therefore be assumed that the fill had not completely settled up to the present time and that occasional filling is still required. This is further evidenced by the fact that many of the buildings in the vicinity show signs of unequal settlement.

Under these circumstances it seems certain that retaining walls and other structures on a foundation not carried down to good, firm soil will settle with the fill, causing unequal settlement of parts of the structure which might endanger adjacent property. If such a wall is built it will still be necessary to raise the tracks from time to time to bring them to the established grade, but it will be impossible to raise the wall at the same time. It would be possible to make provision for such future settlement by raising the parapet of the retaining walls above the track level at the time of building, but providing for future settlement is merely a guess at the most and, in general, the guess is in the wrong direction, as the condition of some structures would indicate. This at once suggests that it was evi-



CELLULAR RETAINING WALL ON CIRCULAR CONCRETE PIERS dently the desire to obtain a retaining wall structure which would give the same security as a mass wall on piles but that evidently no fit substitute was found.

In this connection the writers wish to suggest a method of construction which, although it may not be entirely feasible in this particular case (we are unable to state definitely regarding this, on account of lack of specific data as will hereinafter be noted), might prove very satisfactory where the more solid stratum of earth was not so far below ground level or where the intermediate strata do not carry too much water. This method would involve the use of circular concrete piers carried down to the gravel stratum in open wells and so located as to properly support the cellular wall described by the author (Fig. 5). This, of course, would only be feasible where, as mentioned above, water and quicksand in large quantities would not be encountered, their presence making the use of air necessary in sinking the caissons and thereby making the cost prohibitive for this class of work.

The suggested method of construction is shown in the accompanying sketch from which it will be seen that a cellular wall, covering the entire right-of-way (this could, of course, be modified) and consisting of outer walls 10 ft. high and 1 ft. 6 in. thick and 30 ft. apart tied together at intervals of 15 ft. by the walls 1 ft. 6 in. thick, which are in turn connected in pairs by longitudinal struts, is carried on circular concrete piers 4 ft. in diameter belled out at the bottom to give the required bearing area, and spaced 30 ft. centers on each side of the right-of-way.

These piers, or caissons as they are commonly called in Chicago where they are the standard type of foundation for tall buildings (and the method of construction is commonly known as the "Chicago method"), would be put down by open excavation, sheeting the holes with sections of heavy lagging as the excavation proceeded; however, as previously stated, should quicksand or water be encountered in great quantities it would be necessary to use compressed air in the caissons which would make the cost prohibitive.

Assuming that no great difficulty would be encountered in putting down these piers, the cost would probably be about $10.00 per foot of pier, based on Chicago costs, which would reduce to about $60 per foot of structure or about $30 per foot of wall, over and above the cost of the cellular wall described by the author. This is probably much less than the cost of pile foundation which would, in this case, as the author states, not give satisfaction.

If an investigation of the possibility of sinking such piers or caissons has been made it would be interesting to know the results of such investigation and the reasons why a pier foundation was not considered in this case. The additional cost of piers is, of course, considerable and exact knowledge of the local conditions is necessary to decide whether the money invested in such a foundation would offset the added advantages of a structure which would not require any maintenance as far as the structure, not including the fill, is concerned.

CLOSURE

The Author: The author is highly gratified with the discussion which his paper has brought forth, but cannot agree fully with the thought expressed by a number of the members that there is about to be a marked change in the practice of retaining wall design. Mr. Bates has given us much food for thought in his interesting discussion of the examples of the coal dealer's wall and the cross tie crib, but in applying these types we must be sure that we have a proper understanding of the conditions imposed by their application and a sense of fitness. While design based solely on the exercise of good judgment is proper under some conditions, only the most careful analysis will suffice in other cases.

Before we use the coal pile wall, let us consider the relative damage done by the failure of a wall supporting a coal pile and one supporting a railroad embankment. It is well to consider also, as Mr. Vent reminds us, that the coal wall will be largely rebuilt each year. In speaking so enthusiastically of his tie crib wall, Mr. Ford losses sight of the fact, that the walls he built are daily under his watchful care reinforced by mature judgment, and what is permissible and even highly commendable under such circumstances is not necessarily so when he has been transferred elsewhere. Mr. McCullough's observation in California is a good example to keep in mind.

It is a pretty well established fact that the present tendency, particularly on railroads, is toward permanent construction, partly because it involves less hazard but principally because it has proven cheaper, when based on the annual cost to maintain and perpetuate. This has resulted generally in the case of retaining walls in a massive type, either in stone or concrete, because we have known no better way to build them.

One condition imposed in the design of such a wall, as with nearly all of what we call permanent work, is that it shall retain its original shape and position, not only for the satisfaction of esthetic principles, but because in most structures, departure from the true line, or the vertical, has been taken as an omen for ultimate failure. If we can design structures which are permanent in the ordinary meaning of that term, and which are secure against failure, even though they suffer some distortion, and can thereby reduce the cost, we are justified in departing from conventional practice. However, we must be sure that they are really permanent and secure against failure.

In the rapid development of reinforced concrete, we have been constantly applying to that material, ideas which have had previous expression in other materials, notably wood and iron or steel, and in making such application we frequently fall into the error of trying to reproduce too closely the shape and detail of the timber or steel device we are attempting to form in concrete. Even though unit pieces of wood may be fastened together by dowels or mortises to form a very serviceable wall, it is not necessarily true that the use of unit pieces of concrete doweled together will prove the best concrete equivalent of the timber wall. The reinforced concrete warehouse is rarely built out of unit beams, planks and posts like its equivalent in timber.

It is the writer's contention that the true application of the timber crib idea is the monolithic wall shown in Fig. 4. No doubt it is crude as compared to the final evolution, but it is a step in the right direction. There are, of course, certain conditions under which unit concrete construction becomes imperative, but we must always be sure we know why we are using unit concrete instead of monolithic concrete, as the latter is the only form which really affords us the particular virtues of the material.

Mr. Vey points out the need of tests on retaining walls and the writer cannot too strongly confirm this. We have a great fund of information on the strength of materials, but almost nothing to bear out the prevailing theories of earth pressure. Tests to this end should, like other research, be carried on under laboratory conditions and methods, for thus only do we obtain the refinement necessary to eliminate all the variables except those under consideration. This fact was brought very forcibly to the writer's attention at various times during the test.

Messrs. Wolf and Hoffman call attention to the wisdom of providing surplus height for a wall of the cellular type on soft foundations to allow for settlement. On the walls at Milwaukee a surplus of 9″ to 15″ is provided.

In this connection it might be well to mention that the mass wall on piles has been used for most walls over 14 feet in height or closer than about 16 ft. to the center line of track. With increased experience or better foundations it may be permissible to make a bolder use of the new types of walls.

The use of concrete wells is suggested. This was also considered, not only for the walls, but for the street subways as well. The conditions existing, however, would require the use of pneumatic methods, involving a cost that would be much greater than the pile foundation. With the use of the concrete wells or other method affording equally good support for the wall, it would seem that the design of the superstructure would be controlled by consideration governing under ordinary circumstances.

As pointed out also by Mr. Bates, the wall shown in Fig. 5 has a number of marked advantages, but it is of limited application. For more than two tracks or for a wide right-of-way it becomes uneconomical, the ties must be made very heavy to be secure against uneven settlement. For only one track, with more than 10 feet of height, the structure becomes unstable, unless the foundations are such as to insure little settlement.

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METHODS OF INSTRUCTION IN ENGINEERING EXTENSION

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Next in importance to the general plan of organization of a Department of Engineering Extension comes the determination of methods of instruction. The methods described in this paper are not methods discovered by an exhaustive investigation, but those which have come within the range of the writer's experience in Wisconsin and Iowa.

Methods to be used depend on two things:

(1) Subjects to be taught or treated of.

(2) Character and geographic location of industries, municipalities or individuals to be reached.

The following methods are in use at the present time:

1. Lectures.
2. Class work.
3. Short courses.
4. Correspondence study.
5. Bulletins.
6. Co-operative and combination methods.

There are in reality only three methods; for short courses, bulletins and combination methods are only special developments of lectures, class work and correspondence study. These methods will be discussed in turn.

Lectures. In the field of Engineering Extension, the popular lecture, as generally understood, has no place, unless popular lectures on scientific topics are to be considered one of its legitimate functions. Lectures confined strictly to the field of Engineering Extension may be divided into three classes, (1) lectures before technical audiences on topics of engineering interest; (2) lectures given for instructional purposes before groups interested in particular topics in engineering or industry; (3) lectures before non-technical audiences partaking of the nature of general engineering advice.

The first class, lectures before technical audiences, comprises the papers and addresses usually given before engineering societies and need not be further discussed. The field for such lectures is very limited.

The field for instructional lectures before groups interested in particular topics is not extensive, except in large industrial centers where industries are concentrated, because there are few topics of general interest to men employed in widely different industries. The writer has given a number of noon lectures in shops on special topics with the co-operation of employers and local Y. M. C. A.'s.

The actual value of these single lectures as an educational force is doubtful, though numbers of men may be reached in this way. One of the most successful lectures of this type given by the writer was an illustrated lecture on "The Locomotive." This was given before an audience of one hundred and fifty men in a railroad shop while standing on the bed of a large planer with coat and collar hanging from the cross-rail. It is needless to say that such a lecture differs in form, subject matter, and manner of presentation from the "Common or garden variety." These lectures must be accompanied by illustrations or demonstrations to make them effective. Moving picture films can be used in this work and, when they are available, there is no difficulty in getting a crowd. At present, however, it seems that the real efficacy of the moving picture as an educational factor in Engineering Extension is yet to be demonstrated. Its efficacy as a "crowd getter" and publicity agent is not to be denied.

Lectures of real technical value can be given before class groups studying a particular course. These will be more fully discussed under class study. Lectures partaking of the nature of general engineering advice to be given before city councils, commercial clubs, etc., are just being developed in Iowa in connection with the Experiment Station. The demand for these must grow exactly as the demand for the services of a consulting engineer must grow in any state developing industrially.

On the whole, the lecture method may be said to be the easiest method of giving engineering extension instruction. It is a valuable publicity agent and can be used most efficiently in large industrial centers.

Class Study. To make class study a success as a means of extension instruction, two things are necessary, (1) a definite, laid out course of a certain number of lessons; (2) an instructor who has a strong personality and who knows how to teach extension classes.

The course may vary from a carefully outlined standard text book to the specially prepared printed or mimeographed text. Class study may be conducted in two ways, depending upon the subject taught. Subjects like mathematics and drawing must be taught by the individual method. Each man has his own lesson and works upon it, receiving a new lesson or task as soon as the one in hand is completed. Thus, in the same class all stages of advancement may be represented. Even totally different subjects may be taught in the same class. Such a class is not a recitation, it is more like a study hour, in which each student is writing out his own lesson.

Subjects in which there is chance for discussion may be taught by the class method, one lesson being covered at each meeting, and a new one assigned. Written work may or may not be done at the option of the student. According to the plan used in Iowa, written work must be done and an examination passed if a certificate is granted, and no certificate is granted for class work alone. In a class of this kind the instructor leads discussion, answers questions, and sees that all points are thoroughly understood. No written work is done during the class hour. Such subjects as plumbing, heating and ventilation and gas engines can be taught by this method.

The best instructor for class work is, of course, the regular extension man.

Unless classes are held near the central office, or unless there is a district extension instructor, traveling expenses and train schedules will prevent sending a regular extension man as often as once a week to meet a class. In this case, a good live local man can usually be found who will meet classes at so much per evening. When co-operating with Public Schools and Y. M. C. A.'s such instructors can more easily be found and often men of experience in this class of work can be secured.

One plan the writer has successfully tried is to alternate a local man with a regular extension man, i. e., once in two weeks a regular extension man meets the class. If the course is twenty lessons, he has ten lessons and the local man ten lessons. Sometimes it may be possible for the regular man to take only every third or every fourth meeting, or possibly only two in the whole course, the local man taking all the rest.

When the extension man can be present only at long intervals, the work becomes combination lecture and class work, the regular man giving two or three lectures and the local man all the class work. The lectures in this case are sometimes summaries of the work up to the present point reached or they may be interesting expansions of the work covered, all depending on the capacity of the class and the character of the course.

When the course is one of many, conducted by a city night school, the lecture by the extension man may be made an interesting feature for the whole night school and not for his class alone.

To sum up class study as a method of instruction, it is exceedingly effective, adapts itself well to co-operative plans with local agencies, but requires definite courses and careful supervision from regular extension men. It may be combined very effectively with lecture work and correspondence study.

Short Courses. The short course is distinctly an agricultural extension development and it by no means follows that it will be equally successful as an engineering extension development. There are many reasons for this statement, the chief one being the diversification of industry. An engineering extension short course should be highly specialized and adapted to the needs of one particular group or trade. If the course is advanced and the instruction given by lectures only, we have merely a development of lecture study, but the same rule of specialization holds good.

A short course for tradesmen should not consist of lectures, but rather of actual practice on some special trade feature under expert instructors. Such a course for painters and decorators was given last winter at Ames. Actual trade instruction under master craftsmen was given in graining, stenciling and tiffany. This course was a success in every way. It does not follow at all that short courses can be given for every trade. The following are the conditions which make a successful trade course possible:

(1) The trade must be capable of subdivision into special topics in one or more of which instruction can be given.

(2) The trade must require manual skill, technical knowledge, or both.

(3) The materials and equipment must be such as can be provided without too much expense.

It goes without saying that a careful study of conditions in the trade as to character of men, support of organized labor, number of men in the industry and their desire for further training must be made before short courses are offered, if their success is to be at all assured.

A development of the short course in the shape of a travelling short course for automobile owners and operators was put on in twenty-seven Iowa towns last winter and spring. An auto expert was sent out who gave five lectures a week, conducted an exhibit of auto appliances, rendered expert advice to car owners and adjusted numerous defects in machines. Local committees paid all expenses save the salary of the lecturer. This year thirty towns are on our circuit.

The short course on the whole is a very effective way of reaching special groups of men, for a brief length of time, but requires a great amount of preparation, advertising and supervision, and is really only an intensified form of class and lecture study.

Correspondence Study. Correspondence study as a method of instruction is too well known to need explanation. The writer's experience leads him to think that this method unaccompanied by class work of some sort is not successful in the elementary industrial work for the majority of students. There are young ambitious fellows who will do work well by correspondence, but on the whole in elementary correspondence work, the percentage of students dropping work is high. In the more advanced work correspondence study is one of the most effective ways of handling engineering extension work. There seems to be no reason why a number of preparatory and four-year engineering courses cannot be prepared and handled in this way.

To handle a large number of correspondence students requires a large office force. To avoid congestion of work in our department, we are having a number of correspondence papers corrected by local instructors who report on grades once a month to the central office. This is really a combination of class work and correspondence study. All papers from students working wholly by correspondence come to the central office.

How large the field for correspondence study is in engineering alone, is at present uncertain. It would seem that the great opportunity for this work is in the field of general arts and science, not comprehended under the term *engineering*.

Correspondence study is the "handy man" so to speak, of all forms of engineering extension work. It can be combined effectively with lecture study, class work and short courses, and makes each one of them more definite and valuable.

Bulletins. The bulletin is another form of extension work so familiar as to need no explanation. The most recent and perhaps most interesting development of this form of extension work is in connection with the engineering experiment station. The extension department is the sales organization for the experiment station. It advertises, popularizes and assists in distributing experiment station wares as well as its own particular products.

The Extension Department has published a bulletin entitled "What Iowa State College Can Do for the Municipalities." This is a plain statement of what the Experiment Station can do in the way of advice and tests. It is a catalog of its wares, so to speak.

The Extension Department, too, will publish in simple and popular form results of investigations of interest in special lines. It publishes *no technical* bulletins, these are left entirely to the Experiment Station. For example, the department has now in press four bulletins on automobile topics for automobile owners. It has already published a gas engine trouble chart and a bulletin on the oiling of streets. For the public libraries of the state, it has published a list of pamphlets of assistance to librarians interested in vocational education and vocational guidance. Full particulars are given as to the content, publishers and price of each pamphlet.

There has also been published a circular of books recommended for tradesmen and mechanics. All are of a very practical character and sufficiently elementary for the average workman to read. No "popular" treatises are included, for they as a rule disgust the real craftsman. He knows the difference between simplicity and superficiality. This list contains the name of the book, the author, the price, the publisher and two or three characterizing sentences giving the purpose of the book and the particular class of persons to whom it appeals. The list is, of course, divided according to the different trades and occupations. It is distributed to all public libraries and to any individuals desiring it.

In getting out publications of this sort, the department searches for fields in which plain, concise information is lacking and endeavors to get that information to the interested public in readable form. In this, the department is strictly an opportunist. Should questions arise involving scientific research, these are turned over to the Experiment Station.

Co-operative Plans. It has been our experience many times to meet prejudice on the part of organizations which have been and are engaged in somewhat similar work, such as public night schools, Y. M. C. A.'s and social settlements. The secret of success here is co-operation unaccompanied by motives of self-aggrandizement and self-seeking. To assist in organizing and conducting a course in which no engineering extension material is used is perfectly legitimate provided the work given meets the needs of the parties concerned. The writer has in mind a group of forty men enrolled in one plant for whom a special course in drawing, adapted to their needs, is furnished by the employer. An extension instructor has assisted in carrying on this work, using but little extension material. The course has been very successful and the department expects to grant certificates on its completion in accordance with the recommendations of the extension instructor. No work comes to the central office, the expense entailed is very slight, and the men have something which fits their needs better than any extension course now available.

In carrying on this co-operative work, three plans are used, any one of which may be adopted by the co-operating organization.

(Plan 1) All responsibility on the engineering extension department.

(Plan 2) Joint responsibility.

(Plan 3) All responsibility taken by the co-operating organization.

One of these three plans will be acceptable to almost any organization. The department has had very good success with all three.

THE TECHNICAL SERVICE BUREAU.

The newest development in the field of engineering extension and the one in which engineers are particularly interested is the Technical Service Bureau organized jointly by the Experiment Station and Engineering Extension Department. The relation between these two has already been suggested as that of a manufacturing plant and a sales organization. The function of the bureau is an educational one in making available so far as possible the services of the Engineering Experiment Station. These services consist of preliminary expert advice as given by members of the Experiment Station Staff and tests made in the station laboratories.

Examples of Service Rendered. In one case a city had been considering for a long time plans for sewage disposal. An engineer was sent there to confer with the authorities and give general advice as to possible methods and approximate cost. As a result the work is now being vigorously carried forward. In this connection let me say that the representatives of the Technical Service Bureau are not allowed to do consulting work and therefore cannot use the opportunities offered by the bureau for the purpose of building up a private practice. The report of the engineer sent out for this work is made to the Technical Service Bureau and a copy sent to the parties concerned.

A short time ago a set of specifications for a small electric light plant came to our office for checking. We did not believe this to be within our province as a service bureau. On inquiry it developed that no engineer had been employed. Our recommendation was that a competent engineer be employed who would no doubt make certain changes in the specifications.

Some months ago a request came in from a small contracting firm asking to have one of the engineers call. On investigation he found that they were trying to pump sand and water with a suction lift of twenty feet. In this case the trouble was quickly remedied, money saved, and the services of a consulting engineer not required.

For many years people have consulted the family rector, doctor or lawyer in case of trouble in "mind, body or estate." They have not, however, been educated to consult the engineer not only in time of trouble, but in order to keep out of trouble. This education of the public may well be considered engineering promotion work and bears the same relation to the engineer that preventive medicine does to the physician.

Tests and Analyses. The Experiment Station is constantly receiving from the cities, towns, counties, townships, factories and other corporations, and the individual citizens of Iowa, samples of cement, concrete, brick, building tile, sewer pipe, drain tile, asphalt and other paving materials, iron, steel, wood, stone, gravel, sand, clay, cement, materials, fuels, water, sewage, etc., with the request that they be tested and the results reported. The volume of such work is increasing and more and more the Engineering Experiment Station is coming to be considered the final authority to decide many questions of quality of materials, or the value of fuels, clays and other materials. For public work such as for county and municipal governments, no charge is made for the time of the regular staff and equipment. The municipality having the tests made is expected to pay transportation charges. To secure this concession, application must be made by a properly accredited officer in behalf of the governing body on a regular form which can be secured on application. The amount and character of this service will be so restricted as not to overburden the Experiment Station Staff nor interfere seriously with its investigations, nor will it be done where it would take the place of the work of the regular testing departments which should be maintained by cities of fair size, nor where it would take the place of the work of a regular inspection bureau in making tests on the ground in connection with inspection during construction.

In order to keep the engineers of the state fully in touch with the activities of the bureau a committee of fourteen representative engineers has been appointed.

This committee passes upon all questions of the relations of the Technical Service Bureau to the practicing engineers of the state. Full records are kept of all service trips and investigations, and summarized reports are furnished all committee members. The Executive Committee holds meetings when needed, and the full committee meets occasionally at Ames. The Advisory Committee will assist in arranging a fair and impartial method by which the Bureau can bring the names of the many very competent engineers of the state to the attention of those authorities and persons who ought to employ them to secure better and more efficient work. The object is better service for the public, through competent well paid engineering service.

Summary. In conclusion, it may be stated that engineering extension cannot hope to reach the large numbers of people that are reached by university extension. The field is too narrow and does not offer the possibility of large popular audiences. On the other hand, the results of its work of instruction can be more definitely seen and stated. Engineering projects will be carried out in accordance with advice received, the efficiency of men will be increased and their wages raised.

In short, engineering extension is intensive and special, university extension is extensive and general. A *university extension* man may do work in a number of well tried ways and be reasonably sure of success. An *engineering extension* man must try new methods and run the chance of failure.

Initiative, persistence and adaptability to conditions are the prime requisites, no matter what methods of instruction may be used.

I thank you very kindly for your attention, and if there are any questions, I should be glad to answer them and I should be particularly glad to get your opinion on the subject of a technical service bureau, and whether such a bureau is in danger of invading the field of the consulting engineer or whether it will promote it.

DISCUSSION

President Jackson: We have had with us this evening a person whom I suppose I might call an exponent of one of the newest and most important activities of our state universities, or, I might say, the universities of the people; that is, the work which some of our universities are undertaking to make the university possible, not only for those young men of ability and having the desire who can come to some particular point and spend from three to four years, but to so extend our university work that the young men wherever they may be located can have a university course. In other words, if we may hark back to one of our noted men, this plan, the university extension, would make possible the carrying of the university to such men as John Muir in Wisconsin, who only through the most serious hardships, not only to himself but to a certain extent to his family, was able to obtain his college course, and would make it possible for such men to have their college course and get their degree without spending three to four years at a university town.

I have listened with great interest, indeed, to what Professor Smith has told us this evening. He has very clearly demonstrated to us that his work is in the line of conservation of human endeavor, which, when we come down to the facts of the matter, is possibly even more important than some of the other conservations just now so popular in America.

I could not help but wonder when Professor Smith told about these lectures from the planer bed, with his coat hanging on the cross bar and his collar off, whether he had learned how to do that from our great Bob. He will have to tell you that later. We always thought that Bob was the best fellow in Wisconsin to do that kind of a job. I would not wonder but that Professor Smith may have been a good second.

I do not want to call upon anyone tonight. This is a big enough subject and an important enough subject to warrant all of you getting up promptly and telling us what you believe about this matter of university extension, and the paper is now open for general discussion.

F. W. Kasschaum, Jr., M. W. S. E.: Mr. President, I want to tell a little experience I had in a Southern State. I was connected with a steel plant and was called upon to put in a bid on some bridge work, a span, sixteen feet roadway, 100 lb. per sq. ft. live load, 50 feet long, and wanted it put up according to the best engineering specifications. Not knowing what they considered the best, I got the specifications of the United States government and had the bridge designed and put in my bid. When the bids were opened there was a bid from a firm in the state of Indiana, based on the use of five inch I beams. The southern state evidently has not had a university extension course. They have a saying down there that the bridges are not shipped on cars but on postal cards. I noticed in one of the periodicals lately some bridge specifications gotten up in Iowa, and if this engineering extension course is the cause of those specifications, I really think it is the best thing for the engineers of the country because the engineer cannot design bridges in competition with some of the bridge sharps now doing business.

Director Smith: I want to say if this came from Iowa it was from the highway commission, an institution authorized by the Thirty-first Assembly. They have supervision of all contracts. There was a great deal of opposition at the outset, but I want to say it has lessened very much this year and I have no doubt that the highway commission law not only will not be repealed but will stand on the statute book with very little change, because the people and engineers in general are pleased with it.

Douglas A. Graham, M. W. S. E.: Mr. President, I have listened with a great deal of interest to Mr. Smith's description of the scope of the work of the technical service board, and I judge from his remarks that there had been some discussion as to whether the work of this board invaded the field of the professional man throughout the state. I would say, for one, that I believe it does not. It has always seemed to me that the division between the work of such a state board and the work which it should not undertake should be decided from the standpoint of the welfare of the community rather than of its purse. To illustrate: if a town is suffering from the want of water or from a bad water supply, it seems to me within the field of the public authorities to require that community to improve its service and to advise them as to the procedure to follow to remedy their difficulties. Such work is in the interest of the welfare of the community. But when it comes to making detailed advisory reports, with plans and estimates of cost, or of choosing between several supplies of equal sanitary merit, a public board is invading the field of the professional man. In the same way work tending to improve the skill of the workers throughout the state is of benefit to the entire state, but work tending to save money to a municipality or to any industrial concern should properly be left to the private engineering profession. It seemed to me, from the way Professor Smith described his work and its scope, that he had solved this problem in a very admirable manner.

Ernest McCullough, M. W. S. E.: I think a bureau such as Professor Smith has described would be a very good thing in every state, in order that people would really know something about the engineers who are in private practice. The correspondence schools, with their wholesale advertising, are pretty well fixing it in the public mind that engineering is a munificently paid profession, that there is a wonderful dearth of engineers and that every young man in the country ought to study engineering. But the advertisements fail to show how the man is to be connected up with the work. An engineering service bureau such as Professor Smith speaks of should certainly do a great work in introducing the engineer to his public. The whole idea at present is to fill the schools and turn the boys out, but nothing as yet has been attempted along very good lines to connect the graduates with something better than a job. If a graduate could really be turned into a line of work where he could feel that he was a professional man and that people with whom he came in contact knew that he was a professional man, perhaps, we will say on the same plane, with medical men, lawyers and clergymen, it will be a great help for the engineer.

University extension work always interested me. It was twenty-eight years ago that I first started teaching in evening classes, not for the money there was in it, because the first class that I taught for several years carried no pay at all, but as a purely eleemosynary proposition, and nearly every year since I have had work of that kind to do. When vacation starts I make up my mind that I will not go back next winter because the family really ought to see more of me in the evenings. The fall comes along, the announcements come out that I am to have a class, and I go back to it again. It is something from which it is hard to break away.

The world today is paying a lot of attention to the men who in the early years failed, sometimes through their own fault, sometimes through the fault of environment, perhaps the mistakes of parents, to get what they considered was a proper chance, and the university extension work comes right in here to help such men.

The first university extension work was started by Glasgow University early in the last century. The wonderful industrial development of Great Britain led to a demand for trained men that simply could not be met. Boys who went in to study engineering were apprenticed in shops and in offices of engineers in private practice and picked up their education as they went on. Glasgow University commenced giving extension lectures to young mechanics and young engineer apprentices, which work gradually spread over the entire kingdom, until along in 1869, after an investigation made by a commission of engineers, the Kensington Science and Art classes were started with a great deal of night class work, and hundreds of cramming schools sprang up all through the country.

Within the last few years engineering education in the British schools bears a close resemblance to that given in American schools. The apprenticeship system is still retained to some extent. A boy is apprenticed at the age of fourteen to work for nothing until he is twenty-one, his parents paying a premium for the privilege. While instruction is supposed to be given him by his master he receives very little outside of the evening classes in local municipal technical schools, or in crammer schools for the Science and Arts examinations. A young man graduating from an engineering school must also work for nothing for several years but pays no premium. The apprenticeship system was never favored in the United States, but there are present indications that it may come in, and in a far better form than the world so far has witnessed. I refer to the part time instruction wherein the employer employs two boys at small pay and they alternate in attending classes.

Tyndall, Faraday and other eminent British scientists made their lasting reputations as university extension lecturers. These master minds placed this work on a high plane in Great Britain, from which it has never receded, and a plane to which it is rapidly approaching in the United States.

F. E. Davidson, M. W. S. E.: Mr. President, I have listened to this talk with a good deal of interest. It is my personal thought that the state can well afford to devote more money to this extension work and perhaps somewhat less to the actual university course of engineering. In other words, I am convinced that the rivalry between our universities for students is resulting in turning out more alleged engineers than there is necessary to meet the demand. Today I will venture the assertion that there is in Chicago at least sixty-five per cent of all of the recent graduates in engineering who are out of work. Yet these students have spent their four or six years in the university, have done hard work to secure a degree in engineering. There is nothing for them to do; there are too many engineers, at least, too many alleged engineers; there are too many men who are trying to do engineering who ought to be skilled artisans, skilled workmen. I mean that in all sincerity. I am an Iowa man, a graduate of the college which Director Smith represents, and I think I know the state of Iowa pretty well. There is hardly a city of any size in the state in which I have not been and have not acquaintances. I know and love the state. At the same time, looking back over my acquaintance at the university as well as the State College of Iowa and the other schools in Iowa—and, by the way, there is a college or university in almost every town in the state of Iowa which is turning out engineers or alleged engineers—I am absolutely firm in my belief, Mr. President, that the money that has been spent in university work itself could be better expended in university extension work; in making more skilled workmen, skilled artisans, rather than in turning out a lot of alleged engineers who are drifting out of the profession in a very short time, and who will always feel that they have devoted a great many years to hard work which has accomplished but very little, leaving out of the question the training which comes from an engineering course in any university. If I had a dozen children and I was going to send them to the university they would have to take the engineering course purely for the training, no matter what they were going to do, because there is no work I know of that is so difficult as the work in engineering. But the rivalry in getting students, the boosting being done by the universities themselves is getting into the class rooms, made up of young men, perhaps one-half, perhaps two-thirds of whom have no more business entering the engineering profession than I have of going to a school of theology.

I think, Mr. Chairman, that this is a serious question, and I will suggest that Director Smith speak on this subject. I would like to know his own thoughts based on his own observation. Is it not a fact that we have too many alleged engineers and not enough skilled artisans? I claim yes.

President Jackson: I think personally that there is a great deal in what Mr. Davidson has said and that many of us graduate from engineering courses when we ought to graduate from something else. I do not believe there is any question about that.

Mr. Williams, if you have any remarks you would like to make we shall be glad to hear from you.

Prof. S. N. Williams: Mr. President and Gentleman of the Society. I read not long ago in one of the many valuable magazines published in our country, the statement that baseball championships were habitually decided in fractions of a second. I appreciate the necessity of quick improvement of time by all, whether engineers, baseball men or others, so express appreciation of the kindness shown me for years past, up to the present, by your Secretary in the use of your library in getting information so easily accessible; also to express appreciation of the work done by our great college at Ames, which Director Smith has represented to you this evening, not alone in agriculture but more recently in other directions, especially in the line of engineering extension. As I have consulted your periodicals in studies for the American Railway Engineering Association, I have been delighted with the breadth, variety and extent of information covered by the different lines of engineering work, civil, mechanical, mining, marine and others; it is a wonder to me how far the engineering profession will go in the future in accommodating itself to the needs of humanity.

I have been pleased with the way in which the agricultural department of the State College of Iowa has covered the field in showing farmers how to improve crops, develop their resources in various ways and in developing what we might call agricultural extension work. I have also been pleased with the way in which it has more recently taken up the department of roads and bridges. A few years ago I had occasion to look up the subject of bridges, and found both Illinois and New York were giving excellent information while Iowa was just commencing on highway bridges. Since that time it has greatly developed this branch.

As an engineer of many years' experience I am deeply interested, not so much in the subject which our brother here has mentioned, that of producing too many engineers, as in the extension of engineering information to the people at large. The college with which I have had the honor to be connected is known as a classical college and I did much hard work years ago in trying to build up an engineering department, which was mainly limited to railway engineering, that being my particular field. I was surprised this year to see how much attention it is now giving to the subject of agriculture. Here is an old classical college picking up some of the crumbs falling from the bountiful table at Ames giving students in the institution new and practical information. It pleases me greatly to know it is broadening out and getting more liberal ideas. You might expect that, of course, from a college of liberal arts.

To take up some points Director Smith has mentioned, I personally am fond of moving pictures. I presume most of you enjoy these as well as myself. Several years ago I was delighted with an exhibit in the Coliseum, of a ditching machine company from Indiana. It was giving exemplifications of the work of their machine. I said that is a good thing; it shows just what the ditcher is capable of doing and does so without the trouble of going out in the field a good many miles to see how it is done. I grasped the ideas at once and believe that moving pictures ought to be used much more than they are in exemplifying engineering processes. I think our friends at Ames could use them to advantage as compared with the object exhibits of the agricultural department.

I sympathize with him in the trouble he has experienced, as have most engineers, in finding there is a prevalent or popular opinion with many councilmen and municipalities that they do not need an engineer; they know it all themselves. I had to fight that idea and one of the best engineers in the state was subjected to annoyance caused by the way in which his services were taken by the town council, who thought, they knew a little better than he did what should be done. Pardon me for mentioning this because it touched me in a vital spot, as he was one of my best men. You probably understand this without giving further illustrations.

Now, you know we have to come to Chicago for a great many fine ideas, and during the past nine months I have been making a diligent study of the Chicago Daily Tribune; I confess it has been something of a postgraduate course. I do not know whether you prefer some other Chicago daily or not, but I have a liking for it. There are other daily papers, but the Tribune has two features in which I am much interested. One is the Department of Public Health by Dr. Evans. For many years I have paid much attention to the subject of sanitation and have given my students in sanitary engineering the benefit of the points thus secured both on account of the course and my interest in the subject. His articles, while more, perhaps, along the line of hygiene, represent procedure I recommend to the director as being helpful for his purposes, that is, to use the Iowa press by putting engineering information in a popular form and publishing it in daily or weekly papers.

I have also enjoyed the legal articles published for the good of the public, and those with reference to difficulties being met here in city street matters.

As Ames stands among the best colleges, not alone in the United States but also in the world, we are glad to offer these suggestions.

While not urging extension of college resources, I would like to make one correction: we have not so many engineering schools as our friend would indicate. We have first class departments at Ames and Iowa City, also the Highland Park engineering school, the department at Cornell College, Mt. Vernon, and more recently at Iowa College in Grinnell, which completes the list. Then we are making an effort to give engineering information, so that while possibly afflicted with a multiplicity of schools and colleges in Iowa, we hardly think so in engineering.

Robert Y. Williams, M. W. S. E.: In extension work, one of the pleasing things to the teacher is to have a voluntary discussion by the audience follow the regular lecture. Therefore, while I came here merely to hear Mr. Smith's lecture, I desire to express my appreciation of his interesting talk by adding a few words about a similar work that is being done in Illinois.

The Illinois Miners' and Mechanics' Institutes, of which I am the director, began active work thirteen months ago. In some respects this work is quite different from that in Iowa. In the first place, the money for the Illinois work does not come from the University of Illinois. It comes from a special appropriation of $15,000 per annum made by the State Legislature. The administration of the institute, however, is vested in the trustees of the University, and the trustees have placed the details of organization under the Department of Mining Engineering. In the second place, instead of attempting to offer educational assistance to employees in several different industries, the Illinois endeavor has been confined to the men who work in and about the coal mines. The reason for this is that the establishment of the Institute was due to legislation which followed the Cherry Mine fire and which was enacted in order to lessen the dangers attending the mining of coal.

There are 80,000 coal miners in Illinois. This industrial army is mining coal in more than 800 mines which are scattered over an area of 36,800 square miles. The 269 towns or cities in which these miners live may be divided into 3 groups: the first group contains 25 communities in each of which more than 1,000 miners live, the second group contains 85 towns with 200 to 1,000 miners, and the third group 159 towns with each less than 200 miners. If sufficient money is appropriated by the Legislature, it is the plan of the Institutes to hold regular sessions in the large towns of the first group on two nights each week during 8 months of the year beginning the first of October; to offer unit courses four nights each week during two months of each year in the 85 towns of the second group; and through correspondence courses to make technical education possible for the men who live in the small towns of the third group.

The regular courses are conducted as follows: In the first place, the instructor gives a series of short and simple lectures (not popular lectures) on a particular phase of coal mining, such as "Mine Gases." In the second place, all the men in the class are given an Instruction Pamphlet published by the Institutes and containing a very full synopsis of the lectures. In the third place the instructor, either himself or in co-operation with a high school teacher, illustrates the particular points of the lectures with experiments, and it is remarkable how the men like the experiments. And finally, toward the end of each lecture the instructor helps the men in arithmetic by giving problems on the subject being studied. Most of the men are deficient in arithmetic, and practically all mining men are interested in working problems. One miner fifty years of age could not add when he enrolled in the night school; but he was able to work in fractions at the completion of one of the coal mining courses and was the most delighted man in the class.

During the first year, classes have been organized in 13 towns; 464 two-hour evening sessions have been held; the attendance has averaged 26 at each session and the total man-lecture attendance has been about 12,000. The places of meeting have usually been township high schools which have been donated for this purpose by the School Boards with free light, heat and janitor service.

Director Smith has mentioned the difficulty of getting the proper men to conduct these courses. If a boy goes to college possibly his father is paying the bill, but he wants the sheepskin and will remain at college no matter if some of the teachers appear to him to be absolutely "no good." The Institute students, however, if they take a dislike to the instructor, will simply remain at home. Consequently, the Institute instructor must be specially qualified; (1) he must be technically trained, otherwise the men say, "How can he teach us if he has not been technically trained?" (2) he must have had practical experience or woe betide him; the wilting of the collar will not save him. (3) He must be a very congenial person in order to gain the friendship of the miners.

With these few scattered, quickly put together remarks, I want to thank you all for allowing me this opportunity to bring to your attention the work of the Illinois Miners' and Mechanics' Institutes, and to invite your investigation of our methods.

Philip B. Woodworth, M. W. S. E.: All I have to say I can say in a very short time. I am intensely interested in the paper of to-night and I do not feel like saying any definite thing to you but to hurrah for the kind of work that Director Smith has been describing here to-night, because it does seem to me that few of us appreciate what it means to stand up before an audience anywhere and speak of work being done as he has explained to us, all laudable enough, I think, in our estimation, and to say that college credit will be given for that kind of work as engineers and in regularly organized schools.

I had the great pleasure of being, with our worthy president, last summer, seated at a table with a gentleman now living, who was the first engineering graduate of one of the leading universities of this country, and who was not recognized by a single member of his class when he stood up to graduate. In fact, a petition had been circulated by the people in that university, by his classmates, requesting that he should not appear; he was graduating as an engineer. Now, that man is within our memory and is still living

Not very long ago a considerable sum of money was set aside to look out for just this kind of work. It fell into the hands of certain men and they questioned whether it could be done. There is just one standard way it can be done; only that and no other way. I am just trying to get at what Professor Smith has been describing to us to-night, going out and disseminating engineering information. This is entirely distinct from a couple of criticisms offered here to-night, and one of them is about the call for engineers, that we should reduce the output of the engineering schools. Do not waste any sympathy on them. They are taking care of themselves first rate. You need not waste any sympathy on the engineering graduate of to-day, because the records go to show that they are pretty well taken care of and they are about three to one against the other fellows. Do not necessarily confuse them with the consulting engineer. He belongs to another type.

F. H. Wright, M. W. S. E.: Mr. President, if your will excuse me for getting back, Mr. Davidson said a few minutes ago that there were too many engineers. I am like Bernard Shaw. I am going to disagree with him and then I am going to prove he is right. There are not too many engineers, but they ought to be at work. That is where the trouble is. There are too many for the jobs there are at present. Mr. Smith and his technical service bureau I think will help remedy this. In my experience in knocking around the country I have had to do with local boards and small town councils and people like that. They are business men, but when it comes to engineering and matters of which they have charge, they are, to put it mildly, ignorant, and the man who has to do business with them directly, that is, the local engineer or surveyor, whoever he may be, perhaps does not know any too much himself, and perhaps he is young, and whatever he is they always let him get up because it looks well to have an engineer address them. But they always take his remarks with a great deal of skepticism and say, "Well, that boy will come out all right but he thinks he knows an awful lot." If somebody comes from the state university and gives them some good advice they will believe what the young fellow has been telling them and then they will go ahead and do the thing in the right way.

I was down in southeastern Missouri some few years ago connected with some ditch work. They had what they called a county judge. He was about what might be called a county engineer. That is, his duties were to pass on public work and decide how much money they ought to spend and then appoint a board of commissioners or viewers who would decide to have a ditch district here or there and build a ditch. Then they would call a surveyor in and let him run a line and some levels and lay it out for them. In running that line he would be supposed to follow a certain section or township line, and of course, when he got to a certain point, if some property owner had enough influence to get him to swing it, he was to swing it. I have run a line myself for one ditch that was about eleven miles long and then run another one two miles from it and at points where we had to swing to satisfy property owners they would approach to less than a quarter of a mile apart, whereas the system should have been laid out with a main ditch with laterals and perhaps not another parallel ditch in twelve miles. I brought this to the attention of the commissioners in charge and advised that they should have a survey made of the whole territory to be drained. They could not understand why you could build the one ditch cheaper than you could three or four small ones, but eventually they did come to it. This was not a small matter. Perhaps a million dollars was spent needlessly in that way. Some engineer, I think it was President MacHenry of the Northern Pacific, said that an engineer was a man who could take a dollar and spend it as easily and make it go as far as the average man could two dollars. I think that is about the truth of it.

I had another case in a small town where I was a city engineer. Different matters used to come up and, of course, I would be called in for my learned advice, and if the council felt like taking it they would take it, and if they did not they would do something else. But the city attorney had a great deal of influence and also the secretary of the board of public affairs, who was also another attorney. I always noticed when a lawyer got up to speak he had a way of getting away with the goods, no matter what he said. This was a very flat town and right back of it there were some very high hills and when it rained the flood was terrific. I remember through the main part of the town there was an alley, which had an open ditch, they wanted to cover. I had made a sort of a tentative investigation of this thing. It had a drainage area in the flat of something like a square mile, besides quite a bit more from the hills; I do not know how much. One evening I was preparing some sort of an estimate in the next room to the council when they were in session and the question arose of covering this ditch and putting in some kind of a culvert. The grade was such that there would not have been over a foot fall in about a half mile. The secretary of the board of public affairs suggested that they put a smooth, sanitary, vitrified pipe; on account of the smooth surface the friction would be so much eliminated that the velocity of flow was so great that very small pipe would drain an immense area. He told them the capacity of a twenty-inch pipe—he had looked this up, in a book giving the drainage that a twenty-inch pipe would carry—and he so convinced the council that before I got back in the room they were already in the notion of buying three carloads of pipe. One of the board happened to be superintendent of the Arkansas Midland Railway Company. I do not think it is any worse there than it is in lots of other states. But he happened to be a superintendent of a railroad company, and had had some experience with putting pipe under tracks, and he did not believe what this fellow said, so he asked me what I thought about it. I told him I figured out about a seven-foot sewer was necessary. So they did not buy the pipe. There was another case where I think the technical service bureau could have done a little good and have straightened things out a bit.

President Jackson: I want to say that we never wish to choke off discussion; we want to hear from everybody who has some remarks to make, but we want all to be just as brief as possible now.

Mr. Davidson: Mr. President, I will make it very brief.

In regard to Director Smith's suggestion as to the special service which they are rendering to communities, I cannot conceive of anything that is of more value than the particular service that the extension bureaus are giving, that is, to educate communities as to the needs of the services of experts. I think it is exceedingly valuable.

Referring to what Mr. Wright said, I also wish to bring out the fact that our universities do not devote enough time to the creating, as we may term it, or the training of engineers as men. There is too much time devoted to the mere study of mathematics and the technical branches of different lines of engineering, not enough time devoted to the bringing out of other qualities of a man or a young student which have more influence in making his future than anything he may learn in the way of technical knowledge while in school. I know something of the training which the student receives at Cornell. I had a brother who attended there for some time and he used to tell me about the training he received. I know that the training the boys got there brought out the inherent qualities of manhood, made the men better mixers, made them better students of human nature and students of character and I take it that these qualities are of as vital importance in any engineering school as a mere training of the mind along certain particular engineering subjects. I think that perhaps one reason why so many of our engineering students do not succeed as fast as graduates of other professions is that they have not been trained along proper lines. One of the most magnificent examples of success that I know of, is the last honorary member elected to the Western Society of Engineers. Colonel Goethals is not only the trained scientist but he is a student of men and his success as an engineer without question has been as largely due to the fact that he knows men as to the fact that he knows engineering.

Ray C. Yeoman, ASSOC. M. W. S. E.: Mr. President, I am thoroughly in accord with the paper of this evening by Director Smith of Iowa State College. I want to remark, however, that Mr. Davidson has the right spirit and the right idea. This commission is a good advertising agent for the engineer. As a rule, the engineer is a poor advertiser. You can go to any small town in the state and you will find a dozen lawyers and you can get them at a minute's notice, but do your councilmen know of any engineers that are competent? The engineers are people who like to do things but do not say very much. They keep still and saw wood pretty well, but they are poor advertising agents. I believe, as Mr. Davidson has suggested that some kind of training, modern business training, for engineering students would be a grand thing. I have been thinking along that line for a past year or two and have outlined in a simple way a course of that kind, but it has not been perfected to that stage where I want to try it out. Before the year is over this course will be offered as an elective in our school.

There is one other point. The engineering students are poor public speakers. A course in public speaking as well as in modern business would be of great benefit to them. How many engineers can get up before a council or board of directors and tell them what they know? You will find very few of them. I find in getting my boys up to tell a story of what they have done or what they are going to do, or bring up an argument in favor of one kind of a system or another, that they do not know how to begin. They do not know how to start the subject at the beginning and carry it on logically to the end so that the layman can understand it. I have tried to get around this by giving a course called seminar at the end of the senior year, in which the boys have an opportunity to practice this line of work. There are three recitations a week in which both impromptu and prepared subjects are given and I find a very great improvement and plenty of enthusiasm created in those three or four months' time. It is proving a great success. If more of this were done in school it would be much better. Engineering training is too often given entirely to drafting and mathematics. One of the problems in the above course is to investigate a grocery store or laundry or other industries which one would say are far from engineering and report orally, and with the assistance of diagrams and outline how that business is being carried on. I find it is a great training for them.

I believe that this university extension that Director Smith is carrying out is going to help the engineer to find and do his work as he should.

President Jackson: It is getting so late that I must close the discussion, but we are going to give Professor Smith a closure and when he is talking I am going to suggest that any of you who have questions shoot them at him and I am sure that he will be glad to have you do it and will be glad to answer them.

Director Smith: In regard to one question that has been brought up, that we have too many engineers, that is a pretty big question for me to discuss, but of one thing I am sure and that is that we advise too many young men to become engineers. It sounds so well to say that Charley is going to be an engineer. It sounds a lot better than to say Charley is going to be a machinist or a foundryman or something of that sort and we must get over that idea. There, I believe, is the place to begin. I have no hesitation at all when I talk to young fellows,—and I talk to a good many of them, if I have doubts of their ability,—in telling them that engineering is an exceedingly serious profession and that they should consider long and well before going into it; that it is going to cost time and money to do it; that there is no royal road to the profession; that the road is long and hard and unless they are willing to make the necessary sacrifices they had better not try it. I believe I have turned some young men away from the profession and I believe I can say I am glad I did, although I remember one time when I was called upon the carpet by the head of the institution and asked why I had advised a certain young man not to become an engineer, because he had intended to enter the department of engineering in that particular institution and would have made one more student. I am sorry to say that I believe our engineering colleges are too anxious for students.

We have at Ames what we call a two years' course. It is for the boys who cannot take the regular work in engineering, who are not prepared for it and who intend to become workmen and tradesmen, and I found before that course had been going on very long that a number of students and some of the instructors were talking to those young fellows and telling them that the thing for them to do was not to take the two year course, but to study longer and harder and make up grades, and take a four year course. I do not believe that that is a wise thing for a very large number of those young men and we have had to arrange so that their advice has to come from a particular department now and not through those who are particularly interested in getting them into a certain course.

Mr. Williams spoke about a synopsis of a lecture. I was very much interested in that and I would like to ask you, Mr. Williams, do you give out that synopsis before or after the lecture?

Mr. Williams: We have it printed and hand the whole book to the man so that he has it before he comes, as much as he can before he has the lecture. Then the instructor brings it out and he has it to take home with him to digest.

Director Smith: The idea I have had, and I think it works out successfully, is that before the lecture is given the synopsis should be given to the student. Preferably he should have a week's time to study it before he comes, and very likely he will have some questions so that the instructor will not have to deliver any cut and dried paper and much more benefit will be derived by the student himself.

I want to say one word more. There is another difference between an extension teacher and a teacher in a college or university, and it might be considered the conception of a compliment. I think the greatest compliment I ever received was in Racine. I had given a night school course one year. A young fellow, a workman in one of the shops there, walked down to the train with me every night. One night he said, "Do you know anything about these college graduates?" I said I had met some of them and, barring certain shortcomings, I thought most of them were all right. He said, "I got acquainted with one in night school and nobody learned anything, but since you fellows have been here, you don't know much more than we do and have got along first rate."

I doubt if any professor in the division of engineering would consider it a compliment to be told by his freshman at the end of the course that they didn't think he knew much more than they did.

President Jackson: I am sure we all thank Professor Smith for this very interesting talk that he has given us this evening, and I know that in general we agree with him throughout and that we all must agree that the dissemination of engineering knowledge and the bringing to all the people an appreciation of what engineering principles really are is a great work for anybody.

POLICIES OF THE ENTERTAINMENT COMMITTEE

In order to accomplish effective work in any line it is necessary to have clearly in mind the results desired, and the methods to be followed in their attainment. In order to organize the work of the Entertainment Committee efficiently, it is necessary to set forth clearly its purpose, policies and line of action. These, of course, are governed by the primary conceptions of the purpose and policies of the Society itself.

The Constitution of the Western Society of Engineers states ,Article II, Sections 1 and 2.) :

SECTION 1. The object of this Society shall be the advancement of the science of engineering, and the best interests of the profession.

SECTION 2. Among the means to be employed shall be meetings for the reading and discussion of appropriate papers and matters of engineering interest, and for professional and social intercourse; the collection of a library, and the publication of such parts of the transactions as may be deemed expedient.

"The advancement of engineering and the best interests of the profession" is a very broad purpose; so broad in fact, that there are at present several widely different interpretations. Similarly, the means to be employed, as given in Section 2, are subject to widely differing definitions. Consider first the present work of the Society, and later the elements, both existing and possible, which tend to make this Society valuable to members and other engineers.

The present activities of the Society are as follows:

(1) A regular meeting the first Monday of every month. The program consists of a paper and discussion on some engineering topic.

(2) Meetings of Sections, or of entire Society, on other Monday evenings during the month, with programs similar to those of the regular meetings.

(3) An occasional smoker, ladies' night, excursion or some other form of entertainment.

(4) A few Committees doing certain routine work in connection with the Society.

(5) Certain Committees doing special work, aimed to improve the conditions of the engineering profession.

(6) The maintenance of a library, open during the business day.

(7) The publication of the Journal, in which is printed the papers and discussions presented at the meetings, with various book reviews and similar matter.

These are the activities which are specifically mentioned in the section of the Constitution quoted above, and it is our purpose to direct these activities to fulfill the purposes of the Society to the fullest extent and make it of the greatest value to its members and the engineering profession. The first consideration that every man has, in respect to such an organization, is "what good will it do me?" and unless there are some specific and concrete advantages, the Society has no value to the individual and is not fulfilling its proper function, for it would be taking something without giving adequate return.

Owing to the strong position of the various National Engineering Societies, membership in which is considered more or less of a distinction, and which draw their membership from all parts of the world, it is to be doubted whether this Society can, or should compete in any way with the National Societies. Its field would seem to lie principally in Chicago and the adjacent territory, in which there are several thousand engineers to whom this Society should have a vital interest.

What are the things of value, which a member or possible member would like to secure from the Society? In the first place he would like to attend meetings at which subjects of interest to him would be well presented. If but one or two meetings a year, out of a total of 30 or 40, are of interest to him, he is getting very little for his money. Owing to the diversified character of the membership, all kinds of engineers being represented, the only subjects which will interest all, or a majority of the members, are those covering the broad principles of engineering. Technical details, while extremely important to the men handling them, are unknown and devoid of interest to others. It would seem as if the subjects presented at our general meetings should be these broad features of engineering, and engineering work, which will be of important interest to the majority of engineers.

The other thing which an engineer logically expects from an organization like this, is the broadening of his acquaintance; the opportunity to meet his fellow engineers on equal terms; to get well acquainted with them and to discuss with those whom he meets, who have the same interests, those things which are of importance to him. To secure this result an organized effort should be made to instill good fellowship; and to make the meetings gatherings of friends who are mutually acquainted, and becoming more so every time; and not gatherings of isolated strangers. The engineer is inclined to keep too much within himself to study things and not his fellow men. A knowledge of human nature, and the ability to associate easily with one's fellow men, are important elements in the character of a well-rounded man. This side of the engineer, as well as the intellectual, needs attention. A group of engineers, largely unacquainted with each other, such as those at our meetings, will not relax and mix unless the way is made easy and attractive. A systematic effort must be made to introduce them to each other, and to make them feel at ease. Something to eat, something to drink and something to smoke, are of great value in this respect, not because the guests need food or drink, or are unable to buy their own cigars, but as means of "breaking the ice" and collecting the men into congenial and friendly groups.

Thus, in studying the purpose of the Society it becomes apparent:

First: That the Society's greatest field is among the local engineers.

Second: That attractive meetings, at which are presented papers and discussions of wide interest, whether purely engineering in nature or otherwise, by men who can present and discuss them well, are of great value. A meeting that will draw only 40 people means that only 40 out of 1,100 members, or less than 4 per cent, are interested in that meeting or in other words that the Society's efficiency (at that meeting) is less than 4 per cent. A meeting that will attract 300 members, is of value to 300 of the 1,100 members, or in other words, the Society's efficiency at this meeting is 27 per cent.

Third: That good fellowship should be carefully fostered. If opportunity is given for the members to meet others, having similar interests, under pleasant conditions and in congenial atmosphere, and time is available, they will discuss the technical details which are of mutual interest, without devoting the entire time of the meeting thereto, and more important still, good fellowship will be developed and the human side of the engineers will be brought out.

But it is not enough merely to have valuable meetings; they must be advertised. A business house may have the best goods in its line, but unless the buying public knows their value, the goods won't be sold. In the case of the Society the buying public is very limited in extent, consisting of the members and other engineers, to whom the value of the Society should be brought home. The means of advertising to be employed are therefore limited. Direct, paid publicity is too expensive and is beneath the dignity of this organization. The best advertisement in any line is a satisfied customer. The same is true here, and if this effort is headed by a group of men who sincerely believe in the value of the Society, and are endeavoring to build it up, and who will "Boost" the Society and its meetings among its members, and among engineers who should be members, a logical and dignified advertising campaign will result, which combined with concerted effort to make the meetings of broad general interest and develop good fellowship, will give the Society a great impetus.

Suggestions for Activities of Entertainment Committee.

In order to carry out the functions of the Society, as set forth in Article II, Sections 1 and 2 of the Constitution, and interpreted by this Committee in its Policies, the following activities are suggested:

A meeting of the Committee will be held on the Monday preceding the regular meeting of the Society, preferably at dinner before one of the meetings of a Section. At this meeting plans will be discussed for the following meetings of the Society. Plans will be made for reception, entertainment, arrangements, and any special features of the meeting. Suggestions pertaining to the Society, or any of its activities, will be received and discussed.

In line with its policies the Committee should build up the meetings to high standards, secure the attendance of members and guests, and see that all of these members and guests are introduced and are well entertained. In general, see that the meetings are so interesting and successful, that the work of this Committee will gain additional momentum from each, or in other words, make the meetings so attractive that those present will want to come again, and that the guests will suggest membership without being asked. To indirectly awaken a voluntary desire is the highest type of advertising and salesmanship.

These Sub-Committees will work out the details of their activities and present them at the regular meetings of the whole Committee. The Committee, as a whole, will pass on the proposed activities of the Sub-Committees, and make suggestions for their betterment. It shall be the duty of the Sub-Committee to see that these approved suggestions are carried out, either by themselves or by or through the proper official or member of the Society.

As the regular meetings are planned to be of general interest to all members, every man on this Committee should work for them. In order to have an efficient organization the General Committee has been divided into sections, corresponding to the Sections of the Society, and the following have been appointed Assistant Chairmen in charge of these meetings:

D. A. Tomlinson, General Meetings.

W. W. DeBerard, Hydraulic, Sanitary and Municipal Meetings.

H. M. Wheeler, Electrical Meetings.

N. M. Stineman, Bridge and Structural Meetings.

Each of these Assistant Chairmen will be in charge of the meetings, and work for the sections indicated and will organize his Sub-Committees in such manner as may seem best. The organization of the Committee, with the names of the men placed in charge of the various Sub-Committees, is shown on the Organization Chart attached.

Interest in the Society has been more or less dormant with the result that members have lost the habit of attending meetings. During the last year much has been done to awaken interest and inject new life into the Society, and the movement is gaining momentum at every meeting. If we all get together and "boost" we'll have by far the best year we have ever had. A concerted effort by the members of this Committee will make future meetings highly successful.

Can you as an individual push things along and do these few things:

1. Come to every meeting yourself.
2. Personally ask several members to come.
3. Bring several guests with you.
4. "Mix" with the members and guests.
5. Think about the Society and make all the suggestions you can for its improvement.
6. Help the various Sub-Committees all you can.

THE ENTERTAINMENT COMMITTEE,

E. H. LEE, Chairman.

March, 1915

PROCEEDINGS OF THE SOCIETY

Minutes of the Meetings

Regular Meeting, March 1, 1915

A regular meeting (No. 892) was held Monday evening, March 1st. The meeting was called to order at 7:50 o'clock by President Jackson, with 260 members and guests in attendance.

The Secretary read the following applications for membership:

Harry J. Carton, Chicago.
F. S. Callender, Chicago.
Charles N. Bainbridge, Chicago.
Charles A. Jennings, Chicago.
Herman E. Beckman, Naperville, Ill.
William R. Matthews, Chicago.
Robert Heffron Murray, Chicago.
Wharton Clay, Chicago.
Elmer Lawrence Andrews, Whiting, Ind.
Eugene Clifford Patterson, Chattanooga, Tenn.
David I. Davis, Chicago.
Fred J. Lamotte, Gary, Ind.

and the following elections to membership:

H. A. Anderson, Evanston, Ill.	Student Member
H. J. Chilton, Chicago	Member
W. F. Kurfess, Chicago	Junior Member
W. H. Allen, Chicago	Member
J. A. Cook, Chicago	Junior Member
C. H. Tylor, Chicago	Associate Member
Henry Missostow, Chicago	Transferred to Member
D. St. P. Gaillard, Chicago	Associate Member
H. P. Fisher, Chicago	Transferred to Associate Member
F. L. Faulkner, Chicago	Student Member
R. G. Miller, Chicago	Associate Member
W. R. Ourand, Chicago	Associate Member

President Jackson then presented Mr. O. H. Basquin, M. W. S. E., with a Chanute Medal in recognition of his paper on "Columns."

Prof. D. W. Mead of Wisconsin University was then introduced. He gave an interesting illustrated talk on "4,000 Years of Engineering in China." Discussion followed from Messrs. Cooley, Shimizu and others. After a few announcements the meeting adjourned for refreshments at 9:50.

Extra Meeting, March 8, 1915

An extra meeting (No. 893) was held Monday evening, March 8th, convening at 7:45 p. m., with about 152 in attendance. Mr. H. C. Lothholz, chairman of the Bridge and Structural Section, called the meeting to order and introduced Prof. W. M. Wilson of the University of Illinois, who presented his paper on "Wind Stresses in the Steel Frames of Office Buildings," with some lantern slide and blackboard illustrations.

Prof. Albert Smith of Purdue University followed, who presented his paper on "Wind Stresses in Office Buildings," also illustrated by lantern slides and blackboard sketches.

Discussion followed from Messrs. H. J. Burt, J. G. Giaver, O. H. Basquin and J. W. Lowell, with replies and explanations from Professors Wilson and Smith.

In conclusion some moving pictures were shown of operations at a coal mine and tipple.

Meeting adjourned about 10:30 p. m.

Extra Meeting, March 16, 1915

An extra meeting (No. 894) was held Tuesday evening, March 16th, convening at 8 o'clock, with 305 members and guests in attendance, many of whom were members of the American Railway Engineering Association then in convention.

The meeting was opened by President Jackson, who introduced Mr. George Gibbs, Consulting Engineer of the Pennsylvania and Norfolk & Western Railways, who gave an illustrated talk on the electrification of certain parts of these two lines.

Mr. Edwin B. Katte, Chief Engineer of Electric Traction, New York Central R. R., then talked on the operating results of their electrification in and about New York.

Mr. E. T. Howson then read a paper describing the electrification of the New York, New Haven & Hartford R. R., which was prepared by Mr. W. F. Murray, Consulting Engineer of that line.

Mr. C. A. Goodnow, Assistant to the President, Chicago, Milwaukee & St. Paul R. R., had prepared a paper on their western electrification. This paper was read by Mr. E. H. Lee.

Motion pictures of the Butte, Anaconda & Pacific electrification were then shown. The films were furnished by the General Electric Company.

President Jackson then called upon the following men for discussion:

Mr. E. H. Lee, Chief Engineer, the Chicago & Western Indiana R. R.

Mr. Jesse Holdom of the Committee on Smoke Abatement and Electrification.

Mr. C. S. Churchill, Assistant to President, Norfolk & Western R. R.

Dr. W. F. M. Goss, Chief Engineer of Committee on Smoke Abatement and Electrification.

Mr. J. C. Mock, Signal Engineer, Michigan Central Lines.

Mr. E. W. Herr, First Vice-President, Westinghouse Electric & Mfg. Co.

Mr. Bion J. Arnold, Chicago.

Mr. H. S. Maddock, Evanston.

After a motion of thanks to the various contributors, and a few announcements, the meeting was adjourned at eleven o'clock for refreshments.

Extra Meeting, March 22, 1915

An extra meeting of the Society (No. 895), a joint meeting of the Electrical Section W. S. E. and the Chicago Section, A. I. E. E., was held Monday evening, March 22nd.

The meeting was called to order by Mr. E. W. Allen about 8:00 p. m., with about 135 members and guests in attendance. Mr. Allen opened the meeting, and then turned it over to President Jackson, who, after a few words of greeting, introduced Mr. Paul M. Lincoln, President of the American Institute of Electrical Engineers, who addressed the meeting and introduced Mr. Robert A. Philip, the author of the paper for the evening. This was on "The Flow of Energy Through Transmission Lines." Discussion followed from Mr. Lincoln, D. W. Roper, G. E. Marsh (Armour Institute),

S. T. Smetters, H. M. Wheeler, E. N. Lake, E. W. Allen and President Jackson.

After the conclusion of the paper and discussion, some moving pictures were exhibited, and the meeting adjourned about 10:15 p. m., when refreshments were served.

Extra Meeting, March 29, 1915

The extra meeting (No. 896) held Monday evening, March 29, 1915, was devoted to "Ladies' Night," it being a custom of the Society to have such a meeting each year, at which the talks and entertainment are of a non-technical nature.

At 8:15 two hundred and fifty members and guests were in the assembly room. Mr. Ernest McCullough, First Vice-President, introduced Mr. Asa Baldwin, who gave a lecture on scenes and experiences in Alaska, as connected with the International Boundary Survey. The fact that Mr. Baldwin was a member of the party of United States engineers, made his first-hand recollections especially interesting.

Many colored slides depicting the plant and animal life of that region and some of the scenery along their survey added greatly to his talk. Two reels of motion pictures taken during the survey concluded Mr. Baldwin's lecture.

Miss Emily Louise Stretch sang several beautiful songs, all of which found a very appreciative audience. At the conclusion of the program moving pictures, "How Moving Pictures Are Made and Shown," were thrown upon the screen, after which the meeting adjourned about 10:15 to the library and reading room for refreshments.

J. H. Warder, *Secretary.*

BOOK REVIEWS

THE BOOKS REVIEWED ARE IN THE LIBRARY OF THE SOCIETY.

THE PRESERVATION OF STRUCTURAL TIMBER. By Howard F. Weiss, Director, Forest Products Laboratory, U. S. Forest Service. McGraw-Hill Book Co., New York, 1915. Cloth; 6 by 9 in.; pp. 312, text, appendices and index; plates, illustrations and diagrams. Price, $3.00 net.

This work is most comprehensive, and should be in the library of every engineer and architect. The conservation of our natural resources is now recognized as the big problem of our government, and the work of the Forest Products Laboratories at Madison, Wisconsin, has been of incalculable value in not only educating the public to the need of conserving our timber supply, but its work has demonstrated that profitable uses may be found for many timbers now assumed to be practically useless.

Unlike other books dealing with the preservation of timber, it practically covers the entire field.

The author discusses causes of deterioration; effect of structure of wood upon its preservation; the preparation and various processes; construction and operation of wood-preserving plants; methods of preserving timber in its various uses; protection of timber from fire; and the use of substitutes.

Particular attention has been given to the best methods of preserving the life of structural timbers for all possible uses, and the chapter on the treatment of cross ties, and the examples noted, should be the subject of earnest consideration by construction and operating engineers of all railway systems.

It is regrettable that more attention has not been given the problem of making wood fire resistive. This matter is an important one as a practical process with effective results would be a very valuable addition to the timber-treating industry.

An appendix classifies the many well-known processes giving the names of inventors and dates of patent issues.

The volume is well printed and illustrated, half-tone cuts being printed on glazed paper.

The author deserves a vote of gratitude from all interested in the conservation and preservation of timber, for having given us this work, which will undoubtedly take and maintain its place as a standard authority on these subjects.

It is hoped that Mr. Weiss will be able to continue his notable work and that he may in the future add another volume on this interesting subject. F. E. D.

GRAPHIC DETERMINATION OF SAGS AND STRESSES FOR OVERHEAD LINE CONSTRUCTION. By Marco Semenza; translated from the Italian by C. O. Mailloux. McGraw-Hill Book Company, New York. 1915. Cloth 9x12 in.; text 24 pp.; 13 diagrams. Price $3.00.

Mr. Semenza presents clearly and concisely the subject of sag and stress in spans of copper wires in two ways, kept clearly distinct by the division of the text into several parts. The purpose of this treatment is to present the theoretical discussion quite apart from the data and charts which are intended to make it relatively simple for a non-technical man to obtain the proper stringing tension while erecting wires under construction conditions. The charts are numerous and furnish the solutions to all problems usually encountered in practice.

While the subject has been reduced to a relatively simple form, and charts covering all conditions which may be encountered furnished, it probably will be impracticable to put the book into the hands of a construction foreman, as the author suggests is possible, and let him compute his stringing tension under existing weather conditions. This is because the matter presents inherent difficulties, and although these difficulties are greatly simplified by the author's treatment, careful supervision should be made by the engineer in charge of the construction to see that the charts are used correctly.

The author gives an excellent discussion of the proper values to be used for working stress in spans of copper conductors and gives working values for the stress due to wind and sleet. The probable concurrence of the wind load and sleet load is considered, and the proper allowance for this superposition of stress is outlined.

The assumptions made in the calculations seem to be justified in each instance. These are: (1) assumption that curve taken by the wire would be a parabola instead of a catenary; (2) that the length of the span is the distance between the two points of support instead of the actual length of the wire; (3) that the stress at the center of the span is equal to that at the points of support. The author shows that assumption (1) leads to an error of less than 2 per cent when the ratio of the length of the span in feet to the stress in the wire at its lowest point in pounds per square inch does not exceed 0.125.

The general subject has been treated in a thorough manner by relatively few men, and this treatise is most welcome to the electrical engineer, because it presents clearly and in as simple a manner as possible the detailed theory underlying the properties of spans of copper wire and gives to a useful scale, charts that will give a good degree of precision in any specific, practical problem. When the construction of the charts is clearly understood, no difficulty is experienced in solving problems, and arithmetical computations are eliminated.

The method of presentation of the data is so straightforward and clear that little difficulty is to be experienced in following the several derivations and analyses. It seems then that Mr. Mailloux has again afforded the English speaking engineering profession a substantial benefit by presenting in English the work of so able an engineer as Mr. Semenza. J. A. C.

Field Practice. An Inspection Manual for Property Owner, Fire Departments and Inspection Offices Covering Common Fire Hazards and Their Safe-Guarding and Fire Protection and Upkeep. Published by the National Fire Protection Association, Boston, Mass. 1914. Green leather; 4½x6¾ in.; 200 pp., text and index. Price $1.50.

This handbook undoubtedly has been prepared for the use of inspectors with the expectation that its suggestions will be rigidly followed. It will be valuable to the property owner in that it informs him as to methods of fire protection and prevention. To the engineer and architect it affords ready reference to the accepted practices as to building details and preferred materials. For the layman it has little value, as it cannot be expected that he will memorize its text or have it at hand in the hour of need.

The discussion of fire hazards is notable for its completeness. No phase of the subject is left untouched nor any question unanswered. Definite fixed rules cover all conditions and if followed should remove all question of the advisability of the procedure under question.

Lighting, heating, power, chemicals, spontaneous ignition and dust explosions, care and maintenance, and building construction are all covered under the head of hazards.

Automatic sprinklers and fittings, their functions, design and reliability are thoroughly treated under the head of protection and upkeep. Beyond this field is fire protection in general, in which all other systems and appliances are explained and their correct use discussed.

Any person interested in fire protection and inspection will find answers to all his problems in this little handbook, which represents an enormous amount of work of compilation, and experience that proves its authority.

HANCOCK'S APPLIED MECHANICS FOR ENGINEERS. Revised and Rewritten by N. C. Riggs. The Macmillan Company, New York, 1915. Blue Cloth, 5x7½ in.; 441 pages, text, appendices, tables and index; diagrams and drawings. Price, $2.40.

The book is just what the title indicates—mechanics in the application and written especially for the engineer whether student or professional. As the student develops each step in the subject he is called upon to apply the new principles to practical engineering problems, which are given in the book. Thus his practical knowledge is developed with the theoretical.

In revising this work Mr. Riggs made very few changes in subject matter and general arrangement, although the methods of treatment have been improved upon.

Analytical and graphical methods are developed simultaneously, thus establishing in the student's mind the relation between the two methods. Again new problems have been added so that each type may be solved by the two methods, if the problem admits of the double solution.

No answers to problems are given, and each problem is stated in such a way as to make solution impossible by the mere substitution into the proper formula. In many cases the solutions require some shifting of terms and a consequent understanding of the relation between the various elements. This method must be recognized as excellent for developing originality and analytical ability.

The text in general is very theoretical, the practical element appearing in the proposed problems.

Three appendices giving tables of hyperbolic and trigonometric functions and logarithms, and conversion tables for weights and measures are of great value in the solution of problems.

As a text book it seems excellent, although the study of mechanics in any course should not end within this volume. A broader book having a more practical treatise of the various methods of solution would make an excellent second.

LIBRARY NOTES

The library committee desires to return thanks for donations to the library. Since the last publication of the list of such gifts, the following publications have been receivel:

PURCHASES.

Municipal Chemistry, Baskerville.
Engineering Geology, Ries and Watson.
Chemistry of Familiar Things, Sadtler.
Electric Furnaces in the Iron and Steel Industry, Rodenhauser and Schoenawa.
An Introduction to the Study of Fuel, Brislee.
Water Supply, Sewerage and Plumbing in Modern City Buildings, Gerhard.
Compressed Air Plant, Peele.
Work, Wages and Profits, Gantt.
Sanitation of Public Buildings, Gerhard.
Guide to Sanitary Inspection, Gerhard.

ADDITIONS.

Myron C. Clark Publishing Co.:
Land, Drainage, J. L. Parsons. Cloth.

McGraw-Hill Book Co.:
Preservation of Structural Timber, H. F. Weiss. Cloth.
Engineering Office System and Methods, John P. Davies. Cloth.
Design of Steel Bridges, F. C. Kunz. Cloth.

The Macmillan Co.:
Hancock's Applied Mechanics for Engineers, N. C. Riggs. Cloth.

Bureau of Railway Economics:
Railway Economics, A Collective Catalogue of Books in Fourteen American Libraries. Cloth.

National Fire Protection Association:
Field Practice Inspection Manual. Leather.

EXCHANGES.

Massachusetts State Board of Health:
Forty-fifth Annual Report, 1913. Cloth.

Boston Public Works Department:
Annual Report, 1913. ½ Morocco.

Society of Engineers, Inc.:
Transactions, 1914. Cloth.

Illinois State Geological Survey:
Bulletin No. 24, Some Deep Borings in Illinois. Cloth.

McGraw Publishing Co.:
McGraw Electrical Directory, Railway Edition, Feb., 1915. Leather.

West Virginia Geological Survey:
County Reports, Logan and Mingo Counties. Cloth and box of maps.

MEMBERSHIP

Additions:

Allen, Walter H., 111 W. Monroe St., Chicago........Member
Anderson, Henry A., Evanston, Ill..................Student Member
Chilton, H. J., 1309 Westminster Bldg., Chicago.............Member
Cook, James A., 111 W. Monroe St., Chicago.........Junior Member
Faulkner, F. L., 5544 South Park Ave., Chicago.....Student Member
Gaillard, D. St. P., 111 W. Monroe St., Chicago....Associate Member
Kurfess, Wm. F., 7125 Euclid Ave., Chicago..........Junior Member
Miller, Richard G., 1231 E. 46th St., Chicago.........Junior Member
Ourand, Wm. R., 2046 McCormick Bldg., Chicago.....Junior Member
Tylor, Chas. H., 4563 Oakenwald Ave., Chicago....Associate Member

Transfers:

Fisher, Harold P., Chicago, from Junior to Associate Member.
Misostow, Henry, Chicago, from Associate Member to Member.

RULES FOR ESTABLISHMENT OF BRANCH ASSOCIATIONS OF THE WESTERN SOCIETY OF ENGINEERS.

(1) Branch Associations of the Western Society of Engineers may be established by the adoption of a Constitution, which shall be approved by the Board of Directors, and by organization of the proposed Branch Association thereunder.

(2) Said Constitution shall provide:

(a) That all members of the Branch Association shall be members, in good standing, of the parent body.

(b) That all fees and dues assessed by the Branch Association against its members shall be in addition to regular fees and dues required by and paid to the parent body.

(3) A copy of the minutes and proceedings of each meeting of the Branch Association shall be filed with the Secretary of the Western Society of Engineers within ten days after the meeting.

(4) The Western Society of Engineers may publish in the Journal such proceedings of the Branch Association as shall be approved by the Publication Committee.

Journal of the

Western Society of Engineers

VOL. XX APRIL, 1915 No. 4

SOCIETY ACTIVITIES

Reports of Membership, Special Meetings, Committee Work, Etc.

Beginning with this number of the Journal, all news of the Society, changes in publications, special meetings, committee work and items of general interest to the members will occupy the first pages of each issue under the head of Society Activities. Since membership is an ever-changing factor in which every member is interested, it will be given a place under the above head instead of its customary position among the last pages of the book.

MEMBERSHIP.

Additions:

Andrews, Elmer L., Whiting, Ind. ....Member
Bainbridge, Charles N., Chicago.............Associate Member
Beckman, Herman E., Naperville, Ill..........Associate Member
Callender, F. S., Chicago....................Associate Member
Carton, Harry J., Chicago....................Associate Member
Clay, Wharton, Chicago..............................Member
Jennings, Charles A., Chicago........................Member
Matthews, William R., Chicago.......................Member
Murray, Robert H., Chicago..........................Member

Transfers:

Lamotte, Fred J., Gary, Ind., from Student to......Junior Member

New Applications

John W. Lowell, Jr., Chicago
Vernon S. Lawrence, Logan, Iowa.
John W. Wilson, St. Charles, Ill.
Robert S. Adams, Chicago.
Eugene E. Altman, Chicago.
John W. Baring, Chicago.
Charles L. Bolte, Chicago.
Joseph C. Dolan, Chicago.
Ellis S. Echlin, Chicago.

David M. Goe, Chicago.
James F. Hillock, Chicago.
John Jucker, Jr., Chicago.
John R. LeVally, Chicago.
Emmet R. Marx, Chicago.
Victor E. Marx, Chicago.
Lawrence J. McHugh, Chicago.
Franklin L. Pond, Chicago.
Herman N. Simpson, Chicago.
George J. Trinkaus, Chicago.
Walter L. Juttemeyer, Chicago.
Samuel E. Sosna, Chicago.
George B. Perlstein, Chicago.
C. A. Grasse, Chicago.
Henry Wilkens, Chicago.
Herbert P. Sherwood, Chicago.
Guy F. Wetzel, Chicago.
Peter J. Vollmann, Chicago.
Robert F. Havlik, Aurora.

Seventy applications have been received since January 1st.

ENGINEERING IN WAR

One of the season's most interesting talks was heard Monday evening, April fifth, when Lieut. Col. W. V. Judson, U. S. Army Engineers, discussed the engineering features of war and gave a descriptive history of the development of fortifications and military bridges and roads. Beginning with the crude fortifications of ancient history, Col. Judson carried his listeners through the last twenty centuries to the fortress of modern times. The history of trenches does not go back so far, their earliest effective use having been made during our war of 1861-5, but in later times their effectiveness cannot be denied as is testified by their constant use in modern warfare. During the present war in Europe trench fighting has developed into an art and an army sometimes finds itself compelled to make the trench its living quarters for long periods of time.

A few words on the use of artillery explained the difference between field and siege operations, the placing of guns and the importance of indirect fire, as a defensive as well as offensive measure.

Concerning highways, Col. Judson said that owing to the necessarily rapid movements of armies excellent military roads were required, it being impossible to move heavy guns and transport wagons over the soft grounds of fields and forests. Bridges capable of sustaining enormous loads must be constructed in short time from materials obtainable in the immediate vicinity and often under the enemy's fire. Pontoon bridges can be very effectively employed if their use is planned ahead so that necessary equipment is at the proper place at the proper time.

Armies of the modern nations use essentially the same methods and systems as none can afford to continue the use of an obsolete method after the superiority of another has been proven. Most of the new developments occur during actual operations when the engineering corps of both sides are using every conceivable plan to gain an advantage over the enemy.

During Col. Judson's talk it developed that the engineers are the pioneers of an army; that most offensive as well as defensive operations are impossible without their success; and that their work is to gain these successes with whatever materials and equipment they may have at hand and in the shortest possible time.

Col. Judson illustrated his talk by the use of numerous lantern slides, many of which were from photographs taken during the late Russo-Japanese War during which he was field observer for the U. S. Army.

ANNUAL STUDENTS' NIGHT

Over a hundred students from Armour Institute, Lewis Institute and Northwestern University attended this year's Students' Night meeting, the annual affair of the Society which appeals especially to under-graduate engineers. With the addition of a large turnout of members the attendance was swelled to over three hundred.

The program was not devoted to one paper as is customary at our meetings, but was intended rather to entertain along instructive lines. Eleven of Chicago's foremost engineers and business men (see minutes of meeting) advised the students and younger members on the determining factors of a successful career. Here are a few of their statements well worth remembering:

"One step of great importance on the road to success is identifying yourself with the Western Society of Engineers.

". . . the most conspicuous inefficiency of the high school graduate is his failure to take responsibility.

"The less supervision a man needs, the greater his value.

"Take an interest in politics, civic improvements and in various lines of activity and the live questions of the day.

—B. F. Affleck, President,
Universal Portland Cement Co.

"Above all things an engineer must be a responsible man."
—Isham Randolph, Consulting Engineer.

"No man's success is another man's success."

—E. H. Lee, Vice-President and Chief Engineer,
C. & W. I. R. R.

"The average man takes himself too seriously.

"The thing the engineer needs is imagination.

". . . what men have done you can do."

—W. H. Finley, Chief Engineer,
Northwestern Railroad.

"Don't specialize too much. Personality is a great asset."

—C. F. Loweth, Chief Engineer,
C. M. & St. P. R. R.

"Opportunity makes success."

—C. A. Morse, Chief Engineer,
Rock Island Lines.

". . . the young engineer should acknowledge his mistakes and profit by them.

"The man who does not make any mistakes does not do anything worth while."

—O. P. Chamberlain, Vice-President,
Dolese & Shepard Co.

Besides these short but splendid talks there were several musical numbers by the Armour Institute Musical Clubs. Their college songs had just the right spirit to bring to the older members the memories of their campus days. Motion pictures closed the program with a real "thriller" of engineering interest, showing scenes from oil well shooting and blowing up rapids in the Columbia River.

The most gratifying feature of the evening was the students' interest in the Society, a large number filling out application blanks during the evening, which assures us that the students of the technical schools in and about Chicago realize the importance of the Society and the many advantages to be gained through membership.

Cider, doughnuts, sandwiches and smokes were always in evidence and helped to make the meeting one of the season's best.

COMMITTEE ON WIND STRESSES

The papers on "Wind Stresses in Office Buildings," presented by Prof. Albert Smith, Purdue University, and Prof. Wilbur M. Wilson, University of Illinois (printed in this number), created among structural engineers such an interest in the subject that there has been appointed a committee known as the Committee to Investigate the Possibilities of Standardizing the Solution of Wind Stresses in Office Buildings, which has as its members Prof. Albert Smith (chairman), Prof. Wilbur M. Wilson, H. J. Burt, N. M. Stineman, J. G. Giaver and Albert Reichman.

Professors Smith and Wilson have developed by different procedures two exact methods for the solution of wind stresses in a typical office building frame. When compared with the approximate methods commonly used in actual work and advocated by several well-known engineers, discrepancies appear in the results obtained, sufficient, if correct, to prove that the approximate methods as now used are at too great variance with methods in which actual conditions are determining. The authors have developed from the exact methods two new approximate methods which should increase the degree of safety in design. These two methods check and it is the work of the committee to develop if possible a practical method of solution, the results of which will approximate those obtained by the exact methods which is by far too laborious to be used in actual work.

Structural engineers look forward to the results of the committee's work with great interest, and the work, as proposed by the authors, should prove very valuable if successfully carried out. All those interested in the work should communicate with Professor Albert Smith, Purdue University, Lafayette, Indiana.

COMMITTEE ON FIRE PREVENTION DATA

At the meeting of the Board of Direction, April 9th, Mr. F. E. Davidson submitted a resolution recommending the appointment of a committee to investigate the possibility of providing a system for the tabulation of fire data that could be used effectively in he solution of fire prevention problems.

The resolution was the outgrowth of a detailed examination of the fire records of Chicago which were found to be lacking in the necessary analysis and classifications. The authors of the resolution contend that the facts of past experience are essential to intelligent progress and that the statistics accumulated by insurance companies, while exceedingly valuable, cannot be considered as a part of the fund of common knowledge. It is further believed that a system can be devised whereby these compilations may become effective without the expense to the city of additional equipment and employment, and that by the inauguration of such a system Chicago would bring to municipalities in general an improvement which is greatly needed.

The work of the committee as stated in the resolution is to investigate present conditions and ascertain the changes and additions that are favorable to the improvements mentioned, and to determine whether or not the work could be carried out with present equipment and under the authority vested in the city fire department and the fire marshal.

This work if carried to completion should provide a means whereby much valuable data would be made accessible to fire prevention engineers and the public.

WORK OF THE COMMITTEE ON CIVILIAN MILITARY RESERVE

Beginning with a resolution presented before the Society at the meeting of February 15th last, which recommended the appointment of a committee to investigate the possibilities of co-operation with the government in establishing an adequate military reserve with special reference to the engineering corps, interest in reserve military forces has been excedingly high. By action of the Board of Direction the President appointed a committee of seven, naming H. S. Baker (chairman), W. W. DeBerard, Ernest McCullough, T. Frank Quilty, Taliaferro Milton, Dabney Maury and C. C. Saner. Although the committee has been in existence only a short time the members have worked hard on the matter and have obtained results of no little importance.

At the meeting of April 5th, at which Col. Judson gave his talk on "Engineering in War," the committee submitted its first progress report. It had been found that at present the government has not provided for the establishment of a military reserve although individual members of the general staff endorse the movement and Secretary of War Garrison has included such a recommendation in his program.

Younger members of the Society were urged to join the Engineer Corps of the Illinois National Guard, as members of which they will be in a position to receive military training with special instructions as to the engineering activities incident to warfare. The Engneer Corps is located in Chicago with an armory at 2356 Lincoln Ave., and Capt. L. S. Marsh has extended to the members of the Society a cordial invitation to enlist.

In prospect of a possible future instruction camp at some convenient point to which those desiring could go for military engineering instruction, the chairman asked for an informal vote on the following questions:

1. How many engineers belonging to this Society would be willing to take up a course of study in military engineering?

2. How many could attend summer camps of instruction held at some convenient point, possibly Washington Barracks, D. C.?

(a) If they had to pay their own expenses.

(b) If expenses were paid by the Government.

The result of this vote and the sentiment expressed by those who discussed the questions were most encouraging to the Committee, and it is hoped that such a training camp will be established.

As a final recommendation the Committee suggested the continuance of their work with an increase in membership by the admission of such engineers as are interested and that the committee hold open meetings and endeavor to gain what knowledge they can by individual study.

MOTION PICTURES AT MEETINGS

At several of the January meetings motion pictures of engineering and industrial activities were tried out as a means of developing interest and at the same time adding an instructive diversion from the technical nature of the subjects usually discussed. Although these pictures were projected by a rented machine, the operation of which was not entirely satisfactory, the idea immediately popularized itself, and through action of the Board of Direction a modern high-powered machine was purchased and installed in the Society's meeting room. Now motion pictures of various subjects are shown at almost every meeting.

Usually it is possible to obtain pictures illustrating some phase of the subject under discussion and in this way their use becomes very valuable in aiding the listener to visualize the ideas that are brought to him. On occasions such as "Ladies' Night" and "Students' Night" the pictures have been a source of entertainment as well as one of instruction.

Motion pictures are now recognized as one of the most effective means of instruction and their use at Society meetings has been greatly appreciated.

OPERATING RESULTS OF THE ELECTRIFICATION OF STEAM RAILROADS

Presented "Electrification Night," March 16, 1915.

By George Gibbs, Edwin B. Katte, W. S. Murray and C. A. Goodnow.

For considerable time Chicago engineers have given more or less individual study to the problems incident to the electrification of steam railroads, in anticipation of the report of the Chicago Association of Commerce Committee on the Investigation of Smoke Abatement and Electrification of Terminals. They have been handicapped, however, by a lack of information regarding results under working conditions, their data, for the most part, having been derived from the estimates of engineers who have made a more detailed study of the problems.

Early in the year the railroad engineers in the society conceived the idea of an "electrification night," the purpose being to bring before the profession the results of actual operation as obtained by the various systems which have electrified portions of their lines. Fortunately the program of meetings permitted this meeting being held during the convention of the American Railway Engineers Association in Chicago. Through the efforts of Mr. E. T. Howson, engineers from five representative railroads had consented to prepare papers giving data obtained through experience and careful recording of observations. In addition to this program there followed a discussion in which the foremost electrification engineers in the country took part.

As a result the meeting afforded an opportunity for an exchange of ideas between representative railroad engineers and a consequent understanding of what might be expected of electrification under various conditions. As brought before this meeting, the important facts regarding the electrification of steam railroads are:

(1) That the greatest determining factor is the relative density of traffic.

(2) That electrification finds its most favorable application in terminal problems and under condition of excessive grades.

(3) That any economy incident to electrification must come through operation, as the first cost is far in excess of that of steam installation.

Editor.

THE NORFOLK & WESTERN AND PENNSYLVANIA ELECTRIFICATIONS.

By George Gibbs.*

The Norfolk & Western electrification of a trunk line railway for heavy freight service is nearly completed and partial service has already been successfully inaugurated.

This line has its eastern terminus on the Atlantic seaboard at Norfolk, Va., and its western termini at Columbus and Cincinnati, Ohio. In addition to a large passenger and freight traffic, it conducts an especially important and rapidly growing traffic in coal hauled from the Pocahontas field, near the summit of the Allegheny

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mountains, 365 miles eastward to tidewater and also a heavy westbound coal traffic from the same field. Practically all of this eastbound tonnage must be hauled up the western slope of the mountains to the summit at Bluefield, which is 2,400 ft. above the sea, and thence generally over grades favoring the loaded movement, crossing, however, two other summits, constituting pusher grades over parallel ranges of the Blue Ridge.

The electrified section is the "Elkhorn Grade" on the Pocahontas Division, beginning at Vivian, about 30 miles west of Bluefield, and comprehending the entire main-line gathering divison on whch the bulk of the coal tonnage orginates. It is important to note that this portion of the railway is operated as a separate division in so far as the tonnage coal business is concerned and that this traffic is handled by a special class of power which is confined in its movement to this local division. Along this line are numerous colliery sidings and short branches penetrating the developed coal field, and the normal service consists in collecting loaded cars or trains from the sidings and branches for eastbound trips and delivering empties on the return. Thus the electrified section is a local switching and short haul division between the points of origin of traffic and the classification yard at Bluefield on the east, where the trains are made up for the haul to tidewater. Because of the possibility of thus segregating the very heavy traffic both as to operation and power, there is produced a condition very favorable for electric traction. Other favorable conditions arise from the fact that the tonnage movement is very heavy and the trains may be despatched at fairly uniform intervals throughout the day, thus improving the load factor and limiting the number of locomotives required; also, that the present speeds with steam are undesirably low. The primary purpose, however, of the electrification was to provide for an increase in the capacity of the railway by an increase in operating speed; and to furnish a more economical and efficient method of handling the service over the grades.

The line is double track throughout, with frequent long passing sidings, making it in part a three track line, but the Elkhorn Tunnel is single track. Sixty per cent of the entire division is on curves, the maximum curvature being 12 degrees on the main line and 16 degrees on sidings. From the profile, it will be noted that at Vivian, the beginning, there is a stretch of about 5½ miles of 1 per cent grade to North Fork, then 5½ miles of 1.5 per cent grade to Ennis, and then about 4 miles of 2 per cent grade to the Elkhorn Tunnel, which is 3,000 ft. long, and on a 1.5 per cent grade. Leaving the east portal of the tunnel the line pitches down on a 2.5 per cent grade for about one mile, and then rises again for 9½ miles on a 0.4 per cent grade, finally reaching Bluefield over three miles of 1.25 per cent grade. The main gathering points of the coal occur along the line from Vivian to Flat Top Yard and eastbound trains must, therefore, be hauled over very heavy grades.

The eastbound coal traffic has increased rapidly, doubling in volume during the past four years; in the year 1913 it averaged 40,000 tons per day, but has frequently amounted to over 60,000 tons per day. At present the number of these tonnage trains is about 12 per day, but with the electrical equipment, provision has been made for handling 20 trains or 65,000 tons per day. In addition, provisions have been made to handle through freight trains by electric pushers and to haul passenger trains and their attached steam locomotive with an electric engine. In this latter case the necessity of an electric helper on passenger trains occurs only where the train is so heavy as to require doubleheading on the grade.

It has been customary under steam operation to make up the train to a maximum weight of 2,900 to 3,250 tons, according to weather conditions, behind the engine and handle it by a Mallet road engine and a Mallet helper over the division and in addition a Mallet pusher up the 1.5 and 2 per cent grades, or three engines per train. All of which are of the latest compound type fitted with mechanical stokers and superheaters. They weigh about 370,000 pounds on drivers and 540,000 pounds total, including tender, and are estimated to have a tractive power of about 85,000 pounds. Tonnage trains are handled normally at a speed of from seven to eight miles per hour on the grades, but on account of the ventilating conditions, speed is reduced to six miles per hour in the Elkhorn Tunnel. It may be said that the tunnel is equipped with the Churchill plan of forced ventilation, which consists of blowing air through annular nozzles at the tunnel portal in the direction of the upgrade movement and at a slightly greater velocity than the speed of the train, thus blowing the smoke from the head of the train, and insuring that the smoke from the rear engine does not reach the front engine during the tunnel movement. It will, of course, be seen that because of the slow speed in this tunnel and because of the fact that it is single track, a very serious restriction in the capacity of the line occurs at this point and occasions frequent congestion and delay.

The decision to electrify was made about two years ago and the design and construction work placed in charge of the writer's firm as consulting engineers of the company. The question of a proper electric system was given especially careful study because of the difficult physical conditions and the unprecedented heavy haulage requirements. It was readily seen that an electrified third rail along the tracks was not practicable under the local conditions and that some system using an overhead collector would be required. This narrowed down the problem to a decision between the high-tension direct and the high-tension alternating current systems. Analysis of costs, both first and operating, as well as the consideration of the local operating conditions, indicated that the single phase alternating current system was the one that should be adopted. Attention might be called here to the fact that these heavy trains require enormous power for their movement, which in turn means large currents to be collected if the potential is low, but which is effected with much smaller currents if a system with the maximum allowable potential be used. The practical difficulties of collecting large currents from an overhead wire are well-known, the adoption, therefore, of a high trolley voltage is a logical solution of this problem. Electric braking down heavy grades, accomplished in a simple manner, is another attractive operating feature of the system adopted.

In working out the details of the installation a number of novel features were introduced, notably in the adoption of three-phase motors on the locomotives in connection with single phase current delivered to the locomotives. The required three-phase current for the motors is produced by a "phase converter." This is, essentially, a two-phase induction motor with a short-circuited or cage-wound revolving part, the stationary part having two windings with phase relations at right angles, one of which is connected across the line and serves to drive the motor and the other producing a current at right angles to the line current, thus giving two-phase power which, through connection with the transformer, is converted into three-phase power in the usual way. By this ingenious arrangement all the advantages of single phase transmission and a single trolley wire are obtained with the peculiar advantages, for this special service, of the three-phase motor. This motor is an unusually rugged piece of electrical machinery requiring no commutator and having high weight efficiency, or capacity, for given weight and dimensions. It has, however, constant speed characteristics, which are not desirable in some kinds of railroad operation, but which, for this particular service, have important advantages in respect to maintaining certain predetermined and limited train speeds irrespective of the loads. Furthermore this type of motor has the valuable characteristic of automatically returning regenerated current to the line on the down grades, this being effected without additional machinery or complication when the predetermined running speed is slightly exceeded during the coasting period.

The electric installation comprises the equipment of 29 route miles of main track, or 97 track miles total, with an overhead trolley wire operating at a working voltage of 11,000. A power house has been erected at Bluestone, a central point on the line, which contains three single-phase turbo-generators, each of 10,000 kw. rating for the load conditions, and the usual electrical and mechanical appurtenances, all of the most approved type. Current is generated at 11,000 volts pressure and stepped up to 44,000 volts for transmission to four substations along the line. These substations contain static transformers which lower the voltage to 11,000 for delivery into the trolley.

The overhead structures employed to support the trolley wires embody a number of novel features in respect to the use of tubular pole bridges, the poles being reinforced by rod guys on the outside of curves. This type of structure is simple, light, and relatively inexpensive and presents a minimum obstruction to view along the tracks. Of course, all structures, wiring and attachments have been carefully calculated for the maximum stresses which may occur from temperature change, the accumulation of ice and snow, effects of wind, etc. The insulation of the trolley line has been carefully designed to obtain at all places double insulation to ground.

Twelve locomotives have been provided for the service; each locomotive consists of two units or halves, each weighing 135 tons, giving a total weight of 270 tons for the complete locomotive. The frame of each half consists of two trucks connected by a Mallet type hinge and each truck has two driving axles included in the rigid wheel base, with a radial two-wheel leading truck. The bumping and pulling stresses are transmitted through the main truck frames and through twin draft rigging mounted on the main trucks at each end of the unit. The main trucks each carry two motors securely framed into the truck and both meshing into the same gear on each end of a jackshaft. These main gears are provided with crank pins from which connection to the driving wheel crank is made by side rods in the usual manner. By this arrangement the motors are carried on the main locomotive springs and are thus thoroughly cushioned against shock. Each half of the locomotive is provided with a cab supported on the trucks entirely by spring cushioned friction plates; the center pins carry no weight and serve only to maintain the cab in its proper position on the trucks. The cabs contain all current controlling and transforming apparatus, air brake pumps and reservoirs, with the usual appurtenances for the locomotive operation.

Each locomotive is equipped with eight three-phase induction type motors with wound secondaries for four and eight pole operation. There are two running speeds for the locomotives, namely, 14 and 28 miles per hour; for lower speed all motors are connected in parallel with the eight pole motor combination and for the 28 mile per hour speed they are connected in parallel but with the four pole combination. The motor voltage is 750, being reduced from 11,000 trolley voltage by transformers. In starting the locomotive variable resistance is inserted in the motor circuit by means of liquid rheostats; one of these is provided for each motor and is arranged to control the current by varying the height of the liquid by means of pumps. This liquid is kept constantly circulating to prevent excessive heating and is also passed through a cooling tower consisting of a series of trays arranged so that the liquid will flow over them in a thin sheet and thus be cooled by air from the same ventilating fan which is used for cooling the transformers and motors. The capacity of these rheostats has been made unusually great in order to meet the abnormal starting conditions; the rheostats are furthermore capable of operating the trains at one-half speed over the entire division, if necessary. This, in effect, gives a third operating speed which may be useful at local points.

The main dimensions of the locomotives are:

Length over all	105 ft. 8 in.
Rigid wheel base	11 ft.
Truck wheel base	16 ft. 6 in.
Diameter of driving wheels	62 in.
Diameter of pony wheels	30 in.
Weight on drivers	220 tons
Total weight of locomotives	270 tons

The drawbar pull varies from a maximum of 114,000 pounds during acceleration at the 14-mile per hour speed to 86,000 pounds when operating at this speed uniformly on a one per cent grade, but on a recent test the locomotive has developed a tractive effort in excess of 170,000 pounds, indicating, however, a coefficient of adhesion which cannot be assumed in practice. The maximum guaranteed accelerating tractive effort per locomotive is 133,000 pounds.

A valuable characteristic of the three-phase motors adopted is their capability of safely exerting full tractive effort for a considerable time while standing, the importance of which will be seen when it is remembered that the trains hauled are generally over one-half mile in length, and in the case of an empty train, three-quarters of a mile long. In starting this very heavy and long train there is sometimes difficulty in getting coincident action between the head and rear locomotives and thus it is especially important that both locomotives may be able to exert their full tractive effort for an appreciable time to take care of delays in getting full action and step. The motors in question have been designed to permit of full load current for five minutes standing.

At the present writing the heavy grade of this electrification, from North Fork to Flat Top yard, has been in operation for the past three weeks and the results forecast the entirely successful operation of the service as a whole in accordance with the expectations of the designers and the company. The movement of these very heavy tonnage trains has been electrically effected with ease and smoothness; the trains accelerate promptly and without shock or jerk to their running speed of 14 miles per hour on the heavy grades and it has been found that the full trains can be smoothly controlled by one head engine on the 2.5 per cent down grade by electric braking alone and at a uniform speed slightly above that of the regular running speed. The acceleration of one of these heavy trains is impressive as regards the amount of power required. Preliminary tests indicate the development of as much as 11,000 horsepower per train while getting into motion and operation at uniform speed up the grade requires 8,000 electric horsepower to be delivered to the train, but as far as the writer is aware no such amount of power has ever before been developed on a single train, either steam or electric, in regular service.

The electric apparatus for power house, substations and locomotives has been furnished by the Westinghouse Electric Company, and required much difficult development work by that company to be brought to such a degree of perfection.

PENNSYLVANIA ELECTRIFICATION.

The Philadelphia electrification on the Pennsylvania road is another important trunk line railway electrification which has been under way for the past two years and is now almost completed. It comprehends only suburban passenger train movement on the four-track main line from Philadelphia to the West, and does not include electrification for through passenger trains or for freight. Its primary purpose is to relieve congestion at Broad Street Station, Philadelphia.

The Broad Street Station is of the stub end type, with sixteen tracks approached by six main line and three yard tracks on an elevated railroad from West Philadelphia, at which point the main line routes divide for New York to the north, for Washington to the south and for Pittsburgh to the west. The station accommodates through passenger trains and, in addition, an extensive suburban movement over six different routes. The growth of all business in recent years has been such that the limit in capacity of the station has been reached and many plans have been formulated and discussed for relief by physical enlargement of the station and its approaches, or by rerouting movements. All of these plans involve extensive reconstruction and would require much time for their accomplishment so that a more expeditious method of obtaining relief was desirable. The possibility of employing electric traction for the purpose was investigated by committees consisting of operating officials of the road and their recommendation has resulted in the adoption of an initial program for this form of traction on the one of the suburban lines which promised to effect the greatest relief.

The cruicial point in the operation of the terminal is at the junction between the six approach routes with the sixteen station tracks at the interlocking cabin immediately west of the station. Congestion at this point is due to the regular scheduled train movements, the shifting back and forth from one track to another of cars and drafts, and the movement of empty power. By electrification, which permits the substitution of motor car trains for those hauled by locomotives, a certain number of movements are eliminated; for instance, it will not be necessary to provide for any light engine movements either coupling to an outbound train or for the road engine which has brought this train into the station and must follow it out on the return movement; furthermore, there will be some gain due to the quick acceleration of electric trains and to the shorter length of track occupied when the steam locomotive is omitted.

The most important suburban service is that on the main line west to Paoli, twenty miles out, and this service, therefore, has been electrified to furnish the greatest relief. It is estimated that during the rush hours the relief secured will be from 17 to 19 per cent in this particular service and for the station as a whole will be equivalent to the relief accomplished by reducing the total number of trains by about 8 per cent. This relief should, therefore, be sufficient to take care of normal growth of business even in bad weather, for the next four years and the period of relief can be further extended by electrification of the remaining suburban lines if the trial of this initial service should meet expectations.

The estimates under electric operation indicate that there will be sufficient saving over steam operating costs to pay interest on the investment which, of course, includes the most expensive portion of the work, in that the entire Broad Street Terminal with elaborate yard and restricted property lines and approaches thereto form a part of the construction required for a relatively small amount of train service. This result under the circumstances is not unfavorable, inasmuch as it means that practically speaking the increase in capacity can be made to pay for itself, whereas increase in capacity by a physical enlargement would give no direct return upon the heavy investment. There are, of course, other contingent advantages of electrification, such as higher speed of trains, more punctual service, especially in bad weather, and more cleanly and attractive conditions for the traveling public. But, as before stated, the electrification has been undertaken solely as an emergency measure to effect quickly a station relief which was greatly needed.

The electric system adopted for this installation is the single phase, alternating current system, using overhead contact wires supported from catenary cables, current being supplied to the trolley wire at 11,000 volts. Careful analysis and estimates covering all available systems led to the conclusion that a system using a very high voltage overhead contact wire and one which eliminates moving machinery in substations for the supply of power is most suitable and also the most economical both from the standpoint of first and operating costs. In arriving at the conclusions primary importance was also attached to possible future long-distance through electric operation over the entire divisions affected, rather than to the present requirements of short suburban electric service.

The fact that the New York Terminal is operated by the third rail direct current system does not constitute a serious objection to the use of the single phase system at Philadelphia and for main line extensions to connect with the present New York electrification for the reason that the mercury arc rectifier has now been developed and tried out on Pennsylvania equipment, the railroad having been co-operating with the manufacturers in the development of this apparatus for the last two years, to the point where it can be safely said to be available for use on electric locomotives. By adding rectifiers, transformers and control details to the present locomotives in New York, through operation to Philadelphia can be conducted with the single phase system.

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The character of overhead construction adopted has followed a study of existing electrifications both here and abroad and the erection of an experimental section of the line with various forms of construction to determine the practical advantages, both from the standpoint of cost and especially to furnish the least obstruction to the view of signals along the tracks and reduce the unsightliness of the structures as far as practicable.

The line is of four tracks and used not only for suburban service, but for through passenger trains and for freight. The suburban service is confined to the two outer tracks, but must be occasionally crossed over to the middle tracks and for this reason and to increase the reliability of operation in emergencies it was decided to equip each of the tracks with a contact wire.

The interesting and novel features of the construction are in the use of tubular steel poles guyed on curves by two back guy rods and bridged between by cross catenary wires to carry the longitudinal catenary contact wires. As this line is equipped with a very complete system of automatic block signals, the bridges for these signals, which occur at intervals of about half a mile, have been designed to act as anchor bridges for the longitudinal catenary system. In order to increase the visibility of signals and to secure a type of signal having the minimum amount of mechanism on the bridges, a novel form of position light signals has been developed by the signal department of the railroad company. These signals consist of rows of lenses back of which are placed separate small electric incandescent lights mounted in front of an opaque screen background and hooded to concentrate the light, so that beams of light are projected and these produce "position" signals, as in the case of semaphore arms. The shifting of the lights from a vertical beam, indicating "safety," to the horizontal beam, indicating "stop," as well as to the intermediate position, indicating "caution," is accomplished by the switching of current on and off the respective groups of four lights which constitute the beams.

The cross catenary bridges are located 300 ft. apart and the poles carry one 44,000 volt single phase alternating current transmission line on each side of the outer tracks and a duplicate 2,200 volt signal transmission line.

The longitudinal catenaries consist of the usual form of steel messenger wires suspended to the cross catenary through insulators and from which are hung by bronze fittings a secondary messenger; from this latter the trolley wire is flexibly supported by bronze clips. The construction is designed for a maximum amount of flexibility and for the elimination of hard spots which may cause sparking at the contact when running at high speed. The 44,000 volt transmission current is stepped down in three static transformer substations along the line and fed into the trolley wires at 11,000 volts, from which it is collected by the pantagraphs on the motor cars of the trains.

The motor cars, of which 93 have been provided, are the standard MP-54 suburban steel passenger cars of the road. These cars are 54 ft. 6 in. long over end platforms and are lower over all than the standard main line passenger car, being 13 ft. only from the rail to the top of the roof. The seating capacity of the cars is 68 passengers. It will be noted that the cars are provided with end vestibules so arranged as to form a motorman's compartment at the head end of the train.

Each car is equipped with two Westinghouse single-phase, single-reduction geared motors mounted on one truck. These motors are of the series repulsion type and have been specially designed for this service and have a capacity of 225 horsepower each on a one hour rating. By special designing these motor cars occupy a minimum amount of space and have been mounted on a truck with 38 in. diameter wheels. This has not required any change in the height of the car floor or any reduction in the strength of the floor framing to secure the necessary clearances. Each car is equipped with one pantagraph collecting current from the overhead wire, a static transformer to reduce the current to the voltage required by the motors and the Westinghouse multiple unit electro-pneumatic control, also the usual appurtenances of motor driven air compressor and air brakes. Erection of all electrical apparatus has been done by the Motive Power Department at Altoona.

It should be mentioned that the equipment of this line has not included the building of a power house. Inasmuch as the amount of power required was not very great it was found desirable for the present to purchase the requirements from an existing power plant and a contract has therefore been entered into with the Philadelphia Electric Company to furnish single phase alternating current power at 13,200 volts at the main substation of the railroad company adjoining the line at Gary's Ferry, Philadelphia; at this point the power is stepped up to the transmission voltage, 44,000, for distribution over the line.

Time does not permit the going into details of the construction but it might be said that there has been some specially difficult work in the design and installation of the transmission and trolleys on the Terminal Division where there is a great complication of tracks, grades, curvature, etc. Complete operation into Broad Street Station is expected to take place at the end of May.

General statistics of this installation are as follows:

Route miles	20.3
Track miles	86.1
Grades, maximum	1.6 per cent.
Average westbound grade	0.55 per cent.
Per cent of line on curves	50 per cent.
Sharpest curve	4 degrees.
Number of trains per day (both ways)	84
Average number of cars per train	3.25

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Maximum number of cars per train	7
Number of stops	19
Schedule speed, including stops	24 m. p. h.
Maximum speed	70 m. p. h.
Energy required (1 hr. peak)	3750 kw.
Number required (all motor cars)	93
Material	Steel
Length over all	64 ft. 0½ in.
Length—inside	53 ft. 7⅝ in.
Width over all	9 ft. 11½ in.
Height—rail to top of roof	13 ft. 0 in.
Seating capacity	68-72
Weight	118,600 lbs.
Weight, body	48,555 lbs.
Trucks (two) excluding motors	31,800 lbs.
Motors, with gears and gear cases	14,000 lbs.
Of all other equipment	24,245 lbs.
Total (without passengers)	118,600 lbs.

NEW YORK CENTRAL ELECTRIFICATION.

By Edwin B. Katte.*

The most interesting thing about electrification to railroad men at the present time is the first cost and here the comparison with steam operation is most unfavorable. For example, a modern steam locomotive costs about $25,000, and an electric locomotive of the same capacity will cost about $45,000; and that is not all, the cost of the power station, transmission lines, substations and working conductors must be added, which will bring the equivalent cost up to about $110,000, more or less, depending upon the system adopted and the character of the service. Hence, there should be a large saving in operating costs to cover the increased fixed charges, or there must be some other good reason for incurring the additional expense.

The New York Central Railroad Company electrified its lines into Grand Central Terminal because it had a bad four track tunnel condition to deal with at the most congested point of traffic. After electrification was decided upon, a very comprehensive scheme of improvements followed, which has cost in all, something like one hundred and twenty millions of dollars, resulting in radical changes in the movement and operation of trains. It is for this reason that a direct comparison between the former steam and the present elec-

*Chief Engineer, Electric Traction, New York Central R. R. Edwin B. Katte is a son of Walter Katte, one of the charter members of the Western Society, whose account of its founding appears on page 339.

tric operations is impossible. However, some general comparisons can be made, based upon rather broad assumptions.

The average cost per locomotive mile derived from a large number of records of steam locomotives in all classes of service has been found to be about 26 cents per mile, including fuel and supplies, maintenance, repairs, and engine house expenses. A similar figure for electric locomotives operating in and about New York City can be shown to be about 21 cents per mile, but when fixed charges are added, the comparison becomes 30 cents for steam locomotives and about 60 cents per mile for electric locomotives. This comparison is only approximate and open to criticism because of the fact that conditions in New York permit but an average of 85 miles per day for electric locomotives, while the steam locomotives are averaging about 150 miles per day. Further, many assumptions too numerous to describe in this brief discussion were necessarily made, which would preclude the acceptance of these figures as a direct comparison of facts, but which are sufficiently accurate to indicate the tendency.

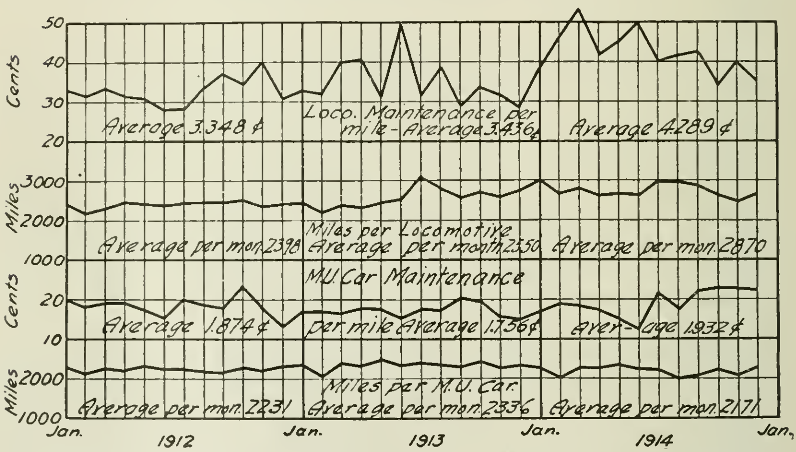
The electric locomotive service in New York and vicinity includes switching in yards and terminals, hauling shop trains about six miles, and a main line express service on one division of 34 miles and another division of 24 miles. The average cost for maintenance, including inspection, repairs, renewals, cleaning and painting varies from month to month, but the average covering a period of eight years is not far from 3½ cents per mile. The maintenance during the past year has been about 4 1/3 cents per mile. The increase was caused by the renewal in one year of driving wheel tires on the first 35 locomotives purchased. Fig. 1 indicates the variation in cost per month for the past three years.

The suburban service in the vicinity of New York City is handled by multiple unit trains consisting of from two to eleven cars, with trailers used in the proportion of two motor cars to one trailer on trains having easy schedules. Maintenance, including mechanical and electrical repairs, inspection, renewals, painting, etc., excluding only sweeping and window cleaning, has averaged somewhat less than two cents per car mile. This variation from month to month is also shown in Fig. 1.

The working conductor used by the New York Central Railroad Company is a special type of underrunning third rail, and is believed to afford greater protection from accidental contact than any other third rail. Its chief characteristics are, first, a wooden sheath enclosing the live third rail, except on the bottom or contact surface, and second, an insulated support so hung as to afford flexibility to prevent strains due to the up and down movement of the supporting ties under traffic. The cost of maintaining this protected third rail is naturally higher than for the usual type of third rail, and the large amount of construction work in progress adjacent to the third rail has increased the maintenance cost above normal conditions. The average cost has been about $26.00 per mile, per month, on the main line and $40.00 for yard and terminals, including track bonding and cable connections, both positive and negative.

The cost of maintaining the New York Central Railroad's cable system can be of little comparative value, because of the great diversity of its character to meet unusual local conditions. Lead covered, paper insulated cables are used in underground tile ducts. Steel wrapped, varnished cambric cables are used in iron pipes on the Park avenue viaduct; armored, lead covered, rubber insulated cables are laid under the Harlem river, while bare copper, aerial cables supported on steel poles are used in the outlying and less con-

Fig. 1. Operating and Maintenance Cost of Electric Locomotives and M. U. Cars. Also Average Miles per Month per Electric Locomotive and M. U. Car.—N. Y. C. & H. R. R. R., Electrical Department.



NOTE—The equipment being comparatively raw, operating costs are not average for the life of the apparatus. The low mileage is due to short car runs and the switching service in which many of the locomotives are engaged.

gested districts. However, as a general statement, it may be said that the cost of maintaining the three phase A. C. lines is about $8.00 per circuit mile, per month, and the direct current cables cost about $13.00 per cable mile.

The cost of electric current varies considerably with the prices paid for coal, which in New York average from $2.50 to $3.00 per short ton. Also the fact should be noted that power stations in the vicinity of New York City are operated on three eight-hour shifts, in place of the more common twelve hour shifts. The cost of eleven thousand volt, three phase, 25 cycle current measured at the bus bars of the Port Morris Power Station averages between 0.45 cents and 0.50 cents per kilowatt hour for operating labor and materials.

Fig. 2. Train Minute Detention Due to Electric Operation for the Year 1914.—N. Y. C. R. R., Electrical Department.

Month	Train Minute Detention: Electric Power Trouble: Power Sta.	Sub. Sta.	Trans. Line 11000 K.	Trans. Line 600 K.	3rd Rail	2200 Volt Signal Line	Total	Electric Locomotives: Fuses	Contactors	Reversers	Misc. Elec.	Brakes	Misc. Mech.	Total	Multiple Unit Cars: Fuses	Contactors	Relays	Control Jumpers	Misc. Elec.	Brakes	Hot Boxes	Misc. Mech.	Total	Total for all Causes	Mileage: Loco's. Total	M. U. Cars Electric Zone	M. U. Cars Total	Av. Miles per M. Det.: Loco's Total	M. U. Cars Elec. Delays	M. U. Cars Mech. Delays	Total for all Causes
Jan.	–	11	–	–	5	—	16	36	18	–	86	5	124	269	—	13	—	–	27	21	5	43	109	394	188,314	459,989	475,607	700	11500	6893	1685
Feb.	–	–	157	–	–	35½	192½	21	4	22	60	8	193	308	2	–	7	5	76	26½	–	35½	152	65½	166,740	409,701	423,680	541	4552	6834	905
Mar.	–	–	47	–	–	3½	50½	–	9	24	9	4	65	111	2	–	–	–	7½	41	22	40	112½	274	175,555	459,250	474,219	1581	48,342	4604	2371
Apr.	–	–	–	–	–	—	—	–	50	–	54	3	–	107	–	–	3	–	17	–	18½	9	47½	154½	164,136	462,703	478,300	1534	23,135	17,393	4158
May.	–	3	133	–	25	14	175	4	–	60	4	19	–	87	–	5	4	–	–	48	–	3	60	322	166,034	471,724	489,234	1908	52,414	9593	2035
June.	–	–	260	–	6½	12	278½	–	–	10	65	–	14	89	–	–	–	–	2	32	95	3	132	499½	165,851	449,854	465,339	1863	224,927	3580	1264
July	–	12	–	–	–	194½	206½	5	32	–	9	7	19	72	–	–	–	3	18	–	16	13	50	328½	185,656	441,956	461,564	2579	21,045	15,916	1970
Aug.	–	–	–	–	3	70	73	–	–	–	41	–	37	78	3	–	–	–	–	6	–	13	22	173	185,659	403,266	420,018	2380	134,422	22,106	3501
Sept.	–	–	–	–	–	—	—	–	14	12	14	–	–	40	–	–	–	3	–	–	–	13	16	56	180,548	412,802	429,728	4514	137,601	33,056	10,898
Oct.	–	–	–	–	–	13	13	5	6	–	13½	4	–	128½	–	–	–	–	12	–	–	7	19	160½	165,670	451,312	467,138	1289	37,609	66,734	3943
Nov.	–	–	–	–	–	—	—	–	39	–	83	9	13	144	38	–	–	–	25	–	22	9½	94½	238½	155,860	421,944	437,350	1082	6698	13,884	2467
Dec.	–	–	–	–	9	121	130	–	–	–	32	–	10	42	–	–	–	–	–	62½	–	–	62½	234½	166,230	458,451	474,426	3958	—	7591	2732
Total.	–	26	597	–	48½	463½	1135	71	172	128	576½	59	473	1475½	45	18	14	11	184½	237	178½	189	877	3487½	2,066,253	5,302,952	5,496,603	1400	19,457	9093	2169

NOTE—Locomotives—Number of detentions, 94; miles per detention, 21,981. M. U. Cars—Number of detentions, 108; miles per detention, 50,894. Does not include New Haven trains. Based on total mileage of locomotives and M. U. cars.

When fixed charges are added, the cost averages about 0.75 cents. The transmission of current to the substations, transforming in substations, the loss in the working conductor system and the addition all fixed charges will bring the average total cost of current, delivered to the shoes of equipment, to about 1.75 cents per kilowatt hour.

As a measure of the reliability of electric equipment, a comparison of the locomotive or car miles per detention is preferable to a comparison of the miles per minute detention, since the former excludes delays to following trains and other causes of delay in no way contributed to by the equipment. During the year 1914, the average locomotive miles per detention was 22,000 while the multiple unit cars averaged 51,000 miles per detention. The train minute delays due to electric power troubles totaled 840 minutes for the year. The aerial lines contributed most largely, namely 535 train minutes; the third rail caused 244 minutes delay, substations 25 minutes and the power stations have never caused a minute's delay during their eight years of operation. (See Fig. 2.)

The electric locomotives are of the latest type used by the New York Central Railroad in express passenger service. They have a speed of 60 miles per hour when drawing a 1,200-ton train. All axles are equipped with motors, each having a continuous capacity of 250 H. P., or 330 H. P. on the one hour rating; that is, 2,640 H. P. total. The locomotive is equipped with an oil-fired, flash type boiler having a capacity of 2,000 lbs. of water per hour for heating through trains. The complete weight of the locomotive is 132 tons, all of which is carried on the drivers, thus giving a draw bar pull of 66,000 lbs., assuming 25 per cent adhesion.

The multiple unit cars are of all steel construction, 60 feet long over buffers and weight about 57 tons. They seat 64 passengers each. There is one motor truck under each motor car, having two motors of 200 H. P. each. The maximum speed of the train is 54 miles per hour.

THE NEW YORK, NEW HAVEN AND HARTFORD ELECTRIFICATION.

By Wm. S. Murray.*

We are rapidly putting far behind us the days when the attitude of railroads was to sit by and watch some one or two other railroads experiment with electricity as a motive power. Indifferent interest has given way to the realization that these pioneer roads which have been using this new power in every form of railroad movement have developed a fund of data which entitles it to more than passing in-

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terest, and requires that they be keenly alive to the possibilities it may hold out in the matter of betterments to their own property.

That a thing of any character has the right to live and improve is based entirely on whether it is founded on correct principles. In the early days when electrical movement was first introduced on heavy traction railroads, theory was strong and practice severely limited. The guiding principle upon which electrical men based their opinion that electrification had its proper place in the economic world, was that by its use certain savings could be effected that would justify the investment necessary to secure it. There was entirely outside of this, but indirectly an economic factor, the advantage accruing to the passenger in the form of a clean ride.

While I have, of course, been keenly interested in electrification that has been applied to other railroads, naturally the past ten years' association with the New Haven work, during which time over $15,000,000 have been expended in this department of betterment, has brought the real elements of its progress within very close range.

In June, 1914, the first New York, New Haven and Hartford passenger train was operated from Grand Central Station to New Haven over a four-track electrified route, 73 miles in length. Between New York and New Haven, measured upon a single track basis, there are some 500 miles of electrified line, of which 184 are included in yards and sidings. On these tracks today, every class of passenger, freight and switching movement is made, and electrical statistics are kept of all power house, line or equipment failures, a reference to them suggesting the features of electrical operation that require first attention for the betterment of service. These statistics of electrical operation will doubtless be available in the Franklin Institute Transactions in a short time.

A feature of electrification that at present is the most appealing to one who has given the subject some consideration, is in the matter of freight and switching movements. Since 1907 the New Haven Road has been operating its regular 100 per cent electric passenger service between Stamford and New York. But recently, experience with regard to electric movement in switching and classification yards, and more recently that with regard to freight movement on main line track, has indeed been a revelation in the possibilities of heavy electrical traction. For example, during the month of January past, on the New Haven over 40,000,000 ton miles trailing load were handled by electric locomotives, this total tonnage being made up of fast, slow and local freight movement. There is installed on all of the electric engines wattmeters to register the kilowatt hours of consumption. Records of these wattmeters indicate that fast freights require on the order of 34 kw. hours per train mile; slow freights on the order of 60 kw. hours per train mile; local freights on the order of 36 kw. hours per train mile. These figures being for trains varying in tonnage from 1,000 to 3,000.

Of interest also are the kilowatt hours per 1000 ton miles of trailing load. For fast freight the kilowatt hours per 1,000 ton miles are on the order of 30; for slow freight 30; and for local freight 85. I make mention of these figures only to illustrate this new and vast sum of information that is daily coming to us. The "watt hour constants" are of necessity average figures, made up of trains having varying weights and schedules, and yet the records from which they are taken admit of instant segregation into any class of service for which a constant is desired. The question that might be asked in looking at these constants is: What do they signify? And the answer is brief; an electrical ton mile as against a steam ton mile reduces the coal pile in a ratio of 1:2.

While our present freight movement by electricity on the main line is today limited both on account of the general depression in business, together with the fact that a full complement of electric freight locomotives is not yet at hand, a record of one day's movement of electric freight trains between Harlem river and Bridgeport shows 14 trains, 804 cars and a tonnage of 28,159. There is no question in my mind but that the greatest returns to be secured by electrification will be through freight movement.

While in the past we have appreciated the economies to be secured through electrification, in virtue of lesser expenditures required in fuel and maintenance of electric engines as against steam, there is fast coming to the front what might be called a more visualized economy in the reduction of expenses by effective savings in train miles.

Illustrative of the economic value of a "kilowatt hour" in its application to an electrification system, I quote from a part of a recent letter which had reference to the utilization of some 4,500 kw. of demand in connection with its application to the eastern section of our electrification zone. I would particularly draw your attention to the item of $49,275.00, which has reference to the economies to be gained by the double heading of freight trains operated between Harlem river and New Haven. This economy, and its automatic complement, the increase of track capacity, are the phases of electrification that are striking deep into the consideration of the steam operation railroad man.

"(1) The extension of the station contemplates, as you know, supplying a maximum single-phase demand of approximately 4,500 kw. This amount of power measured by train units, would permit the operation of twelve additional daily trains in fast freight service of average tonnage, or its equivalent in any other class of service between Harlem River and New Haven.

"(2) The number of kilowatt hours which would be consumed by the above twelve trains would be 17,500,000 kw.h. annually, and, as previously discussed with you, upon a coal ratio of 1 to 2 in electric and steam service and a basis of three lbs. per kilowatt hour and $3.00 per ton, an annual saving to the railroad company of $78,750 is indicated.

"(3) Further translating the above movement into engine miles, our log sheet records indicate that the number of engine miles required for the above movement would be 990, which multiplied by the difference in cost of engine repairs at 5 cents per engine mile, effects annual savings of $18,250.

"(4) The transfer of twelve daily trains from steam to electric service will permit a further extension of our present practice of 'double heading' trains in electric service, thus saving 450 daily train miles, which as shown by our log sheet will secure an annual reduction in train wages of 30c per train mile, corresponding to an annual reduction of $49,275.00.

"(5) A supply of approximately 3,000 kw. (average) to the New Haven end of the line will effect a further saving of $16,500 in transmission losses, as compared with the transmission losses of the same amount of power from Cos Cob Station; the above savings being based upon the conservative cost of 5 mills per kw.h. In explanation of the apparently large value of the saving in transmission losses to be effected by this small installation, it will be evident that its value is maximum when applied at the extreme end of the transmission system.

"(6) No tangible values can be assigned for the very important effect upon the regulation in line voltage at New Haven, which will be reflected in the cost and efficiency of operation in many ways.

"(7) The summary of the total savings as above, which will be effected is as follows:

Fuel	$ 78,750.00
Engine repairs	18,250.00
Engine and train wages	49,275.00
Transmission losses	16,500.00
	$162,775.00

If any criticism can be placed with regard to the matter of freight movement by electricity, I would say it would be in the matter of speed. The electric freight locomotives of the New York, New Haven and Hartford Railroad were built on specifications that permitted them to operate 1,500 ton trains on level track at 35 miles per hour. While the speed element, in as far as the New Haven service is concerned, may be entirely justified due to the very large ratio of passenger to its total service, thus permitting the freight trains to clear more promptly for passenger traffic, I would say that where the ratio of passenger service is less, the speed element for equal horsepower could be more valuably thrown into traction. For example, the New Haven locomotives have draw-bar pull characteristics that permit the operation of 3,000 ton trains by double heading. If these engines were reduced in speed by 35 per cent and their traction increased by the same percentage, 4,000 tons would be the resulting double header trailing load which in turn would effect a large saving in train miles were these engines to be operated on a property less subject to passenger movement.

Much valuable information has been developed in the past two years in connection with the handling of classification and switching yards by electric motive power. An idea as to the reliability of this class of service may be gained in saying that in 1,000,000 electric switch engine miles there has been but one failure.

The New Haven property includes in it two large switching yards: the Oak Point Yard containing 35 miles of track; the Harlem River Yard 25 miles. The introduction of the electric engine in these yards has increased the speed of the yard very greatly, and as near as I can gather from the yardmasters this increase of speed has been secured with a ratio of electric engines to steam engines replaced varying between 4 to 6 and 6 to 10.

Electricity in trunk line territory is now on a plane of consideration entirely different from the earlier days when it was new, untried and problematical. The future will see its agency playing a most important part in railroad competition.

While this paper has had particular reference to the New Haven and its increase of operation through the extension of its electrification zone, it would seem very inappropriate with so good an opportunity as this, not so say a word or two as to "system." I am willing to admit that I am a firm believer in the single phase system for trunk lines, the governing element in which, from an electrical standpoint, has been the transmission system. In a rigorous determination to adhere to this principle as correct for such a field, it has not been to gainsay the application of direct current in the territory where it rightly belongs; namely, where the governing element has been mass (trains under acceleration and breaking in close headway) in translation. As a citation of the two examples I would offer: (1) The electrification from New York to New Haven, and (2) the electrification of the New York subways.

In closing I would speak of two things which to my mind are most pertinent to the advance and successful utilization of electricity in the field of heavy traction.

The first is with reference to the mercury arc rectifier, and the second is in regard to effective electrical administration on the part of railroads electrifying.

Having reference to the mercury arc rectifier, I feel sure that it will be of interest to state that there has been in commercial operation on the New Haven Road a car taking power from the 11,000 volt alternating current overhead contact system, and converting it into direct current for application to its propulsion motors. This car has been giving a most successful service, and the problem of the production and maintenance of the vacuum tube, through the agency of which the alternating current is converted to direct, has been electrically and commercially solved. What are the possibilities accruing from such a result? This can be epitomized in the statement that, if the economies in the transmission system of the single phase system justified the utilization of a heavier and less efficient motive power, today we are in a position not only to secure the economies gained in this transmission, but also to operate beneath the contact wires of such a system the more efficient and lighter direct current apparatus. As a concrete and practical application of this result, the present alternating current motive power now in use on the New Haven will be increased 25 per cent by the application of the rectifier, and also permit it to enjoy simultaneously transmission and motive power facilities of the highest order of efficiency.

With regard to administration, past experience with the engineering, construction and operation of a trunk line property of the character of the New Haven road has indicated with force the necessity of a very complete understanding of the difference between the operation of a steam and an electric property. In my judgment there will be no necessity for any general change in the administration or organization at present observed in steam operated properties to effect proper electric operation, but upon the minds of higher officials in the steam roads using or contemplating using this new mode of motive power, the fact should be impressed that the methods pursued in producing a ton mile of any character, passenger, freight or switching upon a steam basis must be abandoned when the draw-bar pull comes from electricity. The error of holding a steam master mechanic responsible for an electric engine mile of any character is patent, and equally patent is the error of holding a steam railroad shop man responsible for the maintenance and repairs of electric engines. Like electric power houses and transmission lines requiring the proper electrical talent, essentially necessary to the success of proper maintenance and inspection of electric motive power, are the electro-mechanics inside and outside of the shop. Such an arrangement does not change but merely affects the splendid railroad organization and administration that has come down to us. A successful operating result after electrification has been applied, is entirely dependent on a clear understanding and observation of this real difference between steam and electrical operation.

THE C. M. & ST. P. ELECTRIFICATION.

By C. A. Goodnow.*

The Chicago, Milwaukee & St. Paul Railway Company is now engaged in the electrification of that portion of its main line to the Pacific coast between Harlowton, Mont., and Avery, Idaho, a dis-

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tance of 440 miles. This project is of special interest because: (1), it provides for the electrification of four entire engine districts; (2), this work is being done to effect economies in operation on a single track line of moderate traffic and not to overcome congestion on a busy line now working to its capacity or to eliminate the smoke nuisance.

Between Harlowton and Avery this line crosses three mountain ranges, the Belt Mountains at an elevation of 5,768 feet, the Rocky Mountains at an elevation of 6,350 ft., and the Bitter Root Mountains at an elevation of 4,200 ft. There are several tunnels, the longest of which is the St. Paul Pass tunnel at the summit of the Bitter Root Mountains, 9,000 ft. long. The maximum grade westbound is 2 per cent for 20.8 miles on the eastern slope of the Rocky Mountains, while the maximum grade eastbound is 1.7 per cent for 24 miles approaching the St. Paul Pass tunnel. The hardest problem of this nature, however, is presented by the continuous 1 per cent grade for 44 miles, ascending the western slope of the Belt Mountains, involving as it does the necessity for special precautions to avoid overheating the motors while working at their maximum capacities for this long period of time.

Besides the yards at Harlowton and Avery, intermediate terminals are now located at Three Forks, Deer Lodge and Alberton. These terminals are all small and with the exception of Butte and Missoula, there are no towns of any importance within these limits. There is, therefore, practically no breaking up of trains as all traffic is through business. Including these yards and side tracks about 650 miles of track will be electrified.

Power will be purchased from the Montana Power Company. Owing to the ample supply of water power available and the low cost of construction, the unusually low contract rate of $0.00536 per kilowatt hour has been secured. By contracting for its power the railroad thus avoids expending directly the large amount required for the construction of power plants. To minimize peak loads it is probable that the duties of the train and power despatchers will be combined. In this way the spacing of trains can be best arranged to keep the peak loads down to the minimum. With the traffic existing on this line it is expected that this can be done without serious interference with the operation of freight trains.

To minimize the dangers of interruptions to the delivery of power a tie-in transmission system is being built by the railway to permit feeding each substation from two directions and from two or more sources of power. The transmission line is being constructed with wooden poles, will operate at 100,000 volts and in most cases will follow the right of way.

The Montana Power Company will deliver energy to the line at seven points between Harlowton and Avery. On the engine district between Three Forks and Deer Lodge, on which work is now under way, three substations are being built to convert the 100,000 volt, 60-cycle, 3-phase alternating current to 3,000 volts direct current. This is the first direct current installation using as high a potential as 3,000 volts and was adopted after observing the results secured with the 2,400-volt, direct current installation of the Butte, Anaconda & Pacific, which parallels the line of the St. Paul for a short distance west of Butte.

The trolley construction is of the catenary type, with two 4/0 trolley wires flexibly suspended from a steel catenary and supported on wooden poles with brackets on tangents and flat curves and cross spans on the sharper curves and in yards, the twin-conductor trolley consisting of two 4/0 wires suspended side by side from the same catenary by independent hangers alternately connected to each trolley wire. This permits the collection of very heavy current by reason of the twin contacts of the pantograph with the two trolley wires.

Contracts were let last year for 9 freight and 3 passenger locomotives for use on the first engine district, while 9 additional locomotives were ordered early this month for use on the second engine division from Three Forks to Harlowton. The passenger locomotives are designed to haul 800-ton passenger trains at a speed of 60 miles per hour on the level, or 35 miles per hour on a 1 per cent grade, and will be equipped with oil-fired steam heating outfits for heating the train. The freight locomotives are designed to haul a 2,500-ton train on all grades up to 1 per cent at a speed of approximately 16 miles per hour. This same train load will be carried unbroken over the 1.7 and 2 per cent grades with the help of a second similar locomotive acting as a pusher. At the summits of the grades, provision is being made to run the pusher locomotive around the train and coupling it to the head end to assist in the electric braking on the descending slopes. In addition to providing the greatest safety in operation, this will also enable a considerable amount of energy to be returned to the trolley for the assistance of other trains and reduction in the power bill. The electric locomotives will have sufficient electric braking capacities to hold the entire train on the down grade, leaving the air brake equipment for use in emergencies or when stopping the train.

At the present time work is being actively pushed on the engine district between Three Forks and Avery, 113 miles, crossing the summit of the Rocky Mountains, and it is expected that this will be ready for operation next October. Work is now also being started on the engine district from Three Forks east to Harlowton and it is planned to start work on an additional district each year until all four are completed. The contract with the electrical company provides that the entire 440 miles be in electric operation by January 1, 1918.

Several important economies are expected from the electrification of this line. In the first place this is the first time an entire engine district has been electrified, permitting the complete substitution of electric for steam locomotives between the terminals. In other installations throughout the country only a portion of a division has been electrified, resulting simply in a shortening of the steam operated engine district. With the present schedules enforced with train employees this has not enabled the savings to be secured which will result from the electrical operation of the entire engine district. Furthermore, with the electrification of four adjoining engine districts, it is planned to change locomotives only at the second terminal or at Deer Lodge. The crews will be changed at the intermediate terminals, Three Forks and Alberton, but there will not be the delay incident to the present methods of operation. It will be possible to abandon these intermediate terminals with the exception of a small amount of trackage on which to set out bad order cars, hot boxes, etc. It is also expected that with the low contract price for power which has been secured, a considerable saving will be made over the amount now expended for fuel. From these and other savings expected, it is anticipated that this expenditure will yield a very attractive return on the investment. If this is realized, it is possible that electrification may be extended from Avery across the Cascade Mountains to Seattle and Tacoma, a total distance from Harlowton of 850 miles, but not, however, in the near future.

DISCUSSION

President Jackson: In the past we have had many discussions relating to various systems by which electricity may be applied to the electrification of steam railroads, but on the whole these discussions have accomplished relatively little. However, this evening's discussion of operating results obtained from actual experience in the electrification of steam railroads, by men who have been actively connected with the operation as well as the construction, has been not only interesting but very valuable to the profession.

Regarding the operation of the New York Central electrification at New York, I will take the liberty of saying a few words as to my impressions of this particular work after going over the New York Central electrified zone a few months after all passenger trains were being operated electrically.

Probably the most noticeable feature of that installation was the remarkable smoothness with which everything was operating, as if the whole installation had been in use for years instead of months. I have found this to be the case with several main line electrifications both in the United States and Europe, and believe this has been the result experienced in most main line electrifications.

We have a very unusual gathering of men here who can tell us from personal experience, results obtained from steam railway electrification and also of the results that may be expected of future installations.

Fortunately these men can attack the problem from three different angles; the electrification engineer, the steam railroad engineer and the unprejudiced investigator. Accordingly I shall call upon Messrs. E. H. Lee, Jesse Holdom, C. S. Churchill, W. F. M. Goss, J. C. Mock, E. M. Herr and B. J. Arnold.

E. H. Lee, M. W. S. E., Vice-President and Chief Engineer, C. & W. I. R. R.: You all understand that I make no profession of a comprehensive knowledge of electrification or of its application in the operation of steam railroads, but I fully appreciate this opportunity of hearing this problem discussed, and think that the Society is especially fortunate in having papers from such representative men who are so well qualified to discuss this aspect of the subject. Nobody can doubt that electrification is a great problem; nor can they doubt that electrification is coming. As a steam railroad man I should hesitate to predict that it will not come into general use in the future. However, there is one broad principle that should apply. The most primitive method of freight transportation is probably that of carrying loads on mens' backs, as is still practiced in China. On a trip several years ago I was particularly interested in freight transportation method in the southwestern portion of the country. I noted that man power had been superseded by burro-train and when the requirements became excessive the burro-train was superseded by the mule wagon; then the single wagon was displaced by a three-wagon train. Further along I went into a part of the country where the wagon train of that description was not equal to the demands, and that method was about to be displaced by a gasoline or oil driven motor truck, to be followed by six or eight trailers. Now this all demonstrates the broad principle to which I refer. This same principle was brought out in a discussion which I recently heard between men especially qualified on the question of electrification; that the same reason for the improvement in other methods of freight transportation will determine the use of electricity in displacing steam, or will indicate that such use is not warranted, namely, the relative density of traffic. It seems to me that in reckoning up the possibilities and the needs to warrant such a change, we must get down to bed rock.

The President said that I am "from Missouri." It behooves us all to be from Missouri. We should demand to be shown. If the change is to come, it should be brought about principally by reason of economy. As engineers we must consider the problem both as to whether the change is warranted by other conditions, and whether it will pay.

Judge Jesse Holdom, Chairman, Chicago Association of Commerce Commission on Smoke Abatement and Electrification of Railway Terminals: Mr. President and friends: It is gross flattery to ask a man who knows as little as I do about any kind of engineering to talk to this very distinguished body of engineers. For the past four years I have been instructed a good deal in this line by my brother, Dr. Goss, in the work of a committee of which he and I happen to be members, he being its Chief Engineer. The final analysis of the committee's problem is the necessity and feasibility of the electrification of the railway terminals in the city of Chicago. During these four years I have heard a great deal of discussion of this problem pro and con, and the conclusions of the committee are not yet quite reached. Naturally the railroad men have a great deal of faith in their old, well-tried and reliable steam engines, and I do not blame them. She is a dirty smoky thing but if she were abolished the air pollution would not be perceptibly improved. I do not think anything ever invented did as good, steady and reliable work as the old smoky steam locomotive, and I have noticed that the genius of the best engineers and mechanics have been bended to one thing, that is, to try and invent some other unit of power that will do the same work and do it as well as the old-time steam locomotive, and if they ever get anywhere near to accomplishing so much as this very much despised smoky locomotive with a new unit of power, I am quite sure the good old faithful steam locomotive will have to go to the rear for all time. One among many difficulties in bringing about electrification is, as my brother Lee says, will it pay? Is it an economical possibility? I have no doubt that all of the terminals in this big city would soon be electrified if the roads could get away from the heavy burden of the first cost. This is a bugaboo the roads cannot escape. Just think of scrapping all of those useful, smoky locomotives that cost so much money! It is a tremendous problem, and yet I think in the evolution of time the railroads—passenger, freight and suburban service—will all be operated by electricity, although it may be a hundred years to the time of the fruition of these hopes of today.

Electrical transportation is very attractive to the traveling public; it is comfortable, clean and pleasant. When I look around me and see all of these engineers, and think of others who are not here, I feel sure that when this problem is possible of solution it will come through the ingenuity of these men, and come it will when it is financially possible. The greatest difficulty, as I see it, is the financial consideration. We cannot have changes of so revolutionary a character unless the money is available to pay for them. The railroads must have the money in order to get the new equipment which electrification will necessitate.

It has been a great pleasure for me to be here this evening and listen to Mr. Gibbs and Mr. Katte and others who have accomplished so much in the line of the electrification of railroads. Theirs is grand work and the result of their genius and labors will be their lasting monument.

Mr. C. S. Churchill, Assistant to the President, Norfolk & Western R. R.: Mr. Gibbs has explained this matter so fully that it seems to the speaker he can add very little to the former's statements. Perhaps it might be of interest to say something about the beginnings. The proper beginning was very well described by Mr. Lee. It consists of finding out whether the business conditions are such as to warrant any such expenditure of money as electrification requires. This investigation was started by the Norfolk & Western Railway in 1905. The reports on possible economies were not then satisfactory; they did not show any assured savings. In those days the principal savings that the electrical manufacturers could suggest were those that might result from a reduction in the number of men required, whereas now we know that the services of no men are saved by the motors, because two men are required with each of them; and the original proposition was, therefore, not acted upon. The Norfolk & Western Railway was, consequently, obliged to investigate this subject from a different standpoint entirely, such as economies resulting from savings in coal consumption, which have been found, as just stated, to be on the New York, New Haven & Hartford Railroad, as 1 to 2 in favor of electric operation; in increasing the capacity of the railroad itself; also safety of operation, with resultant decrease in cost. The increasing of the capacity of a line is of great value and was an important element in our case. Mr. Gibbs has brought out this point in calling attention to the fact that coal trains make a speed of about 7 miles per hour with steam locomotives on a 2.0 per cent grade, whereas with an electric locomotive the speed is 14 miles per hour. In order to secure in detail an estimate of economies, the Norfolk & Western Railway kept, for a long period of time, a log record of all freight trains in that 30-mile district described, and also kept a record of all engine repairs, consumption of fuel and supplies and all other costs. It is a hard thing to secure this data and it is seldom accomplished on a district as small as 30 miles. It is difficult to segregate the expenses and it is possible only by keeping full reports by trips. On a grade of 2.0 per cent with three Mallet engines on each train, it is surprising to note what a tremendous loss of time occurs on such a trip, stopping at one time to clear the fires, again to get water, again to coal, again for signals, and short delays from other causes, and so on. These delays multiply so that those steam locomotives make but one trip per day, while the electric motors will make two or three trips per day. From this statement there will be seen at once the main reason for the economy in that type of operation. The displacing of thirty-three Mallet locomotives by eleven electric motors, which will be the result on the Norfolk & Western Railway, brings clearly to mind where the economies will come in. All this indicates, without any further explanation, how such a problem should be approached by any one interested in this subject. The density of the traffic is, after all, the important factor. The fact that 60,000 tons per day was the basis of our estimates is practically a statement that anything much less will be unprofitable for electrical operation on such a railroad district as is being electrified on the Norfolk & Western Railway.

Both Mr. Gibbs and Mr. Katte have pointed out other reasons for electrification than a direct saving of money. Indirect savings of importance may be found at important terminals in many places, but the estimating of either direct or indirect economies should be proceeded with on lines similar to those adopted by the Norfolk & Western Railway, and if sufficient density of traffic of any kind exists the economies may be made up of those resulting from increased capacity of tracks, savings in time, savings in fuel and supplies, savings in repairs, and savings in various types of labor. But none of these savings can be even estimated without first segregating every item of cost under the existing methods of operation of the terminal or district of the railroad in question.

Now, gentlemen, it is well to think over that point very carefully, and remember, at the same time, that a railroad company cannot well approach this subject with the idea of securing real savings unless some such density of traffic already exists.

W. F. M. Goss, ASSOC. W. S. E., Chief Engineer, Chicago Association of Commerce Commission on Smoke Abatement and Electrification of Railway Terminals: Mr. President, members of the Western Society, and friends: First of all, I must congratulate the Western Society upon having been able to attract the attention of these "three wise men from the East," who have brought their message to us. Their presence and contributions make this a significant meeting, for there are none better qualified to speak on the subjects which have been presented to us than Mr. Gibbs, Mr. Katte and Mr. Murray. I am glad to have an opportunity to express my appreciation of their courtesy.

There is not much that I can say concerning the great problem which you would like to have me present. It happens that the report of the committee which I serve, dealing with the problems of smoke abatement and the electrification of Chicago's railroad terminals, is now in the hands of the printer, and until it issues I cannot speak. The fact that Judge Holdom, the distinguished Chairman of our Committee, sits by me, ready I am sure to pull my coat if I venture too far afield, naturally suggests caution.

I may, however, call attention to the significance of the work of the Committee, in the light of the descriptions this evening. The marvelous work which has been done in the electrification of the traffic of limited sections of certain great railroads, presents engineering achievements of the highest quality, but the work in the case of each road described is nevertheless a pioneer installation. When you couple that fact with the fact that of all the steam railroads in the world which thus far have entered upon electrification, the total number is less than the number of railway corporations which make up the Chicago railway terminals, the extent of the committee's problem becomes apparent. It is probable also that the number of electric locomotives required for the operation of the traffic of this city is in excess of the total number of electric locomotives which the world possesses today. It is certain that the track mileage making up the terminals of Chicago, which is comprehended by the plans of the committee, is much in excess of the world's total electrified trackage of steam railroad standards. With this understanding of the extent of the problem, and the fact that all locations have been studied, designs have been made, energy requirements involving an extensive and diversified traffic have been determined, and cost has been formulated, should satisfy the members of this Society that the four years which Judge Holdom and the sixteen other busy men who make up the membership of the committee have given to the preparation of their report, has been time well spent. The results of their work will soon be in the possession of the public.

J. C. Mock, Signal Electrical Engineer, Michigan Central R. R.: The problem at the Detroit River Tunnel is a little different from any presented tonight, in that we were changing from a floating equipment for handling traffic across the Detroit River to one of rail, and, of course, you could hardly conceive of its being handled by steam through a tunnel under the Detroit River, because at the time it was contemplated, the New York Central and the B. & O. had been successfully operating electric trains, and the Grand Trunk was just about to begin at Port Huron.

The Detroit River Tunnel is really a terminal problem; merely a switching from the terminal in Detroit to the end of the Canadian Division in Windsor. The grades in the tunnel are 2.0 per cent in one direction and 1.5 per cent in the other. We are handling about 1,500 cars per day, including about 180 passenger cars. Their tonnage, taking an average of both passenger and freight, is approximately 50,000 tons per day. The type of locomotive used is a little different from any shown tonight. It is geared type, four axles, with four motors, mounted similar to street and suburban cars. The first six weighed 100 tons, which is supposed to be about the limit of axle loading for standard track. The last four were increased 20 tons each. The reason for this is increased weight of passenger trains, because of steel coaches weighing from 600 and 800 to 1,000 tons. These on 2.0 per cent grade would require a little more tractive effort than one 100-ton locomotive could develop for proper handling. Many passenger trains were handled, as a matter of safety, with two locomotives, both ahead.

All freight trains of full make-up, of any tonnage above 1,000 are handled with one locomotive ahead and one behind. It is not considered safe, with the present equipment, to exert much more than 50,000 lb. draw-bar pull.

The operation has been very successful. The primary three-phase current is purchased from the Detroit Edison Company. A third rail, like that of the New York Central, is used to carry the 650-volt direct current. The total mileage is about 25; the freight haul is 3.6 miles, and the passenger haul is 2.8 miles. Passenger trains under a maximum speed of 35 miles per hour make the trip in average time of 10 minutes; freight trains under a maximum speed of 30 miles per hr. make the trip in average time of 20 minutes. All engines are changed from steam to electric as trains arrive to go through the tunnel. Total trains per day average about 50. The approximate watts per ton mile is 35.

E. M. Herr, President, Westinghouse Electric and Manufacturing Company: The last time I had the pleasure of attending a meeting of the Society I was in the railroad service, and having had sixteen years' experience among the engineers of the Society as a railroad steam motive power man, it might be realized that perhaps I appear before this distinguished audience with some embarrassment, as a manufacturer of electric machinery, but such are the changes in our great country. It has been with a great deal of interest that I have watched the development of the use of electric machinery on railroads.

I was very glad to hear the expression so freely given here tonight, that the engineers ought to be "from Missouri" when it comes to electrification. I agree with that idea, and as a manufacturer of electrical machinery, regard it as of prime importance, because if we get any electrical machinery installed where it ought not to be, the manufacturer is sure to hear of it, and it is of the greatest importance to us as well as to you and all your clients to be sure that the installation of electrical machinery is well considered and properly applied. It is interesting to note the development of the use of this new power in the transportation field. We are only in the infancy of it, and yet very notable progress has been made in the past ten years. It is just about ten years since the first installation of heavy traction work in railroads was made. I was talking to a friend recently, who is vice-president of one of our largest railroad systems, a man I know very well, and with whom I have talked a great deal about the use of electricity in main line traffic. Heretofore he has been very skeptical about the use of it, but I was much interested in hearing him say that one of his neighbors, he felt, had wasted a great deal of money in heavy grade divisions on a badly congested part of their line. Had he instead used electric locomotives he would have accomplished much greater economy for a less expenditure of money. I merely state this as an instance that our minds are changing, and the ability to use this force is advancing, and yet we are only in the infancy of its use. But above all, stick to your principles of being "from Missouri" as to its application.

B. J. Arnold, M. W. S. E., Chairman, Board of Supervising Engineers, Chicago Traction: You are so accustomed to hearing from me in connection with this city's terminal problems that I hardly think you want to listen to me tonight, and especially since the hour is late.

It was a great pleasure for me to see the secretary of the Commission on the Electrification of the New York Central Railroad here tonight. I note that he was called one of the "wise men from the East," and he certainly deserves that title, although he might be considered by some as almost too young to be credited with so much wisdom. I feel certain that he will not disappoint them. It was my pleasure to have been associated with Mr. Katte and Mr. Gibbs in the electrification of the New York Central Railroad—Mr. Gibbs as a member of the commission and Mr. Katte as its secretary. I want to congratulate them on having secured such splendid results.

At one time in my experience I was a steam railroad man and I thought then that I knew something about locomotives. Then, in 1888, I thought I could see that the electric railroad would be the railroad of the future, and since then have been more or less interested in that direction. During the development of the science of electrical engineering—involving the electric railroad, electric locomotives, electric cars, etc.—the steam railway men have not been idle in locomotive design by any means. They have come from the old type of locomotive to the Mogul, then the ten-wheeler or Decapod, then to the Mikado and finally to the Pacific and Mallet type. So the steam designers have been just as alert as the electric designers, and the problem now is the relative efficiency of the steam and electric locomotives, and as far as that is concerned, the steam locomotive is about as efficient as the electric locomotive, with the latter's essential accompaniments. There is always a question as to what is the special advantage in applying electricity to a certain part of any road. My experience with the New York Central Railroad indicated that the economies of electrification just about offset the interest on increased investment, and therefore electricity could not be chosen on the ground of economy. Therefore it usually resolves itself into a question of increased capacity.

So far as economy and operation are concerned, we were not in position in the early days of electric railroading to prove that the increased capacity would warrant the change, nor that by the use of electricity they could make more miles per day per locomotive. For several years after the electrification of the New York Central Company's terminal its electric engines were limited as to miles they could make daily, because of the short run. An enormous investment in power plants, substations and transmission lines was carried and charged against this small amount of mileage. So it was extremely difficult for anybody connected with that road to show that the change had effected economies, but it was easy to see that the change had greatly increased the capacity of the terminal. Only within the past few months has the service been extended to the points for which it was originally planned, and the economies should begin to show.

The New Haven Road, with which Mr. Murray is connected, had the same handicap for some years, but recently the road was extended to Hartford, and now there is mileage enough to begin to get the economies he cites in his paper. He indicated that certain economies are bound to be greater as the length of the division increases. For that reason I look for good results from the Norfolk & Western electrification, as described by Mr. Gibbs, and from the division of the Chicago, Milwaukee & St. Paul road now being electrified in the west. When we get the results from the operation of these roads, I think we will have figures which will be of interest to you steam railway men. I might incidentally state that the electrification of the Sarnia Tunnel of the Grand Trunk, a short engine division electrified under my direction some ten years ago, has proven not only successful from an operating standpoint, but also profitable from a financial one.

My particular function now is to endeavor to convert Mr. Lee and some of his friends to the desirability of ultimate electrification of the steam roads occupying rights-of-way in Chicago. I will admit that there is one very difficult phase of the matter, that is, what to do with our steam railroad terminals so as best to serve the city of Chicago and also the roads themselves. Of course the officials of the various roads know much better what their particular road wants than I do, but it is possible that a particular road may not know what particular features are best for Chicago as a whole. So that, as a member of the Railway Terminal Commission of this city, I am, in common with the other members, endeavoring to point out to the steam railroads the elements involved in clearing up the situation. There are acres and acres of land, within or near our business district, now used for storage of material—storing of freight cars, sand, crushed stone, etc.—which property could just as well be so commercially developed as to give a sufficient capacity for railroad purposes to last for some time in the future, and at the same time make it available for other much needed commercial purposes.

Mr. Lee has furnished good ideas in meeting the problem. In the working out of the problem Dr. Goss and the other members of his commission have in charge the matter of analyzing the smoke abatement and electrification of terminal questions. He has found, as will anybody else who analyzes the question, that if the rights-of-way of the various roads which come into the city could be unified, and their uses readjusted, so that they could be utilized to the best advantage for all roads, then the question of terminals and electrification could be handled to much better advantage, and the cost of electrification greatly reduced.

THE FOUNDING OF THE WESTERN SOCIETY OF ENGINEERS

Personal Recollections of Walter Katte, M. W. S. E.

It is now nearly forty-seven years since the first efforts were made, out of which was evolved the Western Society of Engineers. During the latter part of the year 1868 and the early part of 1869 there was resident in Chicago and its immediate vicinity a large number of civil, mechanical and mining engineers. Several of these men, engaged in active professional practice and allied commercial businesses, were already members of the American Society of Civil Engineers and were keenly appreciative of the great advantages to be derived from such organizations. These men holding almost daily social as well as professional intercourse, felt the need of such an organization centering in Chicago and accordingly began to discuss informally at odd intervals the project of creating and inaugurating a "Society" for the purpose of promoting the best interests of the engineering profession and its membership.

The following list of names contains, I think, all who shared in these preliminary conferences but as that was forty-seven years ago, and as I am in my eighty-fifth year, it is not improbable that there may be others who participated in these early efforts. However, I think not, as my recollection of those days is quite clear.

Col. Roswell B. Mason, who was shortly afterwards elected Mayor of the City of Chicago, and was at that time Chief Engineer of the Ill. & Iowa Bridge Co., and was actively engaged in the construction of the bridge over the Mississippi river at Dubuque, Iowa.

E. S. Chesborough, City Engineer and Chief Engineer of the Chicago City Water Works.

Max Hjortzbery, Chief Engineer, Chicago, Burlington & Quincy Railroad.

Charles Paine, Chief Engineer, Michigan Southern & Northern Indiana Railroad.

W. H. Clarke, Chief Engineer, Illinois Central Railroad.

Louis P. Morehouse, Secretary to the Chief Engineer, Illinois Central Railroad.

Willard S. Pope, Chief Engineer, Chicago & Galena Union R. R.

John E. Blunt, Chief Engineer, Chicago & Northwestern R. R.

Kirtland F. Booth, Chief Engineer, Chicago & Alton Railroad.

Octave Chanute, Chief Engineer of the "Kansas City Bridge," the first bridge built over the Missouri river.

O. B. Green, a leading Public Works Contractor.

Alonzo Paige, an Associate of Crerar, Adams & Co., the leading Railway Supplies House of the Northwest.

Walter Katte, Engineer and Western Agent of the Keystone Bridge Company and Union Iron Mills of Pittsburgh.

The first regular meeting of these men was held in a small private parlor of the old Sherman House hotel, with (probably) Col. R. B. Mason in the chair and L. P. Morehouse, now an Honorary Member, as secretary, which position he continued to hold with such distinguished honor to himself and advantage to the Society until 1888. At this meeting (the date on which it was held I cannot remember, to my great regret), it was resolved to proceed at once with the measures necessary to effect the organization of such a society, and with this purpose in mind a committee composed of some of those present at this meeting was appointed to draft a Constitution and By-laws for canvass of membership.

The first title suggested for the new society was "The Engineers' Club of Chicag." Col. R. B. Mason was its first president and Mr. Morehouse its first secretary, and from out of this small, modest beginning has grown this flourishing, successful Society, incorporated under the laws of the State of Illinois, September 1st, 1880, under the name and title of the "Western Society of Engineers."

Of the foregoing list of thirteen only four are now living, namely: Louis P. Morehouse, John E. Blunt, Alonzo Paige, and Walter Katte, the writer of these recollections of long bygone days, whose membership of the Western Society of Engineers bears date of July 12th, 1869, and of the American Society of Civil Engineers, December 7th, 1868, being Nofl 127 on the roll of membership, now numbering over 7,000 names, and is probably the oldest living member of both of these societies.

WIND STRESSES IN THE STEEL FRAMES OF OFFICE BUILDINGS

By Albert Smith and Wilbur M. Wilson.

Presented Before the Bridge and Structural Section, March 8, 1915.

First Paper by Prof. Smith*

Wind stresses in modern office building frames are figured in practice by methods which depart widely from the actual conditions in some respects and which differ widely from one another in the amounts of the computed stresses.

Mr. R. Fleming, in a paper on "Wind Bracing Without Diagonals," (*Eng. News*, March 13, 1913), outlines the first three methods given below of computing such stresses.

I. Contraflexure at middle of columns and girders. Vertical stress in columns proportional to distance of columns from center line of building.

II. Contraflexure in columns at center. Vertical stress in interior columns equal to zero. Horizontal shears equally divided among columns.

III. Contraflexure in columns at center. Vertical stress in columns proportional to distance from center line of building. Horizontal shears equally divided among columns.

IV. Vertical force on intermediate columns zero. Contraflexure points in middle. One-half as much shear in outside columns as in intermediate columns.

In Table I on the next page are given the stresses in the members of a three bay building when there are twenty stories above, of height 100 ins., with bay lengths equal to 150 ins. All stresses are given in terms of P, the panel load at each floor.

At first glance, the wide discrepancy between these results would seem to indicate that if one were correct, structures designed by either of the other methods would be seriously overstressed in some of their members under maximum wind. Designers have regarded this possible overstressing as unimportant because of the fact that such overstressing would cause a readjustment of the stresses, due to permanent deformation of the members. This would

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TABLE I.

	Method I	Method II	Method III	Method IV	Stresses from Calculations of Author: 30 Story Bldg. 11th Story	20 Story Bldg. Bottom
Mom. in Cor. Cols	150 P	250 P	250 P	166⅔ P	178 P	311 P
Mom. in Interm. Cols	350 P	250 P	250 P	333⅓ P	343 P	360 P
Shear in Cor. Cols	3 P	5 P	5 P	3⅓ P	3P appro.	4¼ P
Shear in Interm. Cols	7 P	5 P	5 P	6⅔ P	7P appro.	5¾ P
Vert. on Cor. Cols.	40 P	$44\frac{4}{9}$ P	40 P	$44\frac{4}{9}$ P	41½ P	41½ P
Vert. on Interm. Cols	13⅓ P	0	13½ P	0		5¾appro.
Mom. Outer Span.	292½ P	487½ P	487½ P	325 P	320	302
Mom. Interm. Span.	390 P	325 P	390 P	325 P		

be a much better action upon which to rely, if the wind could be assumed to come in one direction only, since it is apparent that whatever yielding of the overstressed members has taken place in a south wind, must be doubled in the other direction under a north wind. This, however, supposes that the maximum wind assumed is possible, and will occur at least twice.

To the writer it seems that any reliance, for safe distribution of stresses, upon the passing of the elastic limit by some fibres of an office building column, is very undesirable. Recent tests have shown that large columns fail in a testing machine under an average compressure stress of about 30,000 lbs. per sq. in. It is evident that columns such as are used in office buildings, with possible eccentricities and bending moments from unsymmetrical dead and live load, would have a factor of safety seriously reduced by a bending which caused some of its fibres to pass the elastic limit, since the eccentricity from bending would in such a case be rather large.

This does not mean that buildings as now designed are in any danger, or that under assumed maximum wind there is any probability of their collapsing. It means that the factor of safety which is regarded as desirable has not been secured, although the proper expenditure of steel has been made.

This opinion led the writer, in the fall of 1912, to plan a series of calculations of the stresses in such buildings.

The method of least work was to be employed and two, three, and four-bay buildings were to be examined.

The following assumptions were made:

1. Height of all stories = 100 ins.
2. Bay lengths all equal to 150 ins.
3. Moments of inertia of all columns and spandrels equal in

any story, and varying in proportion to the number of stories from the top.

4. Panel loads of wind to be same at all floors.

5. Lengths all taken from intersection of neutral axis of columns and girders.

The original plan contemplated the calculation of all members in buildings of two and three bays, of heights ranging from one to eight stories. In the four-bay buildings, heights from one to four were to be calculated.

It was found, however, upon the conclusion of these computations, that the variation of values in the two and three-bay buildings was not sufficiently determined in this range, and accordingly the calculations were extended to the ninth story of the two-bay and to the fourteenth for the three-bay.

In the four-bay buildings, in view of the difficulties with the three-bay building, it appears that computations would have to be carried very much beyond the fourth story to justify curves of stresses extending to thirty or forty stories.

It is possible that a method can be developed by which, relating the stresses in the four-bay to those in the two and three-bay building, the four-bay curves can be produced, and it is in the hope of receiving such suggestions that the writer publishes at this time the two and three-bay work and has made no long extensions of the four-bay curves.

METHOD OF COMPUTATION

The method of least work, applied to this problem involves the solution of many simultaneous equations. There were three per story in the two-bay building, four in the three-bay, and six in the four-bay. All this computation was performed on a "Millionaire" calculating machine with a capacity of eight places. This may seem like an unnecessary refinement, but in the third order of differences in the moments it will be noticed that the values derived are approximate in the third place of decimals, and for one place less in our work, the accuracy of the curves of results would have been seriously reduced.

Fortunately the reduction of these equations did not have to proceed with the full number of equations from the beginning. There were in the two-bay only six equations involving M_n, five involving S_n and four involving V_n. In the three-bay there were seven equations involving M_n, six S_n, six V_n and V'_n. In the four-bay twelve equations involved M_n.

The equations were always written in the same order, the coefficient of the first terms reduced to unity by multiplication, and the first term eliminated by subtraction of each of the succeeding equations from the first. The sign of the unit coefficients of the first terms was always reduced to the positive.

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The result of each multiplication was placed just above the subtraction from which it was derived, and a space above that was left for the result of the substitution of answers, when derived.

When calculation had proceeded to the elimination of all but one unknown, and the value of that determined, it was substituted back in the preceding two equations, giving the value of the next to the last unknown, and this process was continued until all the values were determined. When known values were substituted in any block of equations to determine another unknown, the result of these solutions should be the same for each equation, within its limit of accuracy.

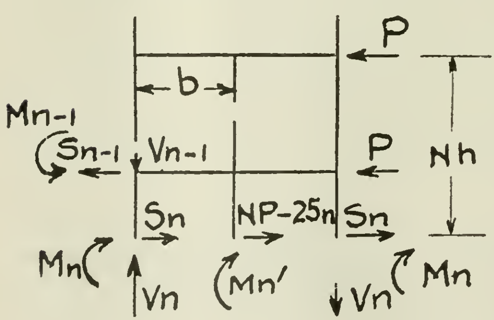
If upon substitution, the different answers checked approximately to the figure derived from the eighth place in the substituted values, and exactly to that derived from the seventh, the handling of the equations in the blocks below was known to be correct.

Such a check has been secured in all the answers here reported. In some cases the values tabulated are given one place beyond the approximate figure as given on the computation sheets, and since, comparing answers from different stories the first exact place is also found to wander, the figures for M and S in the tables are not exact in the last two places.

This operation of back checking has proved in each operation that no error has been made in any of the reductions, and the answers derived may be regarded as absolutely correct within the limits secured by eight place computations.

Table II (insert) shows a part of the calculation for the fourteenth story, three-bay building.

CALCULATION OF WORK IN TWO-BAY BUILDING



b=150 ins. h=100 ins.

$I_n = NI_1$

Taking Moments about right hand column N stories from the top—

$2V_nb + 2M_n + M_n' - Ph\left[N + (N-1) \ldots . 1\right] = 0$

$M_n' = -2M_n - 2V_nb + PhN\left(\frac{N+1}{2}\right) = 0$

(1) Moment in Outside Col. $M_x = M_n - S_nx$

(2) " " Inside Col. $M_x = -2M_n + 2S_n - 2V_nb + PhN\left(\frac{N+1}{2}\right) - NPx$

(3) Moment in Spandrel Gird. $M_x = M_n - M_{n-1} - S_nh + V_nx - V_{n-1}x$

(4) Work in Outside Columns=

$$= 2\int_0^h \frac{(M_n-S_nx)^2dx}{2EI_n} = \frac{2}{2EI_n}\left(M_n^2h-M_nS_nh^2+\frac{S_nh^3}{3}\right)$$

(5) Work in Inside Column

$$+\int_0^h \frac{\left(-2M_n+2S_n x-2V_nb+PhN\frac{(N+1)}{2}-NPx\right)^2 dx}{2EI_n}$$

$$= \frac{1}{2EI_n}\Big(4M_n^2h-4M_nS_nh^2+12M_nV_nh^2-2M_nPh^2N^2+\tfrac{4}{3}S_n^2h^3$$

$$-6S_nV_nh^3+S_nPh^3N^2-\tfrac{1}{3}S_nPh^3N+9V_n^2h^3-3V_nPh^3N^2\Big)$$

(6) Work in Spandrel Girders

$$2\int_0^b \frac{(M_n-M_{n-1}-S_nh+V_nx-V_{n-1}x)^2dx}{2EI_n} = \frac{2}{2EI_n}\left(+\frac{3}{2}M_n^2h-3M_nS_nh^2\right)$$

$$+\frac{9}{4}M_nV_nh^2-3M_nM_{n-1}h-\frac{9}{4}M_nV_{n-1}h^2+\frac{3}{2}S_n^2h^3-\frac{9}{4}S_nV_nh^3$$

$$+3M_{n-1}{}^2S_nh^2+\frac{9}{4}S_nV_{n-1}h^3+\frac{9}{8}V_n^2h^3-\frac{9}{4}V_nM_{n-1}h^2-\frac{9}{4}V_nV_{n-1}h^3$$

$$+\frac{3}{2}M_{n-1}^2h+\frac{9}{4}M_{n-1}V_{n-1}h^2+\frac{9}{8}V_{n-1}^2h^3\Big)$$

Summing up the work in the nth story—mult. by $2EI_1$

$$(7)\ 2EI_1\omega_n=\Big(9M_n^2h-12M_nS_nh^2+\frac{33}{2}M_nV_nh^2-6M_nM_{n-1}h-\frac{9}{2}M_nV_{n-1}h^2$$

$$-2M_nPh^2N^2+5S_n^2h^3-\frac{21}{2}S_nV_nh^3+6S_nM_{n-1}h^2+\frac{9}{2}S_nV_{n-1}h^3$$

$$+S_nPh^3N^2-\frac{1}{3}S_nPh^3N+\frac{45}{4}V_n^2h^3-\frac{9}{2}V_nM_{n-1}h^2-\frac{9}{2}V_nV_{n-1}h^3-$$

$$3V_nPh^3N^2+\frac{3}{2}M_{n-1}^2h+\frac{9}{2}M_{n-1}V_{n-1}h^2+\frac{9}{4}V_{n-1}^2h^3\Big)\frac{1}{N}$$

A similar expression with all subscripts diminished by one gives the work in the (n-1)th story. A similar expression, with all the subscripts increased by one, gives the work in the (n+1)th.

Conceive that for a building of m stories, such expressions have been written for each story, (1,—n-1,n, n+1,m), in only two of these expressions, those for n+1 and n, will the terms M_n, S_n and V_n be involved.

The complete expression for the work in a building of m stories may be differentiated with respect to M_n, S_n and V_n by differentiating with respect to these variables the partial work expressions for stories n and n+1.

Performing this operation, we get (dividing out h and h^2 and dropping 2EI),

$$(8).\quad O=\frac{d\omega}{dM_n}=\frac{18M_n-1200S_n+1650V_n-6M_{n-1}-450V_{n-1}-200N^2P}{N}$$

$$+\quad\frac{-6M_{n+1}+600S_{n+1}-450V_{n+1}+6M_n+450V_n}{N+1}$$

$$(9).\quad O=\frac{d\omega}{dS_n}=$$

$$\frac{-12M_n+1000S_n-1050V_n+6M_{n-1}+450V_{n-1}-100PN\left(N-\frac{1}{3}\right)}{N}$$

$$+\quad\frac{O}{N+1}$$

$$(10).\quad O=\frac{d\omega}{dV_n}=$$

$$\frac{\frac{33}{2}M_n-1050S_n+2250V_n-\frac{9}{2}M_{n-1}-450V_{n-1}-300PN^2}{N}$$

$$+\quad\frac{-\frac{9}{2}M_{n+1}+450S_{n+1}-450V_{n+1}+\frac{9}{2}M_n+450V_n}{N+1}$$

In applying these equations to the bottom story, or rather where the nth is the bottom story, the work terms involving the subscripts n+1 disappear.

Where n=1, for the top story, the terms involving the subscripts n-1 disappear.

Where a one-story building is being computed all terms in the work expression involving subscripts n-1 and n+1 will drop out, and in the equations above there will be left only four terms divided by N.

In preparing the equations above for solution, each equation was multiplied by N, the subscripts evaluated and the terms placed in order. Where a coefficient consists of two numbers with the sign of addition between, the second number is derived from the story below, and is dropped when there is no such story.

In the last equation in Table III, derived from Equation (10) by making N=3, (having multiplied both sides of the equation by N), the coefficient of M^3 results from $\frac{33M_n}{2}+\frac{N}{N+1}\,\frac{9M_n}{2}=$ $\left(16.5\ \frac{3x4.5}{4}\right)M_3$, but in the V_3 coefficient the third figure .245, is due to the

TABLE III									
			$+(18+\frac{6}{2})M_1$	$-1200S_1$	$+(1650+\frac{450}{2})V_1$	$-\frac{6}{2}M_2$	$+\frac{600}{2}S_2$	$-\frac{450}{2}V_2$	$-200P=0$
			$+12M_1$	$-1000S_1$	$+1050V_1$	0	0	0	$-66.6666P=0$
			$+(16.5+\frac{4.5}{2})M_1$	$-1050S_1$	$+(2250+\frac{450}{2}+.18)V_1$	$-\frac{4.5}{2}M_2$	$+\frac{450}{2}S_2$	$-\frac{450}{2}V_2$	$-300P=0$
$-6M_1$	0	$-450V_1$	$+(18+\frac{2\times6}{3})M_2$	$-1200S_2$	$+(1650+\frac{2\times450}{3})V_2$	$-\frac{2\times6}{3}M_3$	$+\frac{2\times600}{3}S_3$	$-\frac{2\times450}{3}V_3$	$-800P=0$
$+6M_1$	0	$+450V_1$	$-12M_2$	$-1000S_2$	$-1050V_2$	0	0	0	$+333.33P=0$
$-4.5M_1$	0	$-450V_1$	$+(16.5+\frac{2\times4.5}{3})M_2$	$-1050S_2$	$+(2250+\frac{2\times450}{3}+.21125)V_2$	$-\frac{2\times4.5}{3}M_3$	$+\frac{2\times450}{3}S_3$	$-\frac{2\times450}{3}V_3$	$-1200P=0$
$-6M_2$	0	$-450V_2$	$+(18+\frac{3\times6}{4})M_3$	$-1200S_3$	$+(1650+\frac{3\times450}{4})V_3$	$-\frac{3\times6}{4}M_4$	$+\frac{3\times600}{4}S_4$	$-\frac{3\times450}{4}V_4$	$-1800P=0$
$+6M_2$	0	$+450V_2$	$-12M_3$	$-1000S_3$	$-1050V_3$	0	0	0	$+800P=0$
$-4.5M_2$	0	$-450V_2$	$+(16.5+\frac{3\times4.5}{4})M_3$	$-1050S_3$	$+(2250+\frac{3\times450}{4}+.245)V_3$	$-\frac{3\times4.5}{4}M_4$	$+\frac{3\times450}{4}S_4$	$-\frac{3\times450}{4}V_4$	$-2700P=0$

DIRECT WORK IN COLUMNS

For the two outside columns this equals $2V_n^2h/2A_nE$. Substituting $A_n = \frac{I_n}{r_n^2}$, we have $2EI_1\ \omega = \frac{2V_n^2r^2h^2}{Nh}$, which is additional work to be added to the general work equation (7). Differentiating and dropping h^2, as was done in Equation (10) we have $O = \frac{d\omega}{dV} = \frac{4V_nr^2}{Nh}$, which for $h=100$, gives $\frac{.04V_nr^2}{N}$ to be added to the right hand term of Equation (10). The value of r^2 was taken as $\frac{(11+N)^2}{32}$ giving values of r ranging from 2.1 up to 12.5 for a 60-story building. No assumption seemed perfectly satisfactory, but these values seemed reasonable for the bottom stories of very high buildings. Substituting $N=1, 2, 3$, etc., we get $\frac{.18}{N}$, $\frac{.21125}{N}$, $\frac{.245}{N}$, $\frac{.28125}{N}$, $\frac{.32}{N}$, $\frac{.36125}{N}$, $\frac{.405}{N}$, and $\frac{.45125}{N}$. These coefficients are multiplied by N, as are all terms in equation (10), and the additions made to the V_n term as in the explicit equations above.

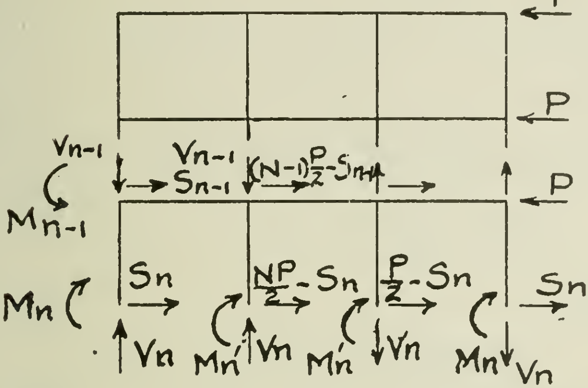
The list of equations equations above can be prolonged indefinitely by writing additional equations with higher subscripts, different fractional exponents, and new values of P.

Thus for the 19th story the fractional co-efficients will have $\frac{19,}{20}$, in place of the $\frac{1}{2}$, $\frac{2}{3}$, and $\frac{3}{4}$ shown above.

If the given story be the bottom one, as the 19th from the top of a 19-story building, the fractional coefficients disappear, having been derived from *work done on the story* below.

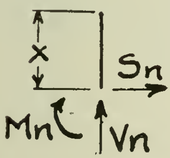
In Table IV (insert), are given the equations for buildings from one to eight stories in height, prepared for calculation by dividing through by the coefficient of the first term in each equation. Figures above the line are substituted for those below when the story in question is a bottom story.

CALCULATION OF WORK IN THREE-BAY BUILDING



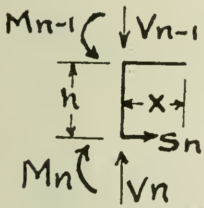
b = 150 ins. h = 100 ins. $I_n = NI_1$ To eliminate M_n' leaving only four unknownas per story, take moments about foot of right hand column $2M_n + 2M_n + 3V_nb + V_nb - \frac{N}{2}(N+1)Ph = 0$

$$M_n' = -M_n - \frac{3}{2}V'_nb - \frac{1}{2}V_nb + \frac{N}{4}(N+1)Ph$$



Moment in outside column $= M_n - S_nx$

$$\text{Work} = \int_0^h \frac{(M_n - S_nx)^2dx}{2EI_n} = \frac{1}{2EI}\left(\frac{M_n^2h - M_nS_nh^2}{N} + \frac{S_n^2h^3/_3}{N}\right)$$



Moment in outside spandrel $= M_n - S_nh + V_nx - M_{n-1} - V_{n-1}x$

$$\text{Work} = \int_0^b \frac{(M_n - S_nh + V_nx - M_{n-1} - V_{n-1}x)^2dx}{2EI_n} =$$

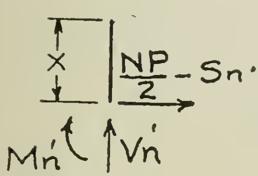
$$\frac{1}{2EI_1}\left(\frac{3}{2}M_n^2h - 3M_nS_nh^2 + \frac{9}{4}M_nV_nh^2 - 3M_nM_{n-1}h - \frac{9}{4}M_nV_{n-1}h^2\right.$$

$$+\frac{3}{2}S_n^2h^3 - \frac{9}{4}S_nV_nh^3 + 3S_nM_{n-1}h^2 + \frac{9}{4}S_nV_{n-1}h^3$$

$$+\frac{9}{8}V_n^2h^3 - \frac{9}{4}V_nM_{n-1}h^2 - \frac{9}{4}V_nV_{n-1}h^3$$

$$+\frac{3}{2}M_{n-1}^2h + \frac{9}{4}M_{n-1}V_{n-1}h^2$$

$$\left.+\frac{9}{8}V_{n-1}^2h^3\right)\frac{1}{N}$$

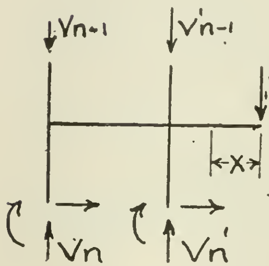


Moment in inside column $= -M_n + S_nx -$

$$\frac{3}{2}V_nb - \frac{1}{2}V_n'b + \frac{N}{4}(N+1)Ph - \frac{NPx}{2}$$

$$\text{Work}=\int_0^h \frac{(-M_n+S_nx-\frac{9}{4}V_nh-\frac{3}{4}V_n'h+\frac{N^2Ph}{4}+N\frac{Ph}{4}-N\frac{Px}{2})^2dx}{2EI_n}$$

$$=\frac{1}{2EI_1}\Big(M_n^2h-M_nS_nh^2+\frac{9}{2}M_nV_nh^2+\frac{3}{2}M_nV_n'h^2-\frac{N^2}{2}M_nPh^2$$
$$+\frac{1}{3}S_n^2h^3-\frac{9}{4}S_nV_nh^3-\frac{3}{4}S_nV_n'h^3+\frac{N^2}{4}S_nPh^3-\frac{N}{12}S_nPh^3$$
$$+\frac{81}{16}V_n^2h^3+\frac{54}{16}V_nV_n'h^3-\frac{9}{8}V_nPh^3N^2$$
$$+\frac{9}{16}V_n'^2h^3-\frac{3}{8}V_n'Ph^3N^2 \text{ etc}\Big)\frac{1}{N}$$



Moment in Inside Spandrel $=V_nx+V_n'x-V_{n-1}x-V_{n-1}'x$

$$\text{Work}=\int_0^{\frac{h}{2}}\frac{(V_nx+V_n'x-V_{n-1}x-V_{n-1}'x)^2dx}{2EI_n}$$

$$=\frac{1}{2EI_1}\Big(\frac{9}{64}V_n^2h^3+\frac{9}{32}V_nV_n'h^3-\frac{9}{32}V_nV_{n-1}h^3-\frac{9}{32}V_nV_{n-1}'h^3$$
$$+\frac{9}{64}V_n'^2h^3-\frac{9}{32}V_n'V_{n-1}h^3-\frac{9}{32}V_n'V_{n-1}'h^3$$
$$+\frac{9}{64}V_{n-1}^2h^3+\frac{9}{32}V_{n-1}V_{n-1}'h^3$$
$$+\frac{9}{64}V_{n-1}'^2h^3\Big)\frac{1}{N}$$

Collecting all the terms, the total work in one half of Nth story is—

$$\omega_n=\frac{1}{2EI_1}\Big(+\frac{7}{2}M_n^2h-5M_nS_nh^2+\frac{27}{4}M_nV_nh^2+\frac{3}{2}M_nV_n'h^2$$
$$-3M_nM_{n-1}h-\frac{9}{4}M_nV_{n-1}h^2-\frac{N^2}{2}M_nPh^2+\frac{13}{6}S_n^2h^3-\frac{9}{2}S_nV_nh^3$$
$$-\frac{3}{4}S_nV_n'h^3+3S_nM_{n-1}h^2+\frac{9}{4}S_nV_{n-1}h^3+\frac{N^2}{4}S_nPh^3-\frac{N}{12}S_nPh^3$$
$$+\frac{405}{64}V_n^2h^3+\frac{117}{32}V_nV_n'h^3-\frac{9}{4}V_nM_{n-1}h^2-\frac{81}{32}V_nV_{n-1}h^3-\frac{9}{32}V_nV_{n-1}'h^3$$
$$-\frac{9N^2}{8}V_nPh^3+\frac{45}{64}V_n'^2h^3-\frac{9}{32}V_n'V_{n-1}h^3-\frac{9}{32}V_n'V_{n-1}'h^3-\frac{3N^2}{8}V_n'Ph^3$$
$$+\frac{3}{2}M_{n1}^2h+\frac{9}{4}M_{n-1}V_{n-1}h^2+\frac{81}{64}V_{n-1}^2h^3+\frac{9}{32}V_{n-1}V_{n-1}'h^3$$
$$+\frac{9}{64}V_{n-1}'^2h^3\Big)\frac{1}{N}$$

The expression for ω_n+1 is found by changing all subscripts. Differentiating both ω_n and ω_n+1 with respect to M_n, S_n, V_n and V_n'.

TABLE V

M_{n-1}	S_{n-1}	V_{n-1}	V'_{n-1}	M_n	S_n	V_n	V_n'	M_{n+1}	S_{n+1}	V_{n+1}	V'_{n+1}	P
−3	0	−225	0	+3 +7	−500	+225 +675	+150	−3	+300	−225	0	$-N^2h/2$
+3	0	+225	0	−5	+433.3	−450	−75	0	0	0	0	$\frac{N^4h^3}{4}-\frac{Nh}{12}$
−2.25	0	−153.125	−28.125	+2.25 +6.75	−450	+253.125 +1265.625	+28.125 +365.625	−2.25	+225	−253.125	−28.125	$-\frac{9N^2h}{8}$
0	0	−28.125	−28.125	+1.5	−75	+28.125 +365.625	+28.125 +140.625	0	0	−28.125	−28.125	$-\frac{3N^2h}{3}$

Note—In all Columns with subscript N+1, all terms are to be mult. by $\frac{N}{N+1}$.

In all Columns mith subscript N Coefficients above the line are to be mult. by $\frac{N}{N+1}$

In Table VI are given the equations derived from the typical equation above. First coefficients above the line are as in typical equation,—the second coefficient above, for V and V′ in third and fourth equations in each block, are derived from direct work in columns and are the same as in the two-bay buildings.

Table VI Table of Equations For Three Bay Building

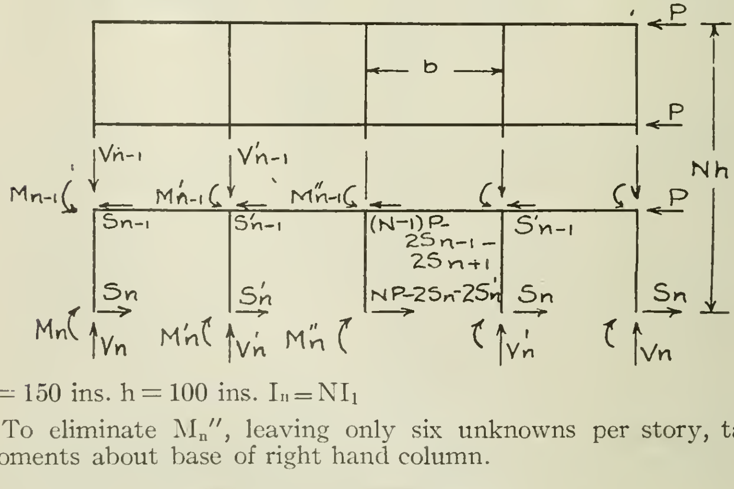
				M_1	S_1	V_1	V_1'	M_2	S_2	V_2	V_2'	P	
				$+3.0\times\frac{1}{2}$ +7	−300	$+2.25\times\frac{1}{2}$ +675	+150	$-3\times\frac{1}{2}$	$+300\times\frac{1}{2}$	$-225\times\frac{1}{2}$	0	−50	=0
				−5	+433.33	−450	−75	0	0	0	0	+16.666	=0
				$+2.25\times\frac{1}{2}$ +6.75	−450	{+.18 $+253.125\times\frac{1}{2}$ +1265.625	$+28.125\times\frac{1}{2}$ +365.625	$-2.25\times\frac{1}{2}$	$+225\times\frac{1}{2}$	$-253.125\times\frac{1}{2}$	$-28.125\times\frac{1}{2}$	−112.5	=0
				+1.5	−75	$+28.125\times\frac{1}{2}$ +365.625	{+.18 $+28.125\times\frac{1}{2}$ +140.625	0	0	$-28.125\times\frac{1}{2}$	$-28.125\times\frac{1}{2}$	−37[illegible]	=0
M_1	S_1	V_1	V_1	M_2	S_2	V_2	V_2'	M_3	S_3	V_3	V_3'	P	
−3	0	−225	0	$+3.0\times\frac{2}{3}$ +7	−500	$+225\times\frac{2}{3}$ +675	+150	$-3\times\frac{2}{3}$	$+300\times\frac{2}{3}$	$-225\times\frac{2}{3}$		−200	=0
+3	0	+225	0	−5	+433.33	−450	−75	0	0	0	0	+66.66	=0
−2.25	0	−253.125	−28.125	$+2.25\times\frac{2}{3}$ +6.75	−450	{+.21125 $+253.125\times\frac{2}{3}$ +1265.625	$+28.125\times\frac{2}{3}$ +365.625	$-2.25\times\frac{2}{3}$	$+225\times\frac{2}{3}$	$-253.125\times\frac{2}{3}$	$-28.125\times\frac{2}{3}$	−450	=0
0	0	−28.125	−28.125	+1.5	−75	$+28.125\times\frac{2}{3}$ +365.625	{+.21125 $+28.125\times\frac{2}{3}$ +140.625	0	0	$-28.125\times\frac{2}{3}$	$-28.125\times\frac{2}{3}$	−150	=0
M_2	S_2	V_2	V_2'	M_3	S_3	V_3	V_3'	M_4	S_4	V_4	V_4'	P	
−3	0	−225	0	$+3.0\times\frac{3}{4}$ +7	−500	$+225\times\frac{3}{4}$ +675	+150	$-3\times\frac{3}{4}$	$+300\times\frac{3}{4}$	$-225\times\frac{3}{4}$	0	−450	=0
+3	0	+225	0	−5	+433.33	−450	−75	0	0	0	0	+150	=0
−2.25	0	−253.125	−28.125	$+2.25\times\frac{3}{4}$ +6.75	−450	{+.245 $+253.125\times\frac{3}{4}$ +1265.625	$+28.125\times\frac{3}{4}$ +365.625	$-2.25\times\frac{3}{4}$	$+225\times\frac{3}{4}$	$-253.125\times\frac{3}{4}$	$-28.125\times\frac{3}{4}$	101.25	=0
0	0	−28.125	−28.125	+1.5	−75	$+28.125\times\frac{3}{4}$ +365.625	{+.245 $+28.125\times\frac{3}{4}$ +140.625	0	0	$-28.125\times\frac{3}{4}$	$-28.125\times\frac{3}{4}$	−337.5	=0
M_3	S_3	V_3	V_3'	M_4	S_4	V_4	V_4'	M_5	S_5	V_5	V_5	P	
−3	0	−225	0	$+3.0\times\frac{4}{3}$ +7	−500	$+225\times\frac{4}{5}$ +675	+150	$-3\times\frac{4}{5}$	$+300\times\frac{4}{5}$	$-225\times\frac{4}{5}$	0	−800	=0
+3	0	+225	0	−5	+433.33	−450	−75	0	0	0	0	+266.66	=0
−2.25	0	−253.125	−28.125	$+2.25\times\frac{4}{5}$ +6.75	−450	{+.28125 $+253.125\times\frac{4}{5}$ +1265.625	$+28.125\times\frac{4}{5}$ +365.625	$-2.25\times\frac{4}{5}$	$+225\times\frac{4}{5}$	$-253.125\times\frac{4}{5}$	$-28.125\times\frac{4}{5}$	−1800	=0
0	0	−28.125	−28.125	+1.5	−75	$+28.125\times\frac{4}{5}$ +365.625	{+.28125 $+28.125\times\frac{4}{5}$ +140.625	0	0	$-28.128\times\frac{4}{5}$	$-28.125\times\frac{4}{5}$	−600	=0

The equations in Table VI are put in form for computation by dividing each by the coefficient of the first term. Where there is no n-1 story, the coefficient multiplied by $\frac{n}{n-1}$ disappears.

Equations involving subscripts 4, 5, and 6; 5, 6, and 7; 6, 7, and 8; and 7, 8, and 9, are produced from the typical equations by making the proper substitutions for N, namely, 5, 6, 7, and 8, and putting in the direct work coefficients, .32, .36125, .405, and .45125. The coefficients which have fractional multipliers will then be multiplied by 5/6, 6/7, 7/8, and 8/9. These and the P coefficients are the only ones which differe in the different blocks.

The direct work coefficients used in the three-bay buildings were derived from $r^2 = \frac{(11\text{-}N)^2}{16}$, which gives r varying values (from 3 for top story to 4¾ for the bottom columns of an eight-story building. When a considerable portion of the three-bay computation had been completed, and equations were being prepared for the two-bay and four-bay work, the direct work coefficients for their columns were taken on a basis of $r^2 = \frac{(11\text{-}N)^2}{32}$. This as noted in the two-bay discussion gives fairly satisfactory values of r, while the former expression gave a value of r of 17.75 for a sixty-story building, which was evidently somewhat large. After the computation of the two- and four-bay buildings, a study of the answers made it evident that recomputation of the three-bay work was unnecessary, as the influence of the direct work is small. Accordingly the three-bay computations were completed with the values first used.

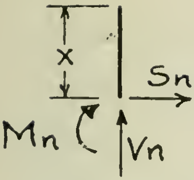
CALCULATION OF WORK IN FOUR-BAY BUILDING



$b = 150$ ins. $h = 100$ ins. $I_n = NI_1$

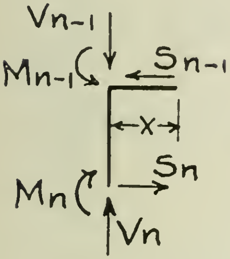
To eliminate M_n'', leaving only six unknowns per story, take moments about base of right hand column.

$$2M_n + 2M_n' + M_n'' + 4V_nb + 2V_n'b - PhN(N+1)/2 \quad = \quad O$$
$$M_n' = -2M_n - 2M_n' - 4V_nb - 2V_n'b + PhN(N+1)/2$$



Moment in Outside Columns $= M_n - S_n x$

$$\text{Work} = 2\int_0^h \frac{(M_n - S_n x)^2 dx}{2EI_n} = \frac{1}{2EI_1} \frac{\left(2M_n^2 h - 2M_n S_n h_2 + \frac{2}{3} S_n^2 h^3\right)}{N}$$



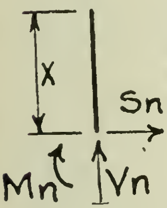
Moment in Outside Spandrel $M_x = M_n - S_n h + V_n x - M_{n-1} - V_{n-1} x$

$$\text{Work} = 2\int_0^b \frac{(M_n - S_n h + V_n x - M_{n-1} - V_{n-1} x)^2 dx}{2EI_n} =$$

$$\frac{1}{2EI_1}\Big(3M_n^2 h - 6M_n S_n h^2 + \frac{9}{2} M_n V_n h^2 - 6M_n M_{n-1} h - \frac{9}{2} M_n V_{n-1} h^2 + 3S_n^2 h^3 - \frac{9}{2} S_n V_n h^3 + 6S_n M_{n-1} h^2 + \frac{9}{2} S_n V_{n-1} h^3 + \frac{9}{4} V_n^2 h^3$$

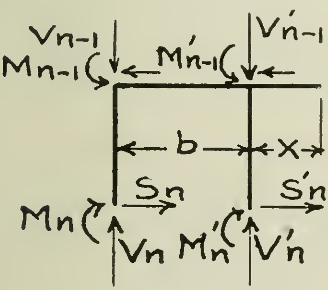
$$- \frac{9}{2} V_n M_{n-1} h^2 - \frac{9}{2} V_n V_{n-1} h^3 + 3M_{n-1}^2 h + \frac{9}{2} M_{n-1} V_{n-1} h^2$$

$$+ \frac{9}{4} V_{n-1}^2 h^3 \Big)\frac{1}{N}$$



Moment in Second Column $= M_n - S_n x$

$$\text{Work} = 2\int_0^h \frac{(M'_n - S'_n x)^2 dx}{2EI_n} = \frac{1}{2EI_1}\left(2M'^2_n h - 2M'_n S'_n h^2 + \frac{2}{3} S'^2_n h^3\right)\frac{1}{N}$$



Moment in Second Spandrel $=$

$M_n + M_n' - S_n h - S_n' h + V_n(b+x) + V_n' x$
$- M_{n-1} - M_{n-1}' - V_{n-1}(b+x) - V_{n-1}' x$

$$\text{Work} = 2\int_0^b \frac{(\text{Mom. above})^2 dx}{2EI_n} =$$

$$\frac{2}{2EI_1}\Big(\frac{3}{2} M_n^2 h + 3M_n M_n' h - 3M_n S_n h^2 - 3M_n S_n' h^2 + \frac{27}{4} M_n V_n h^2 + \frac{9}{4} M_n V_n' h^2 - 3M_n M_{n-1} h$$

$$- 3M_n M_{n-1}' h - \frac{27}{4} M_n V_{n-1} h^2 - \frac{9}{4} M_n V_{n-1}' h^2 + \frac{3}{2} M_n'^2 h - 3M_n' S_n h^2$$

$$- 3M_n' S_n' h^2 + \frac{27}{4} M_n' V_n h^2 + \frac{9}{4} M_n' V_n' h^2 - 3M_n' M_{n-1} h - 3M_n' M_{n-1}' h$$

$$-\frac{27}{4}M_n'V_{n-1}h^2-\frac{9}{4}M_n'V_{n-1}'h^2+\frac{3}{2}S_n^2h^3+3S_nS_n'h^3-\frac{27}{4}S_nV_nh^3$$

$$-\frac{9}{4}S_nV_n'h^3+3S_nM_{n-1}h^2+3S_nM_{n-1}'h^2+\frac{27}{4}S_nV_{n-1}h^3+\frac{9}{4}S_nV_{n-1}'h^3$$

$$+\frac{3}{2}S_n'^2h^3-\frac{27}{4}S_n'V_nh^3-\frac{9}{4}S_n'V_n'h^3+3S_n'M_{n-1}h^2+3S_n'M_{n-1}h^2$$

$$+\frac{27}{4}S_n'V_{n-1}h^3+\frac{9}{4}S_n'V_{n-1}'h^3+\frac{63}{8}V_n^2h^3+\frac{45}{8}V_nV_n'h^3-\frac{27}{4}V_nM_{n-1}h^2$$

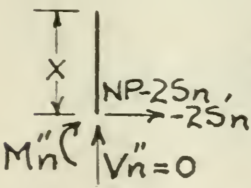
$$-\frac{27}{4}V_nM_{n-1}'h^2-\frac{126}{8}V_nV_{n-1}h^3-\frac{45}{8}V_nV_{n-1}h^3+\frac{9}{8}V_n'^2h^3-\frac{9}{4}V_n'M_{n-1}h^2$$

$$-\frac{9}{4}V_n'M_{n-1}'h^2-\frac{45}{8}V_n'V_{n-1}h^3-\frac{9}{4}V_n'V_{n-1}'h^3+\frac{3}{2}M_{n-1}^2h$$

$$+3M_{n-1}M_{n-1}'h+\frac{27}{4}M_{n-1}V_{n-1}h^2+\frac{9}{4}M_{n-1}V_{n-1}'h^2+\frac{3}{2}M_{n-1}'^2h$$

$$+\frac{27}{4}M_{n-1}'V_{n-1}h^2+\frac{9}{4}M_{n-1}'V_{n-1}'h^2+\frac{63}{8}V_{n-1}^2h^3$$

$$+\frac{45}{8}V_{n-1}V_{n-1}'h^3+\frac{9}{8}V_{n-1}'^2h^3)\frac{1}{N}$$



Moment in Middle Column.

$$M_x=-2M_n-2M_n'+2S_nx+2S_n'x-4V_nb-2V_n'b+PhN(N+1)/2-NPx$$

$$\text{Work}=\int_0^h\frac{(\text{Mom. above})^2dx}{2EI_n}=$$

$$\frac{1}{2EI_1}\Big(4M_n^2h+8M_nM_n'h-4M_nS_nh^2-4M_nS_n'h^2+24M_nV_nh^2+12M_nV_n'h^2$$

$$-2N^2M_nPh^2+4M_n'^2h-4M_n'S_nh^2-4M_n'S_n'h^2+24M_n'V_nh^2+12M_n'V_n'h^2$$

$$-2N^2M_n'Ph^2+\frac{4}{3}S_n^2h^3+\frac{8}{3}S_nS_n'h^3-16S_nV_nh^3-6S_nV_n'h^3+N^2S_nPh^3$$

$$-\frac{N}{3}S_nPh^3+\frac{4}{3}S_n'^2h^3-12S_n'V_nh^3-6S_n'V_n'h^3+N^2S_n'Ph^3-\frac{N}{3}S_n'Ph^3$$

$$+36V_n^2h^3+36V_nV_n'h^3-6N^2V_nPh^3+9V_n'^2h^3-3N^2V_n'Ph^3+\text{etc.}\Big)\frac{1}{N}$$

Summing up, the total work in the Nth Story is

$$\omega=\frac{2}{2EI_1N}\Big(+6M_n^2h+7M_nM_n'h-9M_nS_nh^2-5M_nS_n'h^2+21M_nV_nh^2+$$

$$\frac{33}{4}M_nV_n'h^2-6M_nM_{n-1}h-3M_nM_{n-1}'h-9M_nV_{n-1}h^2-\frac{9}{4}M_nV_{n-1}'h^2$$

$$-N^2M_nPh^2+\frac{9}{2}M_n'^2h-5M_n'S_nh^2-6M_n'S_n'h^2+\frac{75}{4}M_n'V_nh^2+\frac{33}{4}M_n'V_n'h^2$$

$$-3M_n'M_{n-1}h-3M_n'M_{n-1}'h-\frac{27}{4}M_n'V_{n-1}h^2-\frac{9}{4}M_n'V_{n-1}'h^2-N^2M_n'Ph^2$$

$$+4S_n^2h^3+\frac{13}{3}S_nS_n'h^3-15S_nV_nh^3-\frac{21}{4}S_nV_n'h^3+6S_nM_{n-1}h^2+3S_nM_{n-1}'h^2$$

$$+9S_nV_{n-1}h^3+\frac{9}{4}S_nV_{n-1}'h^3+\frac{N^2}{2}S_nPh^3-\frac{N}{6}S_nPh^3+\frac{5}{2}S_n'^2h^3-\frac{51}{4}S_n'V_nh^3$$

$$-\frac{21}{4}S_n'V_n'h^3+3S_n'M_{n-1}h^3+3S_n'M_{n-1}'h^2+\frac{27}{4}S_n'V_{n-1}h^3+\frac{9}{4}S_n'V_{n-1}'h^3$$

$$+\frac{N^2}{2}S_n'Ph^3-\frac{N}{6}S_n'Ph^3+27V_n^2h^3+\frac{189}{8}V_nV_n'h^3-9V_nM_{n-1}h^2$$

$$-\frac{27}{4}V_nM_{n-1}'h^3-18V_nV_{n-1}h^3-\frac{45}{8}V_nV_{n-1}'h^3-3N^2V_nPh^3+\frac{45}{8}V_n'^2h^3$$

$$-\frac{9}{4}V_n'M_{n-1}h^2-\frac{9}{4}V_n'M_{n-1}'h^2-\frac{45}{8}V_n'V_{n-1}h^3-\frac{9}{4}V_n'V_{n-1}'h^3$$

$$-3\frac{N^2}{2}V_n'Ph^3+3M_{n-1}^2h+3M_{n-1}M_{n-1}'h+9M_{n-1}V_{n-1}h^2$$

$$+\frac{9}{4}M_{n-1}V_{n-1}'h^2+\frac{3}{2}M_{n-1}'^2h+\frac{27}{4}M_{n-1}'V_{n-1}h^2+\frac{9}{4}M_{n-1}'V_{n-1}'h^2$$

$$+9V_{n-1}^2h^3+\frac{45}{8}V_{n-1}V_{n-1}'h^3+\frac{9}{8}V_{n-1}'^2h^3\Big)$$

In Table VII (insert), are given the coefficients of the equations resulting from differentiating the work in respect to the different unknowns, all of which equations are equal to zero. All numbers above the line, and all terms involving the subscript n-I are derived from the work of the story below. They result from increasing by one all subscripts in the total work expression above and differentiating in respect to M_n, M'_n, S_n, etc. All such coefficients and terms disappear when the given story is a bottom story.

In Table VIII (insert), are given the equations for the First, Second, Third and Fourth Stories. Coefficients above the line are as in Typical Equations, and the second coefficient, above the line, in the cases of V_n in the 5th and V'_n of the 6th equation of each block, is derived from the direct work in the column, by a method described in the discussion of Two Bay Buildings. Page 8.

DATA FROM COMPUTATIONS

In Tables 9, 10 and 11 are given all the values derived from calculation:

April, 1915

TABLE IX

Data from Calculations, Two-Bay Building

9 Story Building

No. of Story	$M_{cor.}$	$M_{interm.}$	$S_{cor.}$	$S_{interm.}$	$V_{cor.}$	$'M_{span}$
1	188.223376	220.29435	2.67928941	3.6414212	13.010863	191.316491
2	111.6109187	196.02366	2.10762031	3.7847594	10.6025148	192.530023
3	93.3789122	166.0793	1.84604564	3.3079088	8.15720961	170.044176
4	78.818524		1.57672615	2.8465478	5.99998715	

8 Story Building

1	166.80121	195.29788	2.3816996	3.2366008	10.236999	168.786872
2	97.418122	171.21596	1.8446984	3.3106032	8.1131592	166.900958
3	79.849240	142.05072	1.5830868	2.8338264	5.9941660	143.948238
4	65.488797	118.32561	1.3148018	2.3703964	4.1689893	118.138615
5	52.147232	94.181860	1.0532752	1.8934496	2.6717456	91.9786450
6	38.798357	70.158176	0.79122946	1.4175411	1.5074837	65.744177
7	25.419588	46.033364	0.52982399	0.94035202	0.67709153	39.564100
8	12.001289	22.120029	0.26591967	0.46816066	0.17959131	14.590678

7 Story Building

1	145.44753	170.36604	2.0841456	2.8317088	7.7957964	146.24263
2	83.27560	146.45450	1.5818082	2.8363836	5.9566478	141.25742
3	66.35220	118.05200	1.3201668	2.3596664	4.1641455	117.834801
4	52 170321	94.288140	1.0529558	1.8940884	2.6712374	91.9389760
5	38.813717	70.246986	0.79135013	1.41729974	1.5074186	65.740471
6	25.419175	46.035680	0.52981290	0.94037420	0.67708658	39.563604
7	12.001489	22.119707	0.26592148	0.46815704	0.17959075	14.5906590

6 Story Building

1	124.14971	145.48848	1.7866129	2.4267742	5.6873737	123.680211
2	69.16863	121.72014	1.3189754	2.3620492	4.1331419	115.595170
3	52.86626	94.056870	1.0573198	1.8853604	2.6673687	91.695485
4	38.829765	70.228980	0.79109876	1.4178025	1.5070383	65.710053
5	25.429942	46.027356	0.52989820	0.9402036	0 67704219	39.561096
6	12.001218	22.121065	0.26591569	0 46816862	0.17958833	14.5903510

5 Story Building

1	102.89680	120.65150	1.4891218	2.0217564	3.9118497	101.092890
2	55.07751	96.989500	1.0562466	1.8875068	2.6428516	89.905100
3	39.35795	70.041770	0.7944520	1.4110960	1.5041411	65.526612
4	25.439362	46.084396	0.52972118	1.0594424	0.67678961	39.539865
5	12.007109	22.116276	0.26596191	0.4680762	0.17956502	14.589082

4 Story Building

1	81.67885	95.839190	1.1917304	1.6165392	2.4693437	78.466210
2	40.97202	72.237240	0.7935497	1.4129006	1.4860624	64.181884
3	25.798934	45.944562	0.53204229	0.9359154	0.67485858	39.416062
4	12.010767	22.146154	0.26587561	0.4682488	0.17944104	14.576794

3 Story Building

1	60.48016	71.045320	0.8943483	1.2113034	1.3599812	55.785325
2	26.830655	47.398720	0.53142035	0.9371593	0.66313322	38.510158
3	12.198778	21.961510	0.26711192	0.4657762	0.17846978	14.512414

2 Story Building

1	39.328371	46.237018	0.59758009	0.8048398	0.58368747	33.109443
2	12.679805	22.760361	0.26707109	0.4658578	0.17293343	14.027304

1 Story Building

1	18.390805	21.839078	0.29885059	0.4022988	0.13793104	11.494254

All values in terms of P, the Panel Load.

TABLE X

Data from Calculations. Three-Bay Buildings.

14 Story Building

No. of Story	M_{cor}	M_{interm}	S_{cor}	S_{interm}	V_{cor}	V_{interm}	$M_{corspan}$
1	213.17370	246.79567	2.9956569	4.0043431	20.815277	1.4212440	210.94519
2	124.55320	218.24238	2.3129950	4.1870050	18.152116	1.6397110	215.62710
3	108.88080	197.01384	2.1106300	3.8893700	15.415954	1.6735428	199.24973
4	97.067530	181.34183	1.9045710	3.5954290	12.894623	1.6040063	180.53588
5	87.146310	165.18347	1.7173950	3.2826050	10.613922	1.4605036	162.20383
6	77.610640	148.93934	1.5352508	2.9647492	8.5681382	1.2749190	144.31906
7	68.404623	132.52780	1.3577732	2.6422268	6.7504242	1.0696285	126.79720
8	59.424501	116.00949	1.1835030	2.3164970	5.1553819	.86140111	109.53770
9	50 611900	99.413600	1.0115891	1.9884109	3.7790922	.66238337	92.465756
10	41.918746	82.761950	.84134932	1.6586507	2.6187484	.48134553	

13 Story Building

No. of Story	M_{cor}	M_{interm}	S_{cor}	S_{interm}	V_{cor}	V_{interm}	$M_{corspan}$
1	197.39540	228.50777	2.7833153	3.7166847	18.045800	.85055779	195.67036
2	114.73423	200.82958	2.1393580	3.8606420	15.575139	1.0670656	198.93481
3	99.733240	179.96146	1.9406100	3.5593900	13.050039	1.1206204	182.59732
4	88.269560	164.23740	1.7380830	3.2619170	10.738478	1.0844732	164.06491
5	78.526170	148.07323	1.5526730	2.9473270	8.6648173	.98422280	145.86093
6	69.119802	131.83591	1.3716617	2.6283383	6.8241392	.84817296	128.04885
7	60.002482	115.44609	1.1947865	2.3052135	5.2104316	.69605754	110.55184
8	51.075642	98.958960	1.0206965	1.9793035	3.8190067	.54251852	93.281362
9	42.287354	82.398700	.84862811	1.6513719	2.6464729	.39810064	

12 Story Building

No. of Story	M_{cor}	M_{interm}	S_{cor}	S_{interm}	V_{cor}	V_{interm}	$M_{corspan}$
1	181.72340	210.33368	2.5708576	3.4291424	15.461957	.38670133	180.35986
2	104.99750	183.53037	1.9653860	3.5346140	13.184311	.60002870	182.18745
3	90.646350	163.02043	1.7700654	3.2299346	10.871068	.67123896	165.87369
4	79.513500	147.23939	1.5709427	2.9290573	8.7703116	.66569332	147.50923
5	69.928460	131.06687	1.3871295	2.6128702	6.9049238	.60529085	129.41912
6	60.634597	114.83119	1.2071299	2.2928701	5.2707917	.51474771	111 66312
7	51.584729	98.460090	1.0306890	1.9693110	3.8627765	.41107293	94.175719
8	42.691548	82.000390	.85660969	1.6433903	2.6768758	.30681348	

11 Story Building

No. of Story	M_{cor}	M_{interm}	S_{cor}	S_{interm}	V_{cor}	V_{interm}	$M_{corspan}$
1	166.14605	192.26211	2.3582613	3.1417387	13.063894	.02954257	165.00778
2	95.32770	166.33819	1.7909704	3.2090296	10.979861	.23820510	165.37188
3	81.602538	146.18548	1.5988632	2.9011368	8.8794661	.32442812	149.06152
4	70.777742	130.34845	1.4029166	2.5970834	6.9908041	.34590518	130.84565
5	61.331728	114.16484	1.2205333	2.2794667	5.3352639	.32092066	112.84899
6	52.127392	97.929350	1.0413455	1.9586545	3.9095545	.27058000	95.131102
7	43.123944	81.574450	.86514481	1.6348552	2.7093722	.2092381	

10 Story Building

No. of Story	M_{cor}	M_{interm}	S_{cor}	S_{interm}	V_{cor}	V_{interm}	$M_{corspan}$
1	150.6498	174.28553	2.1454624	2.8545376	10.852836	—0.2243123	149.605910
	85.70947	149.24655	1.6160201	2.8839799	8.9631375	—0.0221594	148.47470
3	72.58216	129.45677	1.4268003	2.5731997	7.0767810	0.0758046	132.140277
4	62.042407	113.56391	1.2337965	2.2662035	5.4018084	0.1198239	114.046994
5	52.709751	97.370130	1.0525943	1.9474057	3.9580961	0.1246471	96.121531
6	43.571852	81.134110	0.8739883	1.6260117	2.7431151	0.1079086	

All values in terms of P, the Panel Load.

TABLE X (continued)
Data from Calculations. Three-Bay Buildings.

9 Story Building

No. of Story	M_{cor}	M_{interm}	S_{cor}	S_{interm}	V_{cor}	V_{interm}	M_{cor} S_{pan}
1	135.22441	156.39315	1.9324623	2.5675377	8.8314998	—0.3827335	134.14912
2	76.12730	132.25089	1.4404125	2.5595875	7.1369330	—0.1891749	131.482706
3	63.568756	112.829770	1.2537380	2.2462620	5.4660003	—0.0833146	115.089214
4	53.28417	96 885810	1.0633521	1.9366479	4.0066207	—0.02212856	97.089725
5	44.038685	80.683930	0.8830476	1.6169523	2.7770608	0.00584942	

8 Story Building

No. of Story	M_{cor}	M_{interm}	S_{cor}	S_{interm}	V_{cor}	V_{interm}	M_{cor} S_{pan}
1	119.85779	138.57960	1.7191736	2.2808264	7.0036675	—0.4568344	118.62667
2	66.56710	115.34534	1.2640464	2.2359536	5.5051857	—0.2743897	114.378397
3	54.540857	96.30300	1.0794812	1.9205183	4.0513209	—0.16521407	97.888782
4	44.481519	80.31320	0.8913633	1.6086367	2.8097245	—0.09310309	

7 Story Building

No. of Story	M_{cor}	M_{interm}	S_{cor}	S_{interm}	V_{cor}	V_{interm}	M_{cor} S_{pan}
1	104.54201	120 83468	1.5056044	1.9943956	5.3745879	—0.46211953	103.031466
2	57.013036	98.523010	1.0868355	1.9131645	4.0732501	—0.29356420	97.152692
3	45.182178	79.870070	0.9039152	1.5960848	2.8382311	—0.18605664	

6 Story Building

No. of Story	M_{cor}	M_{interm}	S_{cor}	S_{interm}	V_{cor}	V_{interm}	M_{cor} S_{pan}
1	89.265716	103.15094	1.29172194	1.7082781	3.9502981	—0.41644970	87.359001
2	47.452523	81.77449	0.90873550	1.5912645	2.8472239	—0.2646985	
3	36.373777		0.72699361	1.27300639	1.8329819	—0.16417300	

5 Story Building

No. of Story	M_{cor}	M_{interm}	S_{cor}	S_{interm}	V_{cor}	V_{interm}	M_{cor} S_{pan}
1	74.021826	85.519360	1.0775367	1.4224633	2.7371467	—0.33865590	
2	37.870634		0.72977079	1.27022921	1.8335475	—0.20670543	
3	27.192496		0.54868278	0.95131722	1.0420823	—0.11849893	

4 Story Building

No. of Story	M_{cor}	M_{interm}	S_{cor}	S_{interm}	V_{cor}	V_{interm}	M_{cor} S_{pan}
1	58.80140	67.928347	0.86309714	1.13690286	1.7412732	—0.24688289	
2	28.248360		0.5499780	0.9500220	1.03841409	—0.13759700	
3	17.9187993		0.36935743	0.63064257	0.47168073	—0.0666890	

3 Story Building

No. of Story	M_{cor}	M_{interm}	S_{cor}	S_{interm}	V_{cor}	V_{interm}	M_{cor} S_{pan}
1	43.595720	50.367514	0.64842243	0.85157757	0.96798522	—0.15679878	
2	18.569736		0.3697370	0.7302630	0.46719900	—0.072773136	
3	8 3754050		0 18527880	0.31472120	0.12592944	—0.02121743	

2 Story Building

No. of Story	M_{cor}	M_{interm}	S_{cor}	S_{interm}	V_{cor}	V_{interm}	M_{cor} S_{pan}
1	28.417350	32.825996	0.4338744	0.5661256	0.4213256	—0.08055478	
2	8.844600		0.1875240	0.3124760	0.1233864	—0.02427170	

1 Story Building

No. of Story	M_{cor}	M_{interm}	S_{cor}	S_{interm}	V_{cor}	V_{interm}	M_{cor} S_{pan}
1	13.3803431	15.501124	0.21818823	0.28181177	0.10308733	—0.02768156	

All values in terms of P, the Panel Load.

TABLE XI

Data From Calculations. Four—Bay Buildings

4 Story Building

No. of Story	$M_{cor.}$	$M_{interm.}$	$M_{middle.}$	$S_{cor.}$	$S_{interm.}$	$S_{middle.}$	$V_{cor.}$	$V_{interm.}$	$M_{span\ (cor.)}$	Max. at Mid-Co $M_{span(interm)}$
1	45.895647	53.030477	52.340922	.67571058	.88975660	.86906564	1.3379307	−.17650530	43.116070	35.156747
2	21.440669	37.111202	35.747852	.41932538	.72890958	.70353008	.79475998	−.099025275	34.197569	28.811150
3	13.705700	23.697647	23.017176	.28253634	.48292304	.46908124	.36087433	−.047828226		

3 Story Building

No. of Story	$M_{cor.}$	$M_{interm.}$	$M_{middle.}$	$S_{cor.}$	$S_{interm.}$	$S_{middle.}$	$V_{cor.}$	$V_{interm.}$	$M_{span\ (cor.)}$	Max. at Mid-Co $M_{span(interm)}$
1	34.052614	39.364127	38.805590	.50774549	.66708814	.65033274	.74588582	−.11056854	30.840696	24.820126
2	14.118761	24.402407	23.412567	.28234325	.48462263	.46606824	.35828246	−.051411277	20.677883	17.077106
3	6.5623192	11.397148	10.959956	.14367241	.24069317	.23126884	.096806820	−.016543275	7.804922	6.083464

2 Story Building

No. of Story	$M_{cor.}$	$M_{interm.}$	$M_{middle.}$	$S_{cor.}$	$S_{interm.}$	$S_{middle.}$	$V_{cor.}$	$V_{interm.}$	$M_{span\ (cor.)}$	Max. at Mid-Co $M_{span(interm)}$
1	22.225724	25.700217	25.297715	.33987367	.44410924	.43203418	.32607661	−.055985191	18.504081	14.531511
2	6.7424380	11.740229	11.157319	.14360039	.24141653	.22996616	.094797834	−.016671178	7.617601	5.919648

1 Story Building

No. of Story	$M_{cor.}$	$M_{interm.}$	$M_{middle.}$	$S_{cor.}$	$S_{interm.}$	$S_{middle.}$	$V_{cor.}$	$V_{interm.}$	$M_{span\ (cor.)}$	Max. at Mid-Co $M_{span(interm)}$
1	10.490482	12.195444	11.918352	.17097321	.22212210	.21380938	.080513580	−.018661173	6.606839	4.731293

All values in terms of P, the Panel Load

GRAPHICAL REPRESENTATION OF VALUES TO 20 AND 30 STORIES

Using the data computed as a basis, values for additional stories were computed up to twenty stories in the two-bay buildings, and up to thirty stories in the three bay building.

TWO-BAY BUILDINGS

Moments in Corner Columns.

The moment in the bottom of the one-story building was subtracted from the first-story moment of the two-story building, and that of the two-story from that of the three-story, and so on, giving a series of differences of bottom-story moments. These differences were then successively subtracted giving the second order of differences, and the second order of differences were then successively subtracted giving the third order of differences. This third order of differences for the corner columns was —.167, —028, +.016, +.010, +.011, +'.013. It was assumed that the fourth order of differences was zero, and that the third order was a constant with a value of +.012, giving a moment of the fifteenth story of 318.821P, and at the twentieth story of 431.692P. These and the intermediate answers are plotted on Plate I in the line marked first or bottom story. In a similar manner the constant third order of differences for the second stories of buildings of various heights was determined to be +.024, giving for the fifteen-story building, 199.437P, and for the twenty-story building, 278.667U. In a similar manner the third order of differences for the third, fourth, and fifth were determined as, +.030, +.032, +.033, respectively, giving the results plotted as the third J, and fourth story movements on Plate I.

The dotted lines marked third, sixth, and ninth stories from the top, when drawn for the computed data and for this additional derived data, give sufficiently clear indications of the character of their curvature to enable us to prolong them to the twenty-story building. For instance, that for the third story from the top becomes almost exactly straight before coming to the limit of the computed data. That for the sixth becomes nearly so, and it seems fair to assume that the continuation of these lines is as shown on the drawings. With these curves of moments at equal distances from the top, it is possible to fill in the remainder of the curves for all the stories up to twenty, as shown in dotted lines on the drawing.

This method of determining curves for values at equal heights from the top, as a basis for approximating the uncomputed values, was used on all the Plates I-VIII (insert).

Moment in Intermediate Columns.

The third order of differences was computed as described above, and was determined for the bottom stories to be constant at +.015, for the second stories at +.030, for the third stories at +.033, and for the fourth stories at +.034. Using this third order of differences, moments up to the twenty-story building were computed and plotted as shown in Plate II. In a manner similar to that used on Plate I, the curve of moments at equal distances from the top was drawn and projected, and the curves for which no data had been computed drawn upon them.

Direct Stress (V) in Corner Columns.

For the bottom story, the fourth order of differences was determined as constant with a value of —.00012. Using this fourth order value, values for V for all stories of buildings up to twenty stories were computed and plotted as shown on Plate III. For the second story the fourth order of differences was determined as constant with a value of —.00006, and for the third story, the fourth order was constant with a value of —.00008. Using these fourth order differences, moments for second and third stories in all buildings up to twenty stories were computed and plotted on Plate III. In a manner similar to that used for the moments on Plates I and II, the curves for these in stories equally distant from the top were drawn and curves of the uncomputed values drawn upon them.

Moments in Spandrel Girders at Corner Column.

The moments in the spandrels were found to be a maximum at this point, so no other spandrel moments were computed. The third order of differences was found to be constant with a value of +.004 for the bottom story, +.003 for the second story, +.002 for the third, and the moments in all buildings up to twenty stories were computed from these differences and plotted on Plate IV. On this plate is shown the very surprising fact that for some buildings, the spandrel in the second story has more moment than the spandrel for the first story. This occurs coincident with the regular rise of the point of contra-flexure in the first story column, and the consequent diminution of the moment at the top of the first story column. No curves of heights of points of contraflexure have been drawn, but it may be noted that the point of contraflexure in the bottom story tends to rise at a regular rate, and when computed for the three-bay building, there was no indication to the writer that its rate of rise would become less for very high buildings.

THREE-BAY BUILDINGS

Table 12 below shows above the broken line the computed values for moments in corner columns of bottom stories, and the computed differences of the first, second, and third orders. Now on the basis of these third order differences, a fourth order difference was estimated of .0006 2/3 and the remainder of the columns filled out accordingly, giving a moment of 492.853 P in the thirty-story building.

The writer does not think so much accuracy necessary as the consideration of the fourth order of differences in this case, nor is it entirely certain that the data given, being evidently approximate in the third place of decimals, furnishes a basis for such fine calculation. In the second story, the third order of differences was found to be constant at +.015, was determined in the third at +.019, in the fourth at +.021, and in the fifth at +.023, and the moments in buildings up to thirty stories were computed from these differ-

TABLE XII.

Movements in Corner Columns—Buildings of One to Thirty Stories—
Three Bays First Story.

DIFFERENCES

No: of Stories	Moments	First Order	Second Order	Third Order	Fourth Order
1	13.3803				
		15.0370			
2	28.4173				
		15.1784	.1414		
3	43.5957			—.114	
		25.2057	.0273		
4	58.8014			—.013	
		15.2204	.0147		
5	74.0218			.009	
		15.2439	.0235		
6	89.2657			.009	
		15.2763	.0324		
7	104.542			.008	
		15.316	.040		
8	119.858			.010	
		15.366	.050		
9	135 224			.010	
		15.426	.060		
10	150.650			.010	
		15.496	.070		
11	166.146			.011	
		15.577	.081		
12	181.723			.014	
		15.672	.095		
13	197.395			.012	
		15.779	.107		
14	213.174			.013	
		15.899	.120		.00066
15	229.073			.0137	
		16.033	.134		.00066
16	245.106			.0143	
		16.181	.148		.00066
17	261 287			.0150	
		16.344	.163		.00066
18	277.631			.0157	
		16.523	.179		"
19	294.154			.0163	
		16.718	.195		"
20	310.872			.0170	
		16.930	.212		"
21	327.802			.0177	
		17.160	.230		"
22	344.962			.0183	
		17.408	.248		"
23	362.370			.0190	
		17.675	.267		"
24	380.045			.0197	
		17.962	.287		"
25	398.002			.0203	
		18.269	.307		"
26	416.276			.0210	
		18.597	.328		"
27	434.873			.0217	
		18.947	.350		.00066
28	453.820			.0223	
		19.319	.372		.00066
29	473.139			.0230	
		19.714	.395		
30	492.853				

ences and plotted on Plate V. All the computed data having been plotted, the curve of moments at the fifth story from the top was then drawn, and that for moments nine, thirteen, and seventeen stories from the top drawn to resemble it. The intersections thus given enable us to draw the curves of moments at equal distances from the bottom.

Moments in Intermediate Columns.

The third order of differences was found to be +.009 for the first story, +.006 for the second, +.003 for the third, +.000 for the fourth, —.002 for the fifth, —.004 for the sixth, —.005 for the seventh, and —.006 for the eighth. From this third order of differences the moments in buildings up to thirty stories were computed and plotted as on Plate VI.

Direct Stress (V) in Corner Columns.

The fourth order of differences for bottom stories was found to be +.0012, and for second, third and fourth stories the fourth order of differences was found to be constant at +.0013. From these differences the V's in these stories in all buildings up to thirty stories were computed and plotted on Plate VII.

Moment in Spandrel Girder at Corner Column.

Moments in these girders were maximum at the point of attachment to the corner column. The third order of differences for moments in bottom stories was found to be +.008; for the second stories, +.013; for the third, +.020; for the fourth, +.025; for the fifth, +.029. From these differences moments in spandrels in these stories were computed in all buildings up to thirty stories, and the values plotted on Plate VIII. In this plate is evident, as in Plate IV, the surprising relation between spandrel moments of the first and second stories.

Variation of Bay Length.

Below are compared the results of computing the stresses in three-story buildings of story heights 100″, outside bays 150″, and middle bays in (a) 100″, in (b) 150″ and in (c) 200″.

TABLE XIII

	V_3'	V_3	S_3	M_3	V_2'	V_2	S_2	M_2
(a)	+.4775	+.9197	+.6240	+41.92	+.1565	+.4614	+.3359	+16.74
(b)	—.1568	+.9680	+.6484	+43.60	—.0728	+.4672	+.3697	+18.57
(c)	—.5335	+1.0337	+.6665	+44.70	—.2586	+.5017	+.3930	+19.74

Dividing the (a) and (c) values by the (b) values, we get for S_3—.96 and 1.027, for M_3—.96 and 1.023, for S_2—.908 and 1.062 and for M_2—.904 and 1.062.

These calculations should be carried to four-story buildings, and calculations made for middle bay constant and outside bays increased and diminished.

From such calculations ratios can be obtained which will enable one to adopt the curves of Plates V to VIII to buildings of various bay length.

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GENERAL

While in some cases, it may seem to one checking the operations by which the constant differences of the third and fourth orders were derived, that these determinations are made upon rather scanty data in the cases of the two-bay stresses, yet it will be noted that the manner in which these differences vary in the two-bay work, resembles the manner of variation in the three-bay work for which the data is very considerable. It is entirely possible that in the three-bay differences we should discover a fourth order, where only a third has here been found, if we had more accurate figures in our answers. The writer can only say that the influence of a fourth order so small as these would evidently be quite small within the limits of thirty-story buildings, and that he feels confident that the projections of the computed data give answers accurate within one per cent.

It is hoped that the discussion of the data thus submitted to the society will develop some feasible plan for modifications of these curves to be applied to four, five and six-bay buildings. Some method of applying these data to the case of buildings with unequal bays should also be developed. It is desirable that such additional information as is necessary should be secured from computations of a minimum number of stories, as the labor of making such computations is great.

The results given herein are not considered by the writer to be usable in the first and second stories for three reasons: first, a building of thirty stories will ordinarily extend two stories below the ground floor. The nature of the reaction at sidewalk level and first basement floor is indeterminate, and it is on this point that the writer desires to get the opinion of as many engineers as possible before proceeding to extend these calculations; second, in all cases the bottom story is much higher than the typical stories, and very often the second story somewhat exceeds the typical stories in height; third, it is very probable that the resistance of interior columns is much greater at second floor proportionately than in stories above, thus relieving first and basement columns of considerable moment.

It may be further noted that the presence or absence of spandrel beams at the ground floor and first basement floor very considerably modifies the column stresses.

Foı buildings whose bays are equal these results will give very reliable indications of the stresses above the second floor.

Table II.

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	S_{14}	V_{14}	V_{14}'	P	TERMS
Multiplier—	-111.749682	—582.368265			Substitution
—2.926	-37.3038987	—27.9779243	0	—1262.01493	Multiplication
				+431.23929	Subtraction
	0	0	0	—1898.24448	Copied from 13 Story Sheet
Multiplier— —2.464	-29.2799892	—32.9399881	—3.65999871	—2936.57389	Multiplication
				+1191.5850	Subtraction
Multiplier— +11.137	0	—15.8495026	—15.8495026	—4210.62812	Multiplication
New Equation s14th Story	-499.276160	—4683.43755	—71.062200		Substitution
	-166.666	—225.0	—50.	+3266.6666	New Equation
	-432.705983	—3122.29170	—35.531100		Substitution
	-144.4444	—150.0	—25.0	+1594.4444	New Equation
	-599.131380	—11715.8214	—230.952150		Substitution
	-200.0	—562.847222	—162.5	+9800.0	New Equation
→ +2.31299	-2.84870345	—14.8456305			
	-.950944502	—.713208370	0	+16.2186530	
—Used	-37.303899	—27.977924	0	+636.22955	
	-2.45087146	+1.51564279	+1.11793215	+511.487432	
	-8.0239095	+4.9620638	+3.6599987	+1674.5590	
	-2.00886237	—.653130940	+.853515881	+158.786569	
	-37.303899	—12.128422	+15.849503	+2948.6132	
	-3.60203350	—5.48596889	—1.39222185	+126.098590	
	-129.36277	+197.02208	—50	—4528.6816	
+2.31299	-8.93684827	—70.7227400	—.989343468		
	-2.98326829	—3.39763612	—.696110925	+79.5365010	
	-107.14055	+122.02208	+25.	—2856.4593	
	-4.53018131	—14.8931345	—4.52472101	+308.015580	
	-162.69610	+534.86930	+162.5	—11062.015	

Bracket covers figures which must check exactly. Arrow indicates approx. figure.

		M_{13}	S_{13}	V_{13}	V_{13}'	M_{14}	S_{14}	V_{14}	V_{14}'	P	TERMS
⏞ ↓↓ → +124.5532053 Answer Used	Multiplier ↓ —2.9264841	+1 —.34170697	—88.0684768 —35.9138158 +12.272001	+1734.49017 +95.5530567 —32.651145	+36.1807162 +22.0653018 —7.5398673	—79.5221017 —.373038987	+111.749682 +37.3038987	—582.368265 —27.9779243	0	—1262.01493 +431.23929	Substitution Multiplication Subtraction
		+1	—75.1420770	+104.263665	+33.4744270	0	0	0	0	—1898.24448	Copied from 13 Story Sheet
	Multiplier ↓ —2.4644267	+1 —.40577388	—39.1877164 +15.901352	+191.505512 —77.707936	+56.1029745 —22.765122	—.292799892	+29.2799892	—32.9399881	—3.65999871	—2936.57389 +1191.5850	Multiplication Subtraction
	Multiplier ↓ +11.137465	+1	—54.4834797	+242.952082 +21.813948	+94.1862972 +8.4567087	0	0	—15.8495026	—15.8495026	—4210.62812	Multiplication
⏞ ↓ +124.553516	New Equation s14th Story	+1	0	+1361.40870 +75.0	0	—497.405293 —2.333333	+499.276160 +166.666	—4683.43755 —225.0	—71.062200 —50.	+3266.6666	Substitution New Equation
⏞ ↓ +124.553179		+1	0	+1361.40870 +75.0	0	—355.289507 —1.666666	+432.705983 +144.4444	—3122.29170 —150.0	—35.531100 —25.0	+1594.4444	Substitution New Equation
⏞ ↓ +124.55383		+1	0	+2042.11305 +112.5 —4.03066483	+20.4963862 +12.50 —.476892584	—639.521100 —3.0000 —2.02716358	+599.131380 +200.0 +2.84870345	—11715.8214 —562.847222 —14.8456305	—230.952150 —162.5	+9800.0	Substitution New Equation
	⏞ ↓↓ → +2.31299504 Used	+.025491826	+1 +39.228261	—222049311 —8.7106083	—.290839429 —11.409125	—.00950944502 —.37303899	+.950944502 +37.303899	—.713208370 —27.977924	0 0	+16.2186530 +636.22955	
		+.30544605	+1 +3.2739006	—29.3082984 —95.952455	—10.3966728 —34.037673	—.0245087146 —.080239095	+2.45087146 +8.0239095	+1.51564279 +4.9620638	+1.11793215 +3.6599987	+511.487432 +1674.5590	
		+.053851271	+1 +18.569664	—7.93762511 —147.39903	—3.88380725 —72.120995	—.0200886237 —.37303899	+2.00886237 +37.303899	—.653130940 —12.128422	+.853515881 +15.849503	+158.786569 +2948.6132	
	⏞ ↓ +2.31299756	—.027844437	+1 —35 913816	—.572288301 +20.553057 —10.3882436	—.614395911 +22.065302 —1.00743167	—.0545832911 +1.9602943 —7.67858809	+3.60203350 —129.36277 +8.93684827	—5.48596889 +197.02208 —70.7227400	—1.39222185 —50 —.989343468	+126.098590 —4528.6816	
		"	+1 "	" "	" "	—.0360203350 +1.2936277	+2.98326829 —107.14055	—3.39763612 +122.02208	—.696110925 +25.	+79.5365010 —2856.4593	
		"	+1 "	+.471878087 —16.946943	—.266340443 +9.5653018	—.0731462501 +2.6269610	+4.53018131 —162.69610	—14.8931345 +534.86930	—4.52472101 +162.5	+308.015580 —11062.015	

TABLE II

Table IV.

	+1	0	+ 75.00	—3.75 —3.0000	+ 200.00	— 275.0 — 331.250	0 + .750	0 — 75.0	0 + 56.25	+ 300.00
3rd.	+1	0	+ 75.00	—2.00	+ 166.66667	— 175.000	0	0	0	+ 133.3333
				—3.666666		— 500.05444	0	0	0	
	+1	0	+ 100.0	—3.66666 —4.5416666	+ 233.33333	— 500.0900 — 587.59	0 + .8750	0 — 87.50	0 + 87.50	+ 3266.666
	M_7 +1	S_7 0	V_7 + 75.0	M_8 — 3.8888888 —3.00	S_8 + 200.00	V_8 — 341.66666 — 275.0	+ .8888888	— 88.888888	+ 66.66666	P + 2133.333
8th.	+1	0	+ 75.0	— 2.00	+ 166.66667	— 175.0	0	0	0	+ 1022.222
	+1	0	+ 100.0	— 4.555555 — 3.66666	+ 233.3333	— 588.989166 — 500.100277	+ .88888	— 88.888	+ 88.888	+ 4266.666

364²

P
$-100N^2$
$-100N^2$
$+50N^2$ $-16.66N$
$+50N^2$ $-16.66N$
$-300N^2$
$-150N^2$

TABLE IV

1st.	M_1 +1	S_1 —66.66666 —57.1428571	V_1 + 91.666666 + 89.2857143	M_2 0 —.142857143	S_2 0 + 14.2857143	V_2 0 — 10.7142857				P — 11.1111111 — 9.56380952
	+1	—83.333333	+ 87.500	0	0	0				— 5.555555
	+1	—63.636363 —56.000	+ 136.374545 + 132.00960	0 —.1200	0 + 12.00	0 — 12.00				— 18.18181818 — 16.000000
2nd.	M_1 +1	S_1 0	V_1 + 75.000	M_2 —3.0000 —3.666666	S_2 + 200.000	V_2 — 275.00 — 325.00	M_3 0 + .66666666	S_3 0 — 66.666666	V_3 0 + 50.00	P + 133.3333
	+1	0	+ 75.0000	—2.0000	+ 166.66667	— 175.000	0	0	0	+ 55.55555
	+1	0	+ 100.00	—3.666666 —4.333333	+ 233.3333	— 500.046944 — 566.713611	0 + .6666666	0 — 66.666666	0 + 66.66666	+ 266.6666
3rd.	M_2 +1	S_2 0	V_2 + 75.00	M_3 —3.75 —3.0000	S_3 + 200.00	V_3 — 275.0 — 331.250	M_4 0 + .750	S_4 0 — 75.0	V_4 0 + 56.25	P + 300.00
	+1	0	+ 75.00	—2.00	+ 166.66667	— 175.000	0	0	0	+ 133.3333
	+1	0	+ 100.0	—3.666666 —4.41666667	+ 233.33333	— 500.05444 — 575.054444	0 + .750	0 — 75.0	0 + 75.0	+ 600.00
4th.	M_3 +1	S_8 0	V_3 + 75.0	M_4 —3.8 —3.0000	S_4 + 200.00	V_4 — 275.0 — 335.55	M_5 0 + .80000	S_5 0 — 80.000	V_5 0 + 60.000	P + 533.3333
	+1	0	+ 75.0	—2.00	+ 166.66667	— 175.00	0	0	0	+ 244.4444
	+1	0	+ 100.0	—3.666666 —4.4666667	+ 233.33333	— 500.0625 — 580.0625	0 + .8000	0 — 80.000	0 + 80.000	+ 1066.6666
5th.	M_4 +1	S_4 0	V_4 + 75.0	M_5 —3.0000 —3.8333333	S_5 + 200.00	V_5 — 275.00 — 337.50	M_6 0 + .833333	S_6 0 — 83.33333	V_6 0 + 62.5	P + 833.3333
	+1	0	+ 75.0	—2.00	+ 166.66667	— 175.000	0	0	0	+ 388.8888
	+1	0	+ 100.0	—3.66666 —4.5000000	+ 233.33333	— 500.071111 — 583.404444	0 + .833333	0 — 83.33333	0 + 83.33333	+ 1666.6666
6th.	M_5 +1	S_5 0	V_5 + 75.0	M_6 — 3.0000 — 3.85714285	S_6 + 200.00	V_6 — 275.000 — 339.285714	M_7 0 + .85714285	S_7 0 — 85.714285	V_7 0 + 64.285714	P + 1200.00
	+1	0	+ 75.0	—2.00	+ 166.66667	— 175.000	0	0	0	+ 566.666
	+1	0	+ 100.0	—3.66666 —4.52380952	+ 233.3333	— 500.080277 — 585.7945624	0 + .85714285	0 — 85.714285	0 + 85.714285	+ 2400.0
7th.	M_6 +1	S_6 0	V_6 + 75.0	M_7 —3.000 — 3.875	S_7 + 200.00	V_7 — 275.0 — 340.625	M_8 0 + .8750	S_8 0 — 87.50	V_8 0 + 65.625	P + 1633.333
	+1	0	+ 75.0	—2.00	+ 166.66667	— 175.000	0	0	0	+ 777.7777
	+1	0	+ 100.0	—3.66666 —4.5416666	+ 233.33333	— 500.0900 — 587.59	0 + .8750	0 — 87.50	0 + 87.50	+ 3266.666
8th.	M_7 +1	S_7 0	V_7 + 75.0	M_8 —3.8888888 —3.00	S_8 + 200.00	V_8 — 341.66666 — 275.0	+ .8888888	— 88.888888	+ 66.66666	P + 2133.333
	+1	0	+ 75.0	—2.00	+ 166.66667	— 175.0	0	0	0	+ 1022.222
	+1	0	+ 100.0	— 4.555555 — 3.66666	+ 233.3333	— 588.989166 — 500.100277	+ .88888	— 88.888	+ 88.888	+ 4266.666

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Table VII.

V_n-1	V_n-I_n+1	M_n+1′	S_n+1	S_n+1′	V_n+1	V_n+1′	P
—900	—2: —6	—3	+600	+300	—900	—225	—100N^2
—675	—2: —3	—3	+300	+300	—675	—225	—100N^2
+900	+2: 0	0	0	0	0	0	+50N^2 —16.66N
+675.	+2: 0	0	0	0	0	0	+50N^2 —16.66N
—1800	—5(—9	—6.75	+900	+675	—1800	—562.5	—300N^2
—562.5	—2: —2.25	—2.25	+225.	+225.	—562.5	—225.	—150N^2

Note:—In at_{-1}

—In aliplied by $\frac{N}{N+1'}$

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Table VII.

TABLE VII.
Table of Typical Equations.

	M_n-1	M_n-1'	S_n-1	S_n-1'	V_n-1	V_n-1'	M_n	M_n'	S_n	S_n'	V_n	V_n'	M_n+1	M_n+1'	S_n+1	S_n+1'	V_n+1	V_n+1'	P
$\frac{dW}{dM_n}$	—6	—3	0	0	—900	—225	+6 +12	+3 +7	—900	—500	+900 +2100	+225 +825	—6	—3	+600	+300	—900	—225	$-100N^2$
$\frac{dW}{dM_n'}$	—3	—3	0	0	—675	—225	+3 +7	+3 +9	—500	—600	+675 +1875	+225 +825	—3	—3	+300	+300	—675	—225	$-100N^2$
$\frac{dW}{dS_n}$	+6	+3	0	0	+900	+225	—9	—5	+800	+433.33	—1500	—525	0	0	0	0	0	0	$+50N^2$ $-16.66N$
$\frac{dW}{dS_n'}$	+3	+3	0	0	+675.	+225	—5	—6	+433.33	+500	—1275	—525	0	0	0	0	0	0	$+50N^2$ $-16.66N$
$\frac{dW}{dV_n}$	—9	—6.75	0	0	—1800	—562.5	+9 +21	+6.75 +18.75	—1500.	—1275.	+1800 +5400.	+562.5 +2362.5	—9	—6.75	+900	+675	—1800	—562.5	$-300N^2$
$\frac{dW}{dV_n'}$	—2.25	—2.25	0	0	—562.5	—225.	+2.25 +8.25	+2.25 +8.25	—525.	—525.	+562.5 +2362.5	+225. +1125	—2.25	—2.25	+225.	+225.	—562.5	—225.	$-150N^2$

Note:—In all columns with subscript $_{n}+1$, all terms are to be multiplied by $\frac{N}{N+1}$

—In all columns with subscript $_{\underline{n}}$, coefficients above the line are to be multiplied by $\frac{N}{N+1}'$

Table VIII. 364

	V_1'	S_2'	V_2	V_2'	P	
ript y ch	$+225\times\frac{1}{2}$ +825	$+300\times\frac{1}{2}$	$-900\times\frac{1}{2}$	$-225\times\frac{1}{2}$	−100	=0
tc.,	$+225\times\frac{1}{2}$ +825	$-300\times\frac{1}{2}$	$-675\times\frac{1}{}$	$-225\times\frac{1}{2}$	−100	=0
25 a	−525	0	0	0	+33.33	=0
char	−525	0	0	0	+33.33	=0
pre e co	+562.5× +2362.5 +.18	$+675\times\frac{1}{2}$	$-1800\times\frac{1}{2}$	$-562.5\times\frac{1}{2}$	−300	=0
hen eff.	$+225\times\frac{1}{2}$ +1125	$+225\times\frac{1}{2}$	$-562.5\times\frac{1}{2}$	$-225\times\frac{1}{2}$	·150	=0
	V_2'	S_3'	V_3	V_3'	P	
0	$+225\times\frac{2}{3}$ +825	$+300\times\frac{2}{3}$	$-900\times\frac{2}{3}$	$-225\times\frac{2}{3}$	−400	=0
0	$+225\times\frac{2}{3}$ +825	$+300\times\frac{2}{3}$	$-675\times\frac{2}{3}$	$-225\times\frac{2}{3}$	−400	=0
0	−525	0	0	0	+166.66	=0
0	−525	0	0	0	+166.66	=0
0	+562.5× +2362.5 +.21125	$+675\times\frac{2}{3}$	$-1800\times\frac{2}{3}$	$-562.5\times\frac{2}{3}$	−1200	=0
0	$+225\times\frac{2}{3}$ +1125	$+225\times\frac{2}{3}$	$-562.5\times\frac{2}{3}$	$-225\times\frac{2}{3}$	−600	=0
	V_3'	S_4'	V_4	V_4'	P	

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Table VIII.

Table VIII

Equations involving subscripts 4,5 and 6, 5,6 and 7, 6,7 and 8, etc. may be formed by changing the fractional multipliers to 5/6, 6/7 and 7/8 etc., and changing the direct work coefficient to .32, .36125 and .405 making at the same time the necessary changes in the P terms.

The equations above are prepared for computation by dividing through by the coefficient of the first term in each equation. When a block of equations are for a bott. story drop all coeff. which have fract. mult.

M_1	M_1'	S_1	S_1'	V_1	V_1'	M_2	M_2'	S_2	S_2'	V_2	V_2'	P	
$+6\times\frac{1}{2}$ +12	$+3\times\frac{1}{2}$ +7	-900	-500	$+900\times\frac{1}{2}$ +2100	$+225\times\frac{1}{2}$ +825	$-6\times\frac{1}{2}$	$3\times\frac{1}{2}$	$+600\times\frac{1}{2}$	$+300\times\frac{1}{2}$	$-900\times\frac{1}{2}$	$-225\times\frac{1}{2}$	-100	=0
$+3\times\frac{1}{2}$ +7	$+3\times\frac{1}{2}$ +9	-500	-600	$+675\times\frac{1}{2}$ +1875	$+225\times\frac{1}{2}$ +825	$-3\times\frac{1}{2}$	$3\times\frac{1}{2}$	$+300\times\frac{1}{2}$	$-300\times\frac{1}{2}$	$-675\times\frac{1}{2}$	$-225\times\frac{1}{2}$	-100	=0
-9	-5	+800	+433.3	-1500	-525	0	0	0	0	0	0	+33.33	=0
-5	-6	+433.33	+500	-1275	-525	0	0	0	0	0	0	+33.33	=0
$+9\times\frac{1}{2}$ +21	$+675\times\frac{1}{2}$ +18.75	-1500	-1275	+.18 $+1800\times\frac{1}{2}$ +5400	$+562.5\times\frac{1}{2}$ +2362.5	$-9\times\frac{1}{2}$	$-6.75\times\frac{1}{2}$	$-900\times\frac{1}{2}$	$+675\times\frac{1}{2}$	$-1800\times\frac{1}{2}$	$-562.5\times\frac{1}{2}$	-300	=0
$+2.25\times\frac{1}{2}$ +8.25	$+2.25\times\frac{1}{2}$ +8.25	-525	-525	$+562.5\times\frac{1}{2}$ +2362.5	+.18 $+225\times\frac{1}{2}$ +1125	$-2.25\times\frac{1}{2}$	$-2.25\times\frac{1}{2}$	$+225\times\frac{1}{2}$	$+225\times\frac{1}{2}$	$-562.5\times\frac{1}{2}$	$-225\times\frac{1}{2}$	:150	=0

M_1	M_1'	S_1	S_1'	V_1	V_1'	M_2	M_2'	S_2	S_2'	V_2	V_2'	M_3	M_3'	S_3	S_3'	V_3	V_3'	P	
-6	-3	0	0	-900	-225	$+6\times\frac{2}{3}$ +12	$+3\times\frac{2}{3}$ +7	-900	-500	$+900\times\frac{2}{3}$ +2100	$+225\times\frac{2}{3}$ +825	$-6\times\frac{2}{3}$	$3\times\frac{2}{3}$	$+600\times\frac{2}{3}$	$+300\times\frac{2}{3}$	$-900\times\frac{2}{3}$	$-225\times\frac{2}{3}$	-400	=0
-3	-3	0	0	-675	-225	$+3\times\frac{2}{3}$ +7	$+3\times\frac{2}{3}$ +9	-500	-600	$+675\times\frac{2}{3}$ +1875	$+225\times\frac{2}{3}$ +825	$-3\times\frac{2}{3}$	$3\times\frac{2}{3}$	$+300\times\frac{2}{3}$	$+300\times\frac{2}{3}$	$-675\times\frac{2}{3}$	$-225\times\frac{2}{3}$	-400	=0
+6	+3	0	0	-900	+225	-9	-5	-800	+433.3	-1500	-525	0	0	0	0	0	0	+166.66	=0
+3	+3	0	0	+675	+225	-5	-6	-433.33	-500	-1275	-525	0	0	0	0	0	0	+166.66	=0
-9	-6.75	0	0	-1800	-562.5	$+9\times\frac{2}{3}$ +21	$+6.75\times\frac{2}{3}$ +18.75	-1500	-1275	+.21125 $+1800\times\frac{2}{3}$ +5400	$+562.5\times\frac{2}{3}$ +2382.5	$-9\times\frac{2}{3}$	$-6.75\times\frac{2}{3}$	$+900\times\frac{2}{3}$	$+675\times\frac{2}{3}$	$-1800\times\frac{2}{3}$	$-562.5\times\frac{2}{3}$	-1200	=0
-2.25	-2.25	0	0	-562.5	-225	$+2.25\times\frac{2}{3}$ +8.25	$+2.25\times\frac{2}{3}$ +8.25	-525	-525	$+562.5\times\frac{2}{3}$ +2362.5	+.21125 $+225\times\frac{2}{3}$ +1125	$-2.25\times\frac{2}{3}$	$-2.25\times\frac{2}{3}$	$+225\times\frac{2}{3}$	$+225\times\frac{2}{3}$	$-562.5\times\frac{2}{3}$	$-225\times\frac{2}{3}$	-600	=0

M_2	M_2'	S_2	S_2'	V_2	V_2'	M_3	M_3'	S_3	S_3'	V_3	V_3'	M_4	M_4'	S_4	S_4'	V_4	V_4'	P	
-6	-3	0	0	-900	-225	$+6\times\frac{3}{4}$ +12	$+3\times\frac{3}{4}$ -7	-900	-500	$+900\times\frac{3}{4}$ +2100	$+225\times\frac{3}{4}$ +825	$-6\times\frac{3}{4}$	$-3\times\frac{3}{4}$	$-600\times\frac{3}{4}$	$+300\times\frac{3}{4}$	$-900\times\frac{3}{4}$	$-225\times\frac{3}{4}$	-900	=0
-3	-3	0	0	-675	-225	$+3\times\frac{3}{4}$ +7	$+3\times\frac{3}{4}$ +9	-500	-600	$+675\times\frac{3}{4}$ +1875	$+225\times\frac{3}{4}$ +825	$-3\times\frac{3}{4}$	$-3\times\frac{3}{4}$	$+300\times\frac{3}{4}$	$+300\times\frac{3}{4}$	$-675\times\frac{3}{4}$	$-225\times\frac{3}{4}$	-900	=0
+6	+3	0	0	-900	-225	-9	-5	-800	+433.3	-1500	-525	0	0	0	0	0	0	+400	=0
+3	+3	0	0	-675	+225	-5	-6	-433.33	+500	-1275	-525	Q	0	0	0	0	0	+400	=0
-9	-6.75	0	0	-1800	-562.5	$+9\times\frac{3}{4}$ +21	$+6.75\times\frac{3}{4}$ +18.75	-1500	-1275	+.245 $+1800\times\frac{3}{4}$ +5400	$+562.5\times\frac{3}{4}$ +2362.5	$-9\times\frac{3}{4}$	$-675\times\frac{3}{4}$	$+900\times\frac{3}{4}$	$+675\times\frac{3}{4}$	$-1800\times\frac{3}{4}$	$-562.5\times\frac{3}{4}$	-2700	=0
-2.25	-2.25	0	0	-562.5	-225	$+2.25\times\frac{3}{4}$ +8.25	$+2.25\times\frac{3}{4}$ +8.25	-525	-525	$+562.5\times\frac{3}{4}$ +2362.5	+.245 $+225\times\frac{3}{4}$ +1125	$-2.25\times\frac{4}{5}$	$-2.25\times\frac{3}{4}$	$+225\times\frac{3}{4}$	$+225\times\frac{3}{4}$	$-5625\times\frac{3}{4}$	$-225\times\frac{3}{4}$	-1350	=0

M_3	M_3'	S_3	S_3'	V_3	V_3'	M_4	M_4	S_4	S_4'	V_4	V_4'	M_5	M_5'	S_5	S_5'	V_5	V_5'	P	
-6	-3	0	0	-900	-225	$+6\times\frac{3}{4}$ +12	$+3\times\frac{4}{8}$ -7	-900	-500	$+900\times\frac{4}{5}$ +2100	$+225\times\frac{4}{5}$ +825	$-6\times\frac{4}{5}$	$-3\times\frac{4}{5}$	$+600\times\frac{4}{5}$	$+300\times\frac{4}{5}$	$-900\times\frac{4}{5}$	$-225\times\frac{4}{5}$	-1600	=0
-3	-3	0	0	-675	-225	$+3\times\frac{3}{4}$ +7	$+3\times\frac{4}{5}$ +9	-500	-600	$+675\times\frac{4}{5}$ +1875	$+225\times\frac{4}{5}$ +825	$-3\times\frac{4}{5}$	$-3\times\frac{4}{5}$	$+300\times\frac{4}{5}$	$+300\times\frac{4}{5}$	$-675\times\frac{4}{5}$	$-225\times\frac{4}{5}$	-1600	=0
+6	+3	0	0	-900	-225	-9	-5	-800	+433.3	-1500	-525	0	$0\times\frac{4}{5}$	0	0	0	0	+733.33	=0
+3	+3	0	0	-675	+225	-5	-6	-433.33	+500	-1275	-525	0	0	0	0	0	0	+733.33	=0
-9	-6.75	0	0	-1800	-562.5	$+9\times\frac{3}{4}$ +21	$+6.75\times\frac{4}{5}$ +18.75	-1500	-1275	+.28125 $+1800\times\frac{4}{5}$ +5400	$+562.5\times\frac{4}{5}$ +2362.5	$-9\times\frac{4}{5}$	$-6.75\times\frac{4}{5}$	$+900\times\frac{4}{5}$	$675\times\frac{4}{5}$	$-1800\times\frac{4}{5}$	$562.5\times\frac{4}{5}$	-4800	=0
-2.25	-2.25	0	0	-562.5	-225	$+2.25\times\frac{3}{4}$ +8.25	$+2.25\times\frac{4}{5}$ +8.25	-525	-525	$+562.5\times\frac{4}{5}$ +2362.5	+.28125 $+225\times\frac{4}{5}$ +1125	$-2.25\times\frac{4}{5}$	$-2.25\times\frac{4}{5}$	$+225\times\frac{4}{5}$	$+225\times\frac{4}{5}$	$-562.5\times\frac{4}{5}$	$-225\times\frac{4}{5}$	-2400	=0

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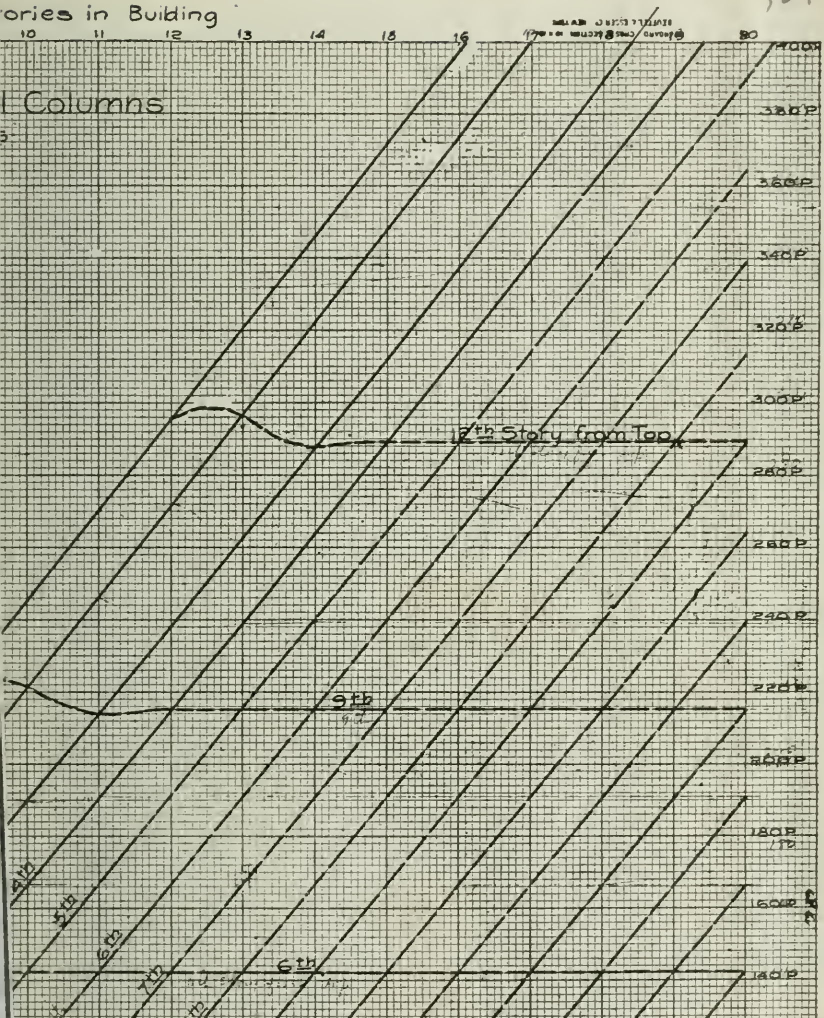
Plate II.



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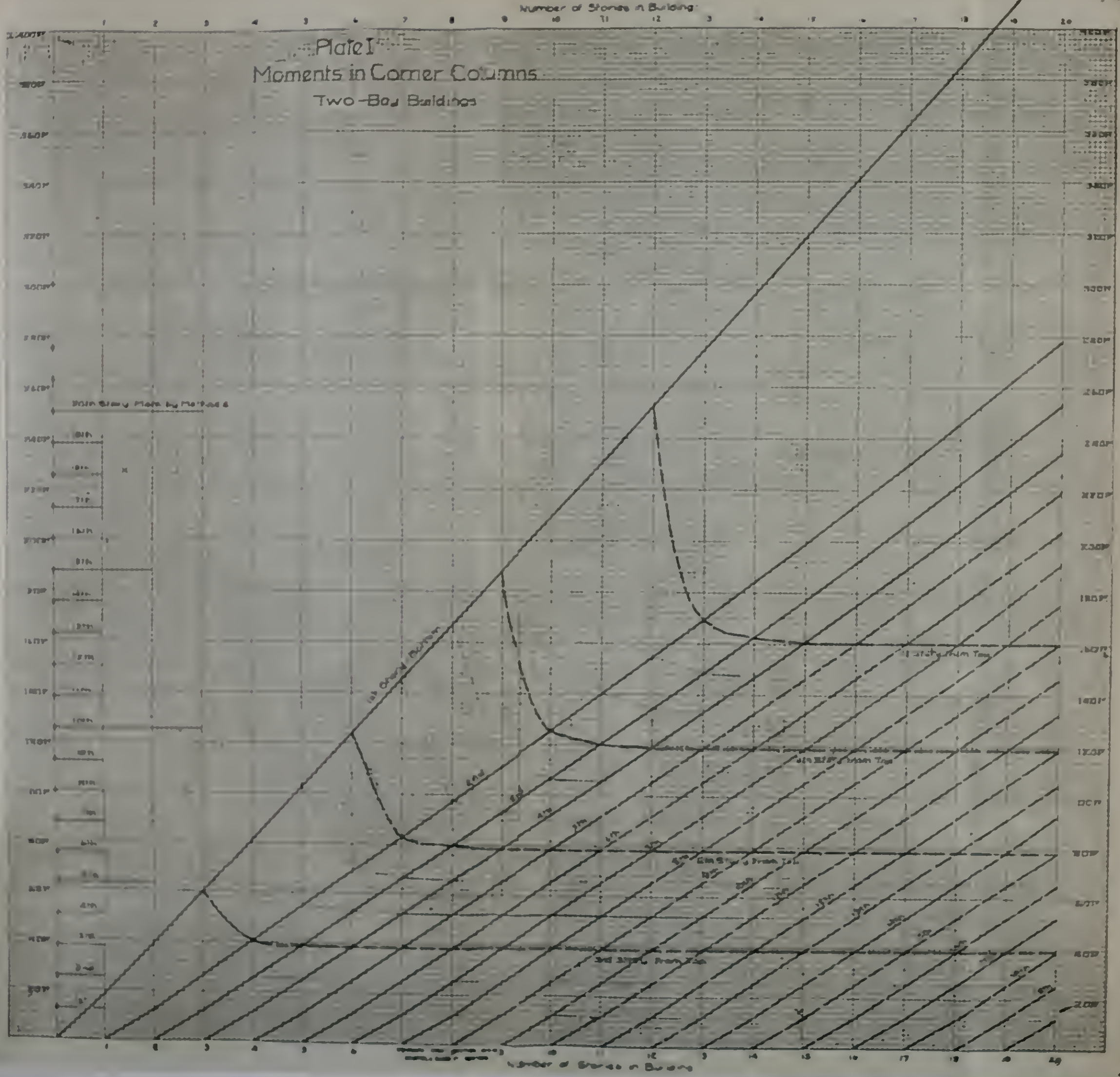
Number of Stories in Building
Plate I
Moments in Corner Columns
Two-Bay Buildings
1st Story Bottom
2nd
3rd
3rd Story From Top
6th Story From Top
9th Story From Top
12 Story From Top
Number of Stories in Building

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Plate III.

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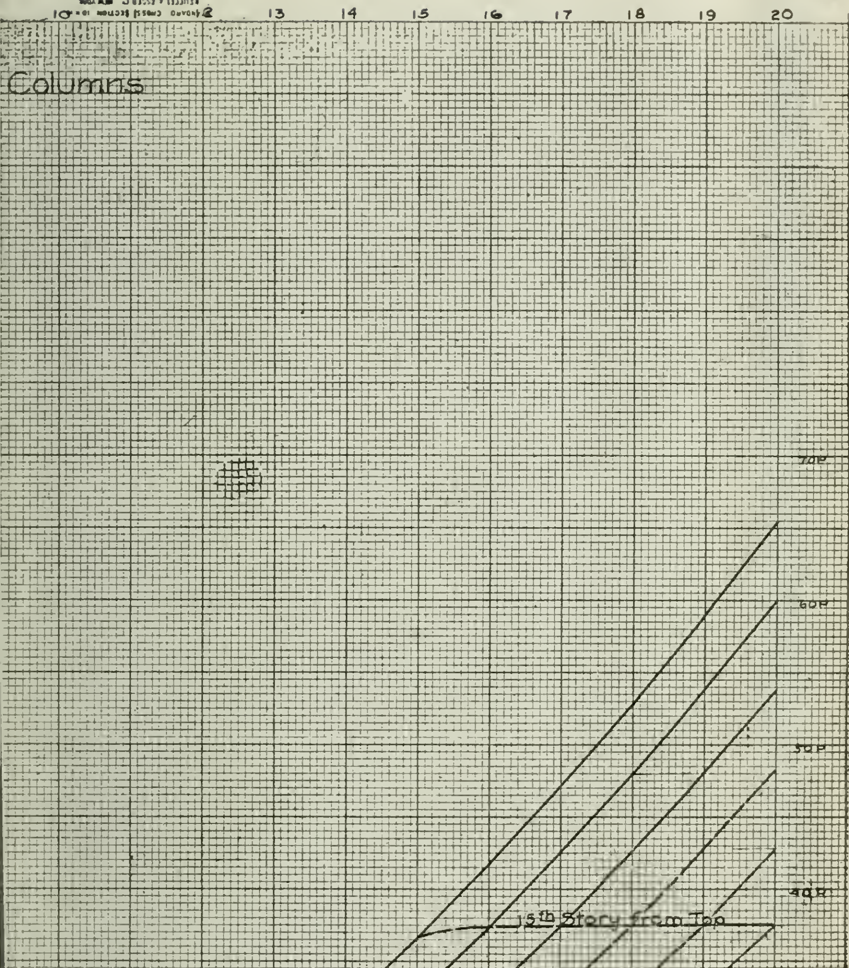

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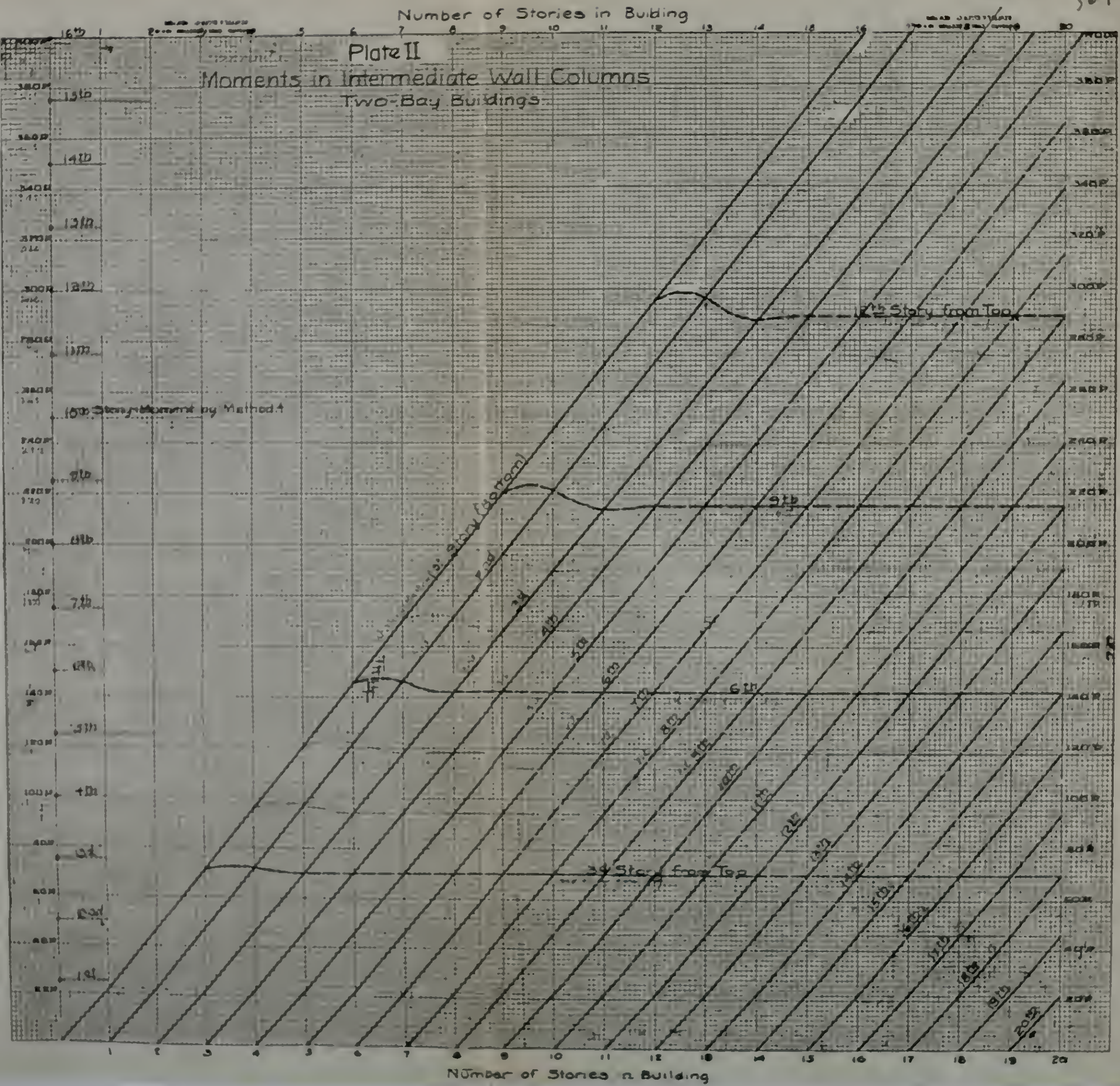
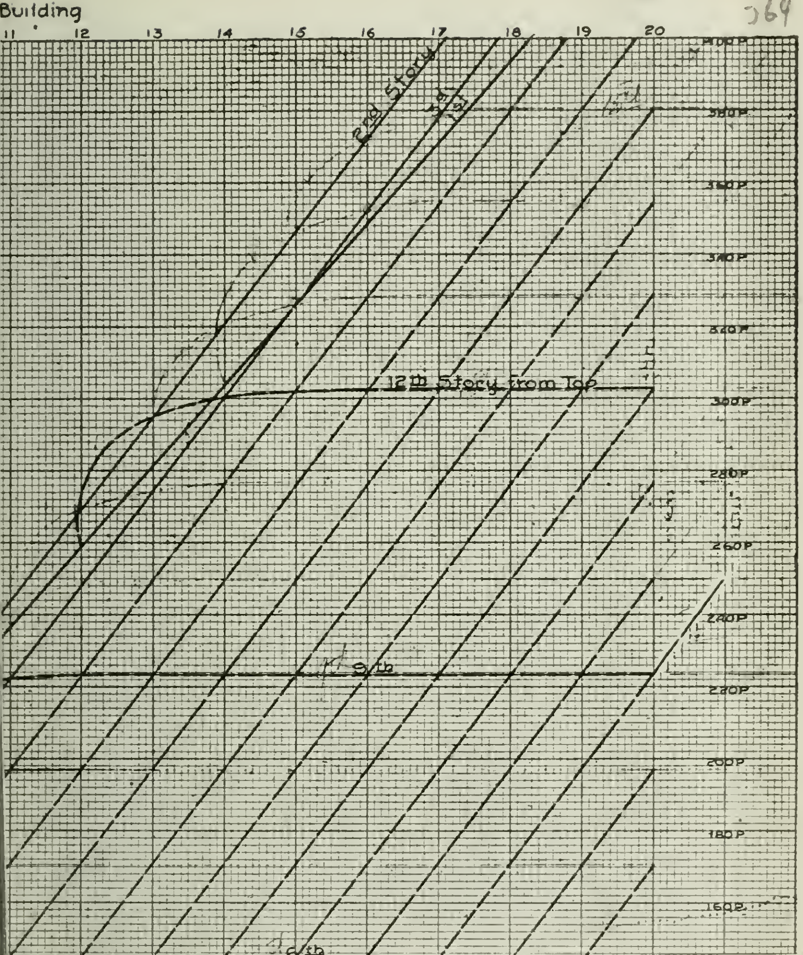

Number of Stories in Building
Plate II
Moments in Intermediate Wall Columns
Two-Bay Buildings
12th Story from Top
9th
6th
3d Story from Top
1st Story (Bottom)
2nd
3d
4th
5th
6th
7th
8th
9th
10th
11th
12th
13th
14th
15th
16th
17th
18th
19th
20th
Story Moment by Method 4
Number of Stories in Building

Plate IV.



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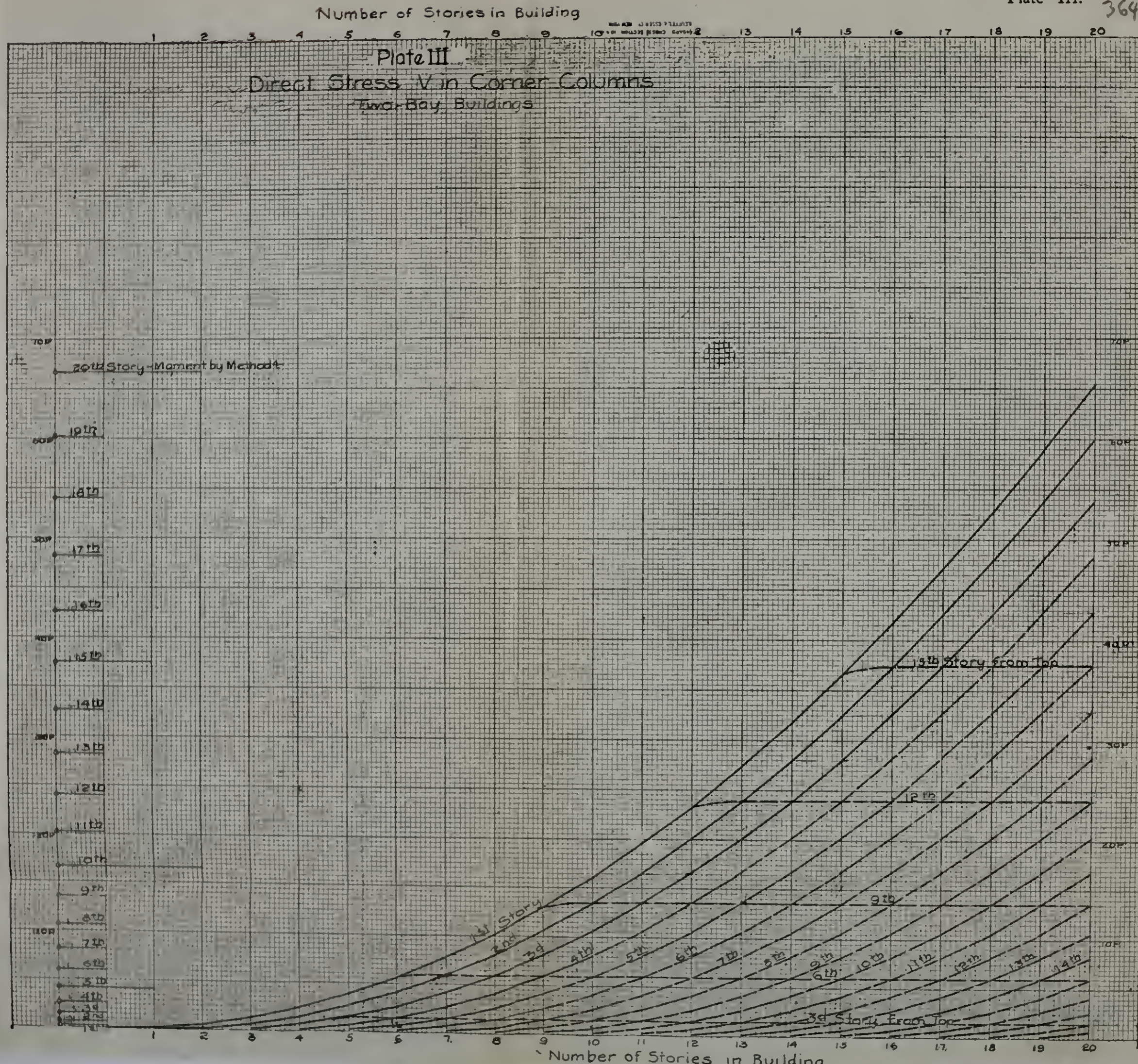

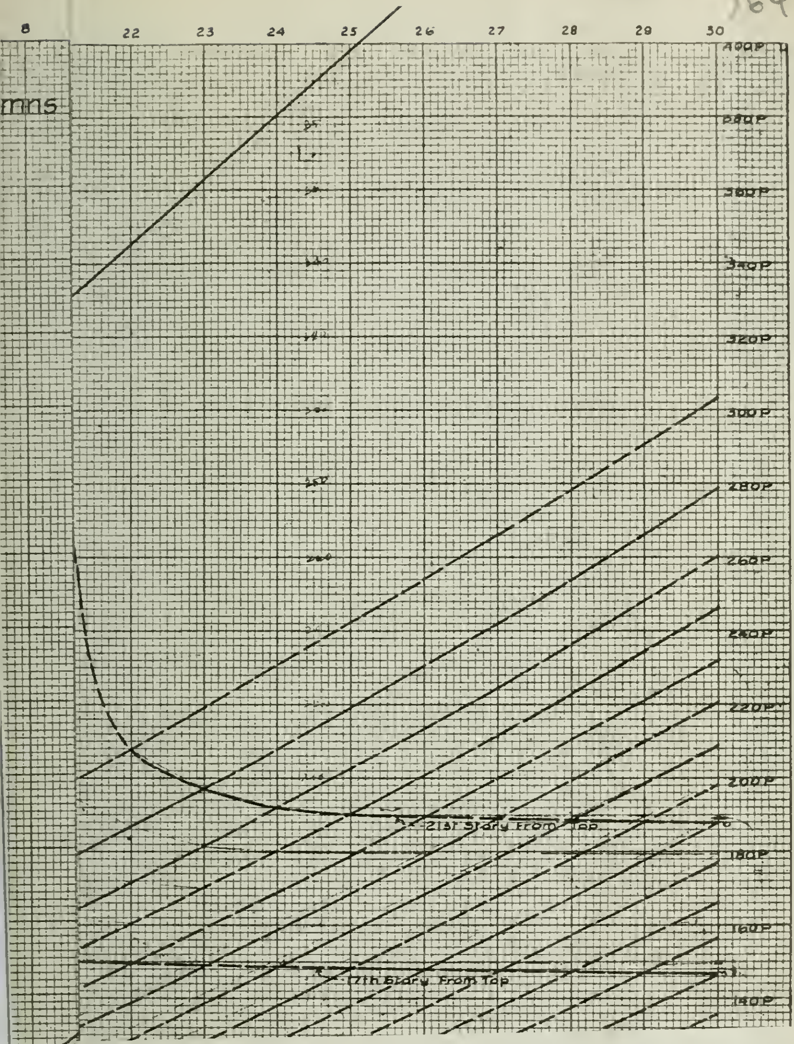

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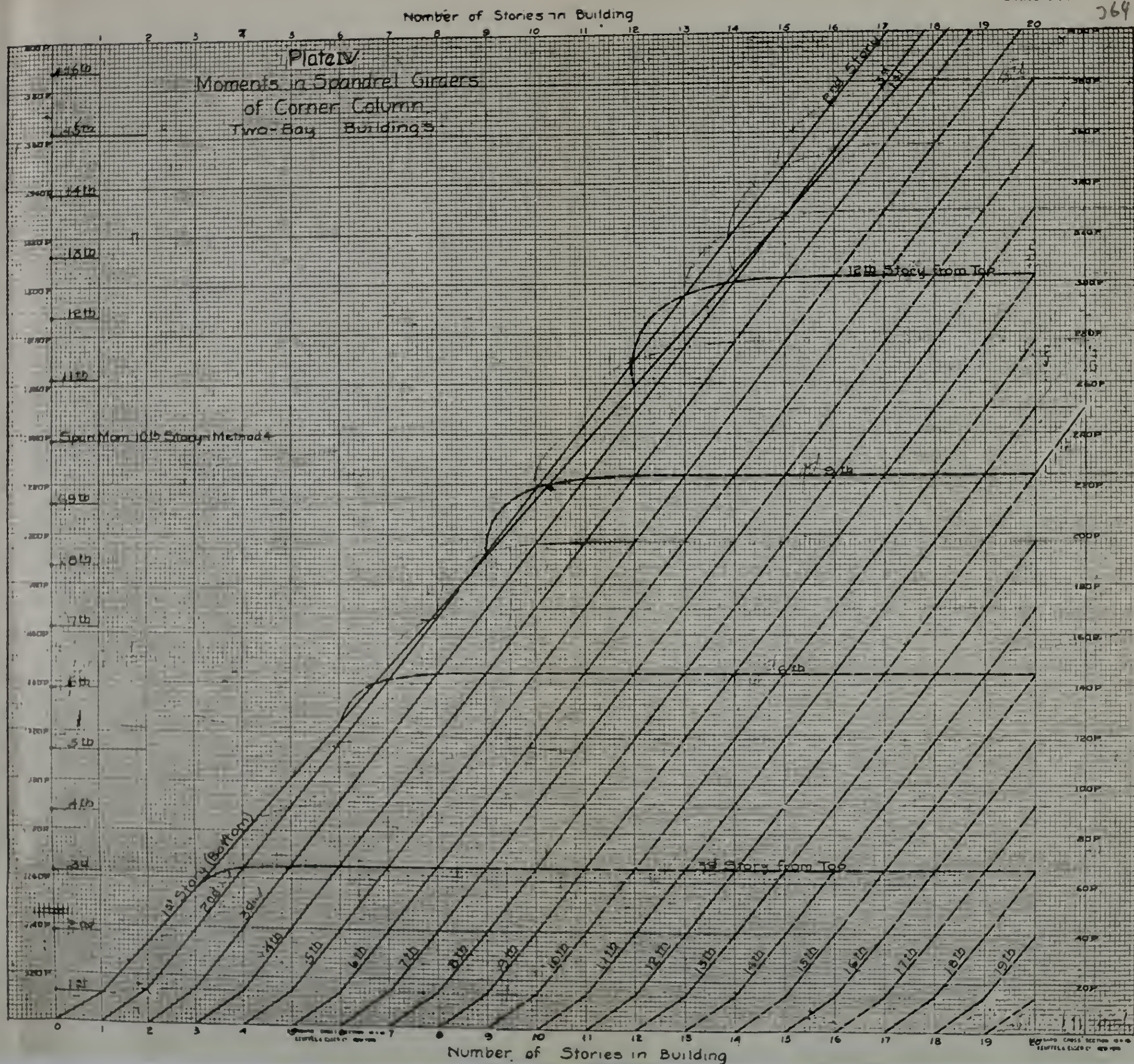
Plate IV
Moments in Spandrel Girders of Corner Column
Two-Bay Buildings
Number of Stories in Building
12th Story from Top
9th
6th
3d Story from Top
1st Story (Bottom)
Span Mom 10th Story Method 4
Number of Stories in Building

10
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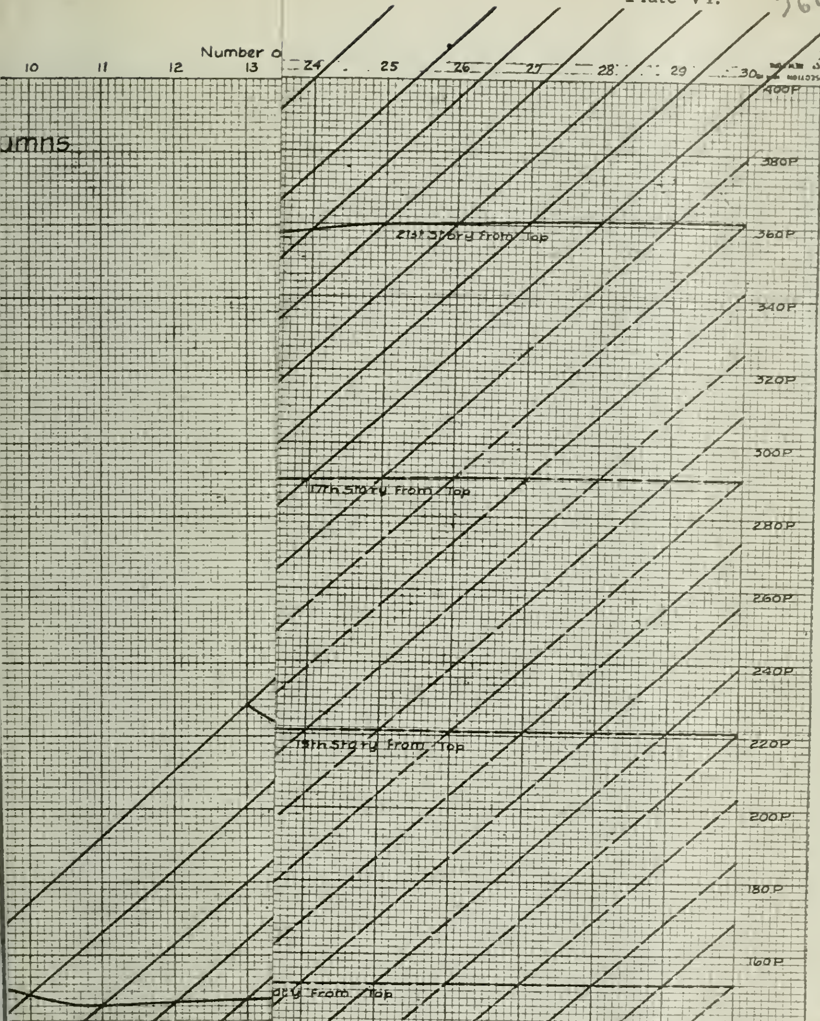

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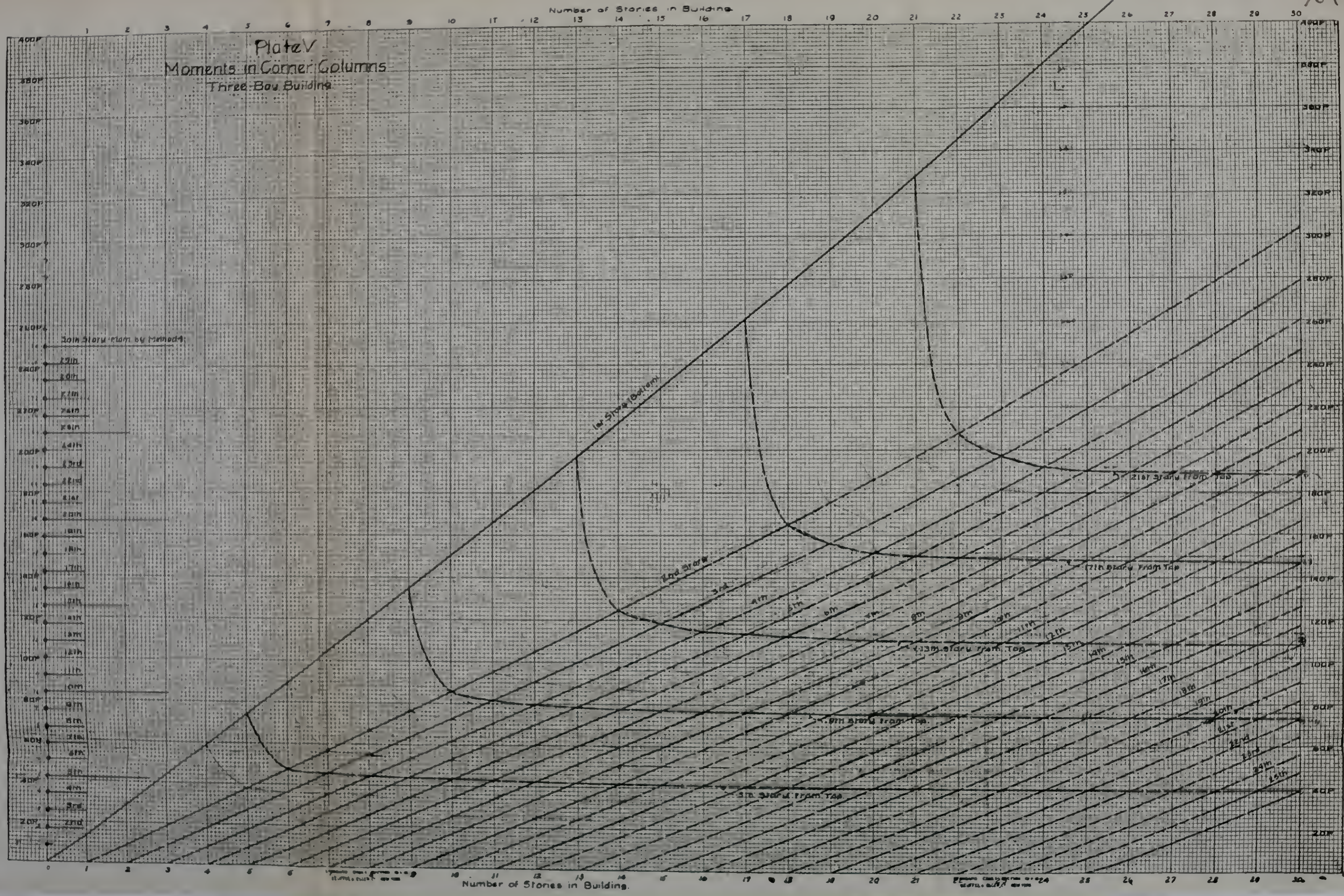

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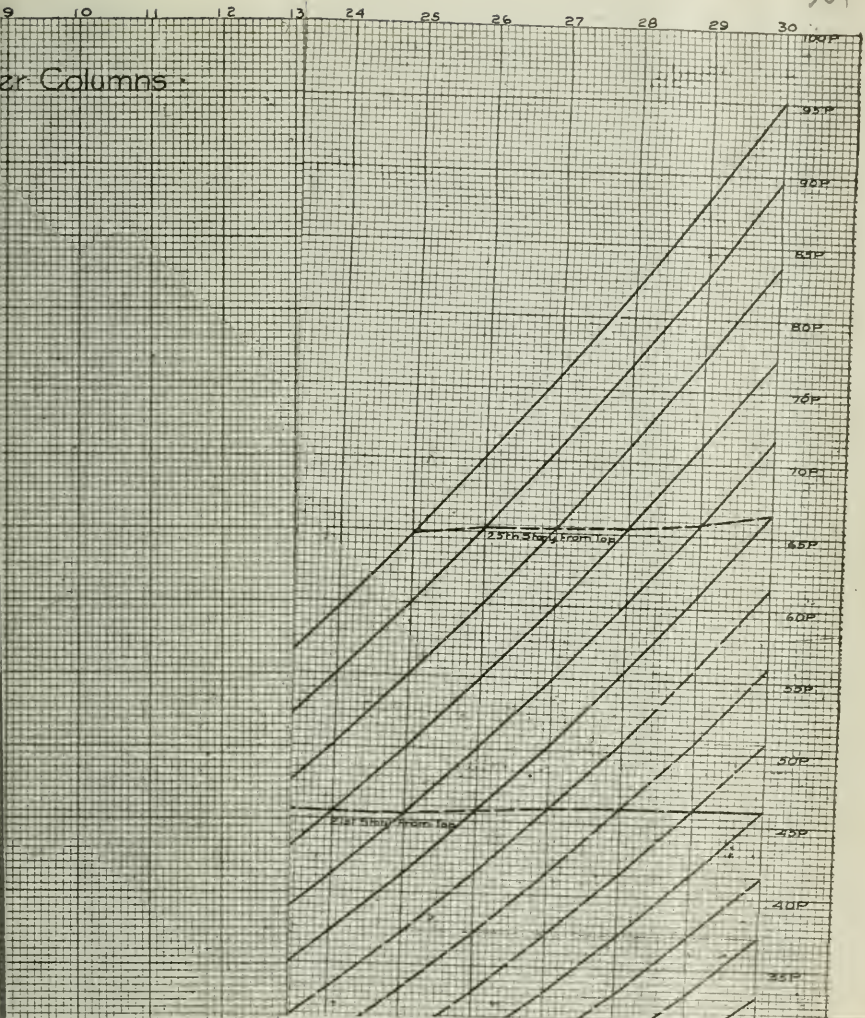

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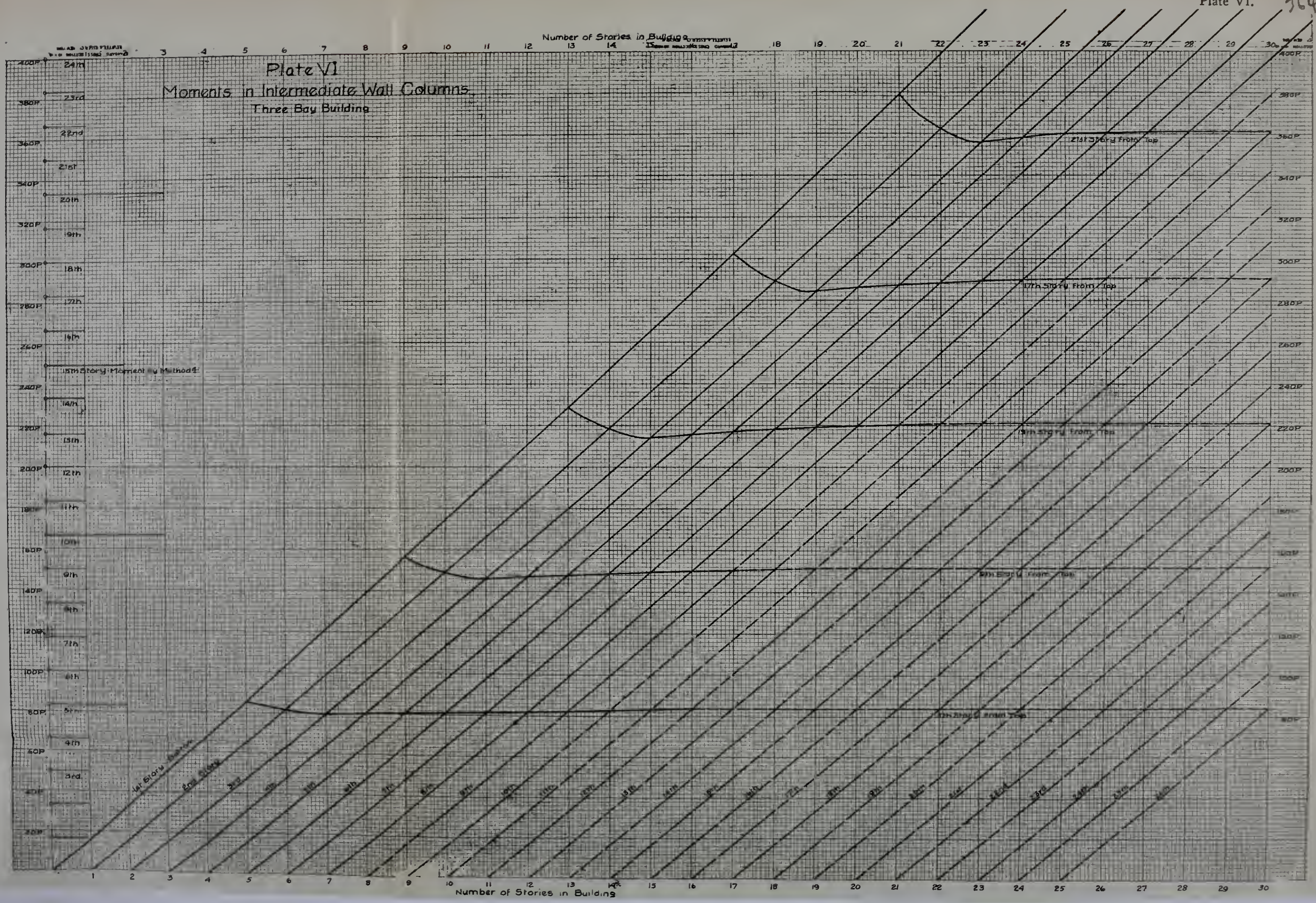
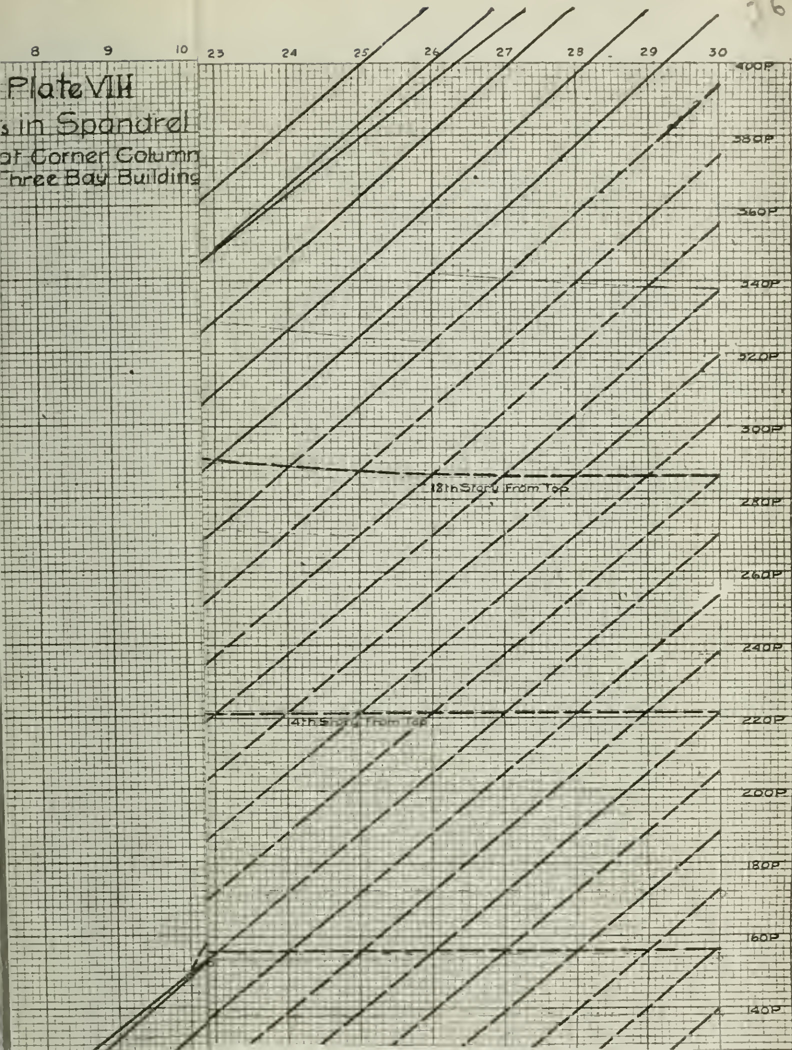
Plate VI.





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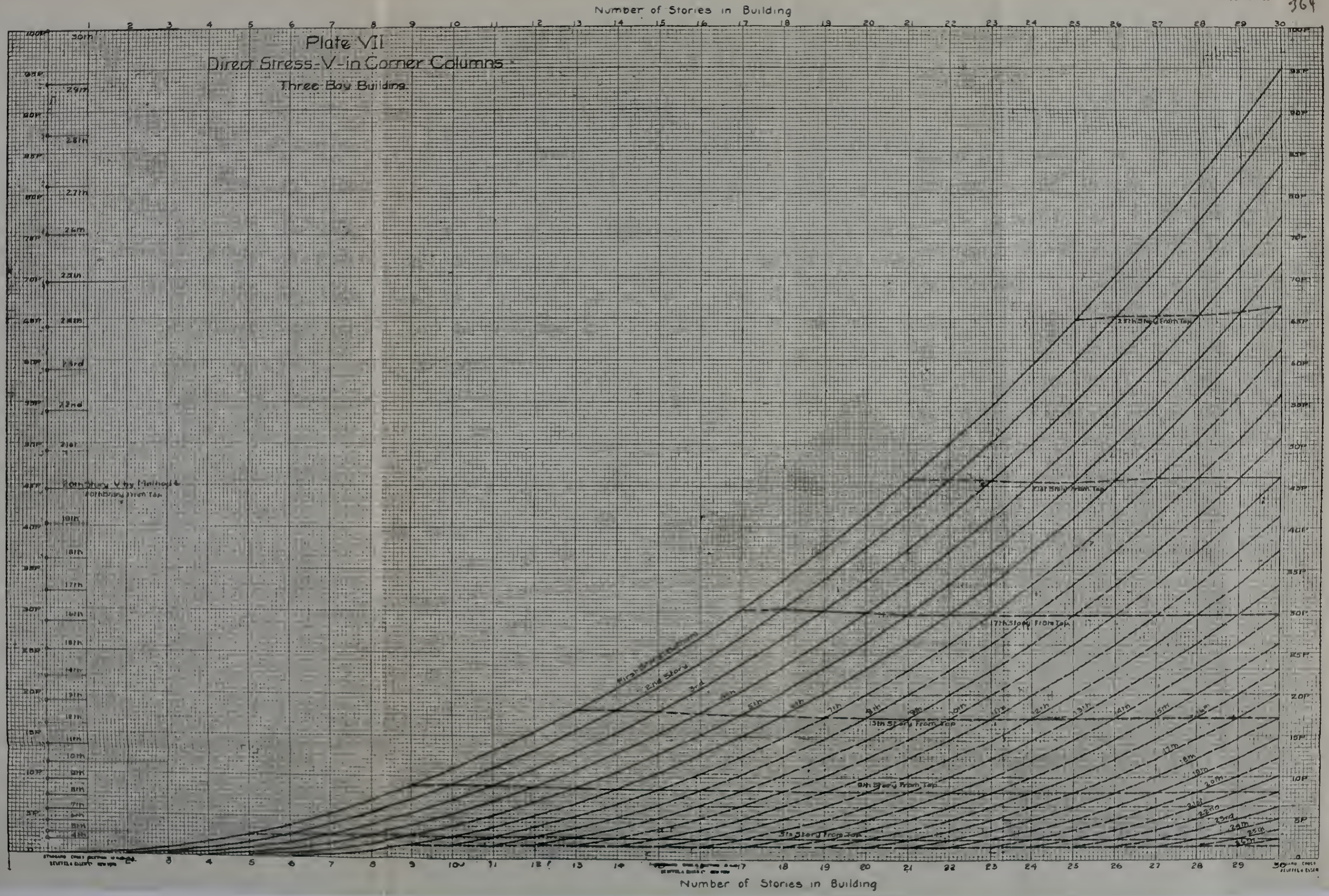

WIND STRESSES IN THE STEEL FRAMES OF OFFICE BUILDINGS.

Second Paper by Prof. Wilson.*

I. INTRODUCTION.

1. Preliminary.—The writer has just presented to the Director of the Engineering Experiment Station of the College of Engineering of the University of Ilinois, an article bearing the above title for publication as a bulletin. This paper is an outline of the work described in the bulletin† and a summary of the results.

2. Acknowledgment.—While making the investigation, which is described below, the writer was assisted by Mr. G. A. Maney and his name will appear as a joint author of the original article.

II. ASSUMPTIONS UPON WHICH THE ANALYSIS IS BASED.

3. Statement of Assumptions.—The proposed analysis is based upon the following assumptions.

1. The connections between the columns and girders are perfectly rigid.
2. The change in length of a member due to the direct stress is equal to zero.
3. The length of a girder is the distance between the neutral axes of the columns which it connects; and the length of a column is the distance between the neutral axes of the girders which it connects.
4. The deflection of a member due to internal shearing stresses is equal to zero.
5. The wind load is resisted entirely by the steel frame.

III. FUNDAMENTAL EQUATIONS.

4. Fundamental Proposition.—The fundamental equation used in this analysis is based upon the following proposition:

When a beam is subjected to flexture, the deflection of any point in the neutral axis from the tangent to the elastic curve at any other point, is equal to the moment of the area of the $\frac{M}{EI}$ *diagram for the portion of the beam between the two points, about the point where the deflection is measured.*

The proof of this proposition has appeared recently in the tech-

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†Bulletin No. 80 of the Engineering Experiment Station of the University of Illinois.

nical press and is given in a number of text books on mechanics and therefore need not be repeated here.

5. Fundamental Equation.—By applying the above proposition, it can be proven that for any portion AB of a member subjected to flexure and not acted upon by intermediate forces.

$$M_{AB} = 2\,E\,K\,(2\,\Theta_A + \Theta_B - 3\,R) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (A)$$

in which

M_{AB} = moment at A.

E = modulus of elasticity.

K = the length of a member divided by the moment of inertia of its section.

Θ_A = change in the slope of the tangent to the elastic curve at the end A.

Θ_B = change in the slope of the tangent to the elastic curve at the end B.

R = ratio of the deflection of the point A, to the length of the member A B.

When the deflection is equal to zero, equation A becomes

$$M_{AB} = 2\,EK\,(2\,\Theta_A + \Theta_B) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (B)$$

It can be proven that equation (A) is general and may be applied to any length of any member in bending provided the length considered has no intermediate external force applied to it. That is, one or more of the quantities Θ_A, Θ_B, and R may be negative, and equation (A) will still give the moment of the point A in both magnitude and sign. Equation (A) is the fundamental equation upon which the analysis which follows is based. Equation (B) is a special form of equation (A). Equation (A) may be expressed as follows:

The moment at an end of any member is equal to 2 EK times the quantity; two times the change in the slope at the rear end plus the change in the slope at the far end minus three times the deflection of theend divided by the length. E is the modulus of elasticity of the material and K is the ratio of the moment of inertia to the length of the member.

The signs of the quantities in equation (A) are determined as follows:

The change in slope, or angular deformation, is positive (+) when the tangent to the elastic curve of the member is turned in a clockwise direction.

Distances and deflections are positive when they are measured in the same direction from the base line as are positive slopes.

The moment at the end where the deflection is measured is positive (+) when it produces a positive change in the slope of the tangent to the elastic curve.

IV. OUTLINE OF METHOD.

6. Outline of Method.—In making an analysis of the stresses, the writer made certain assumptions and applied certain funda-

mental principles of mechanics and obtained equations by means of which the stresses in a frame can be determined. The assumptions which have been made are given in Section II and the method of deriving equations is given in Section V.

It can be proven that the moment at an end of a member of a frame is a function of the changes in slope of the tangents to the elastic curve of the member at its ends and of the deflection of that end of the member relative to the other end (see equation A, page 366.

In the strained position, all the columns and girders which intersect at one point have been subjected to the same change in slope (see assumption 1, Section II), the vertical deflections of the ends of all girders are equal to zero and the horizontal deflections of the tops of all columns of a story are equal (see assumption 2, Section II).

Consider any story of a bent. Take the point of intersection of the neutral axes of a column and of a girder as a free body. It is in equilibrium under the action of the moment at the extremities of the columns and girders which intersect at the point. Each of the moments may be expressed in terms of the changes in slope and the deflections at the extremities of the member. A moment equation can therefore be written for any point where columns and girders intersect, and the only unknown quantities will be the changes in slope at the extremities of the columns and the horizontal deflection of the columns in a story height.

If all the columns of a story be taken together as a free body, the sum of the moments at the two extremities of all the columns will be balanced by a couple whose moment is equal to the total shear on the story multiplied by the story height. The moment in the columns may be expressed in terms of the changes in slope and the deflections at their extremities, the same as in the previous equations, and the shear and the height of the story are known.

It is therefore possible to write as many equations for each story as there are columns in the story, plus one. As the only unknown quantities in these equations are the changes in slope at the extremities of the columns and the deflection in a story common to all columns, there are as many equations per story as there are unknowns. By solving these equations the slopes and deflections can be determined. Knowing the slopes and the deflections, the moments can be determined by the use of equations A and B.

The product of the shear on a member and its length is equal to the algebraic sum of the moments at the extremities of the member. Since the moments and the length of the member are known the shear can be computed.

With the shears in the girders known, the direct stress in any column can be determined by taking the column as a free body and equating the sum of the vertical forces equal to zero.

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The direct stress in a girder can be determined in a similar manner.

V. GENERAL EQUATIONS.

7. Notation.—The following notation has been used.

A, B, C, etc., = the columns of a bent, beginning at the right and reading toward the left.

a, b, c, etc., = the bays of a bent, beginning at the right and reading toward the left. The girder in bay a is designated as girder a, in bay b as girder b, in bay c as girder c, etc.

A_1, A_2, A_3, etc., = the intersections of the neutral axes of the girders at the tops of the 1st, 2nd, 3rd, etc., stories with the neutral axis of column A.

B_1, B_2, B_3, etc., = the intersections of the neutral axes of the girders at the tops of the 1st, 2nd, 3rd, etc., stories with the neutral axis of column B.

d = deflection of the columns in a story height.

E = modulus of elasticity of the material.

h = length of a column measured from neutral axis to neutral axis of the girders.

I = moment of inertia of the girder and column sections.

$J = 2\sum\left(\frac{I}{l} + \frac{I}{h}\right)$ for all columns and girders which intersect at a point.

$K = \frac{I}{2}$ for girders and $\frac{I}{h}$ for columns.

2 = length of a girder measured from neutral axis to neutral axis of the columns.

M = bending moment.

$N = 2\Sigma \frac{I}{h}$ for all columns in a story.

$R = \frac{d}{h}$

W = total horizontal shear in a bent at any story.

θ = change in the slope of the tangent to the elastic curve.

Subscripts are added to the letters to indicate the particular part of a bent to which a given symbol applies. For example, referring to Fig. 1, girder A_2 is the girder in bay a at the top of the 2nd story, Θ_{A_1} is the change in slope of the tangent to the elastic curve at the point A_1; d_3 is the deflection of the columns in the third story; J_{B4} is the J at the point B4; K_{A_2} is the K of column A in the second story. The moment at the right end of the girder in bay a at the top of the second story is designated as M_2^{AB}, and the moment at the left end of the same girder is designated as M_2^{BA}. The moment at the top of the column B in the third story is designated as M_B^{32}, and the moment at the bottom of the same column is designated as M_B^{23}.

8. Derivation of Equations.—Consider a symmetrical three-span bent any number of stories high. It is required to derive the equations for determining the stresses in the bent.

Consider the columns of the third story acting together as a free body. (Any other story could have been used.) The algebraic sum of all of the moments at the tops and the bottoms of all of the columns plus the product of the total shear in the story and the story height, is equal to zero.

That is, $2\,[M_A^{32} + M_A^{23} + M_B^{32} + M_B^{23}] + W_3\, h_3 = 0$

Substituting the values of the moments as given by equation

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$= \frac{I}{l}$ for girders and $\frac{I}{h}$ for columns.

length of a girder measured from neutral axis to neutral axis of the columns.

be written for a bent as there are unknowns to be determined. It is possible to solve these equations for the unknown quantities algebraically, but the large number of equations involved makes the work very difficult. It is simpler to substitute the numerical values of the coefficients in the equations and solve for the numerical values of the unknown quantities.

VI. SOLUTION OF A NUMERICAL PROBLEM.

9. Determination of the Stresses in a Symmetrical Three-Span Twenty-Story Bent.—Figure 1 shows a symmetrical three-span bent twenty stories high. The bent resists a horizontal wind load of 30 lbs. per sq. ft. on a vertical strip one foot wide. It is required to find the moment and shear in the columns and girders and the direct stress in the columns.

The properties of the girder and column sections are shown in Table 1 (insert). Equations similar to equation 1, 2, and 3 of

Wind Load due to a Pressure of 30 lb per sq ft acting on a Vertical Strip 1 ft Wide: Increment on Story = w	Total on all Stories Above = W	Story No
360	360	20
360	720	19
360	1080	18
360	1440	17
360	1800	16
360	2160	15
360	2520	14
360	2880	13
360	3240	12
360	3600	11
360	3960	10
360	4320	9
360	4680	8
360	5040	7
390	5430	6
420	5850	5
420	6270	4
420	6690	3
450	7140	2
570	7710	1

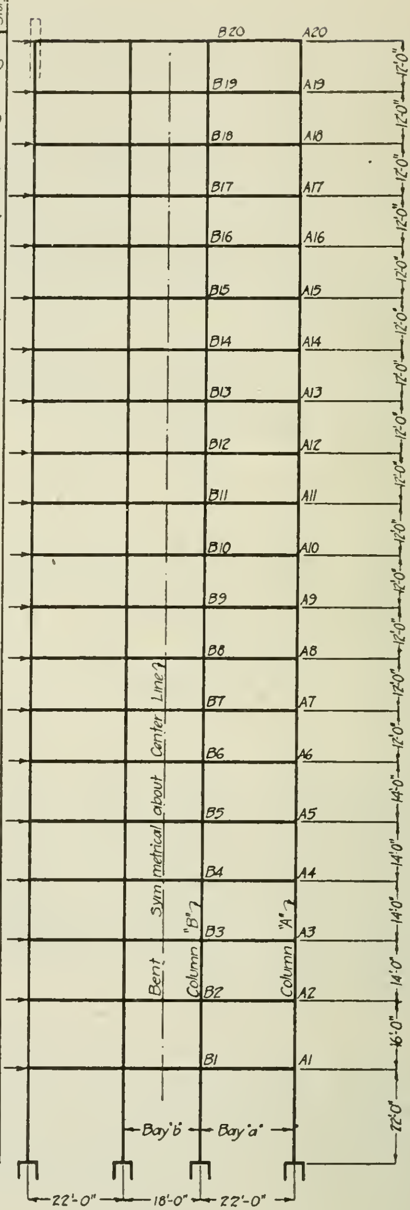

FIGURE 1.
SYMMETRICAL THREE-SPAN BENT
TWENTY STORIES HIGH.

Section V were written for each of the twenty stories of the bent and the resulting sixty equations were used to obtain the forty unknown slopes and the twenty unknown deflections in the bent. Knowing the slopes and the deflections, the moments were determined by the use of equations A and B of Section III. Knowing the moments, the shears and direct stresses were determined by the application of the fundamental principles of static equilibrium.

The moments at the ends of the columns and girders of the bent shown in Fig. 1, as determined by the above method, are given in Table II.

VII. TEST OF CELLULOID MODEL.

10. Description of Test.—In order to check the changes in the slopes and the deflections in a bent as calculated by the slope-

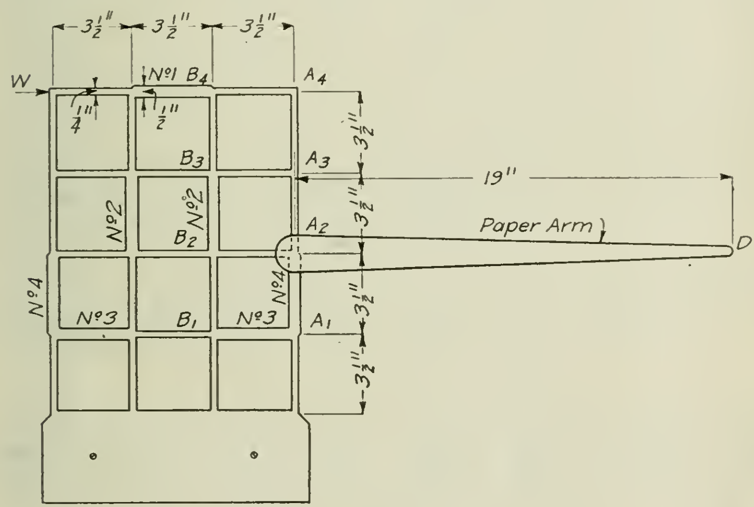

Fig. 2. Celluloid Model.

deflection method, a celluloid model of a bent was subjected to known shears and the resulting changes in slope and the deflections, as measured, were compared with the calculated values of the same quantities. The model was made of celluloid ⅛ in. thick and had the general dimensions shown in Fig. 2. A cord passing over a pulley and attached to a weight at one end and to the top of the model at the other end produced a uniform shear in all stories. Paper arms were fastened to the model at points where the members intersect. The movement of these arms indicated the changes in the slopes. One of these arms, A_2D, is shown in the figure. The shear caused the point A_2 to move in approximately a horizontal line and at the same time to turn through a small angle, Θ. The paper arm

A_2D has the same motion as the point A_2 and the vertical displacement of D measures the angle Θ. The horizontal deflection of the model was obtained by measuring the displacement of a point at the middle of a girder. Paper arms were attached to all four columns at the tops of all stories simultaneously so that the changes in the

TABLE II

Moments at the Ends of the Columns and Girders of the Symmetrical Three-Span Twenty-Story Bent Shown in Figure 1.

Moments are expressed in in. lb.

No. of Story	Moment at the Top of Column A	Moment at the Bottom of Column A	Moment at the Top of Column B	Moment at the Bottom of Column B	Moment at the right End of the Girder at the Top of the Story in Bay A	Moment at the Left End of the Girder at the Top of the Story in Bay A	Moment at the Right End of the Girder at the Top of the Story in Bay B
1	178 800	272 000	251 000	308 200	287 800	245 000	247 500
2	113 000	107 500	226 500	239 000	203 000	184 000	226 000
3	100 300	90 700	187 500	182 000	187 100	171 700	189 600
4	87 800	87 800	176 100	173 500	170 500	153 600	184 400
5	84 500	82 800	162 300	162 000	167 700	152 000	166 000
6	75 000	83 200	143 300	155 700	135 000	125 600	141 500
7	57 600	60 000	122 000	124 000	125 900	117 000	132 500
8	44 400	67 700	97 200	127 500	95 800	92 000	107 800
9	52 550	51 900	104 200	103 300	95 000	91 100	106 800
10	46 500	42 400	102 000	94 200	89 600	85 000	98 500
11	47 500	41 500	89 000	81 200	81 900	76 600	77 500
12	41 400	34 100	81 500	75 100	73 400	68 600	78 300
13	38 300	31 700	71 800	65 600	65 300	60 800	69 100
14	33 700	26 900	65 100	58 900	5 700	52 800	59 600
15	29 420	24 300	53 600	48 350	48 700	49 600	49 600
16	24 450	18 450	45 400	40 600	39 700	36 400	40 500
17	20 450	15 400	35 800	31 400	31 000	28 200	31 100
18	15 920	10 430	27 600	23 400	22 100	20 150	22 300
19	11 680	6 240	18 900	14 930	13 380	12 250	13 650
20	6 150	1 750	10 830	7 040	6 110	5 320	5 530

slopes at all intersections were measured for each application of the load. Similarly, the horizontal deflection was measured at the middle of each girder at the top of each story.

In the original model, known as model No. 1, members No.

1, 2, 3, and 4 were ½ in. wide; all other members were ¼ in. wide. After this model had been tested, member No. 1 was reduced to ¼ in. and the resulting model, now known as model No. 2, was tested. Members No. 2, 3, and 4 were successively reduced to ¼ in. and the resulting models known as models No. 3, 4, and 5 were also tested.

11. Results.—The changes in the slopes at the intersections of the members and the ratios of deflections to story height for the different stories due to a shear of 1 lb. are given in Fig. 3. Each full line in the upper part of the figure shows the measured change in the slope at the same point on all models. For example, the line at the left gives the change in slope, at the point A1 for all of the models. Similarly, each lower full line gives the ratio of the deflection to the story height for some one story for all of the models. The dotted lines give the changes in slopes and the ratios of deflections to story height as computed by the slope-deflection method.

In the computations, the length of a member was taken equal to the distance between center lines whereas the length that is actually free to bend is the distance from outside to outside of the members which it connects. This, no doubt, accounts for the fact that in general the values of the changes in the slopes and the ratios of the deflection to story height observed are less than the calculated values of the same quantities.

Fig. 3 shows that the changes in slopes and the ratios of the deflection to story height as observed and as computed, agree very closely. In other words, the tests support the theory upon which the slope-deflection method is based.

VIII. APPROXIMATE METHODS.

12. Nomenclature of Methods.—The method used in Section VI to determine the stresses in a symmetrical three-span, twenty-story bent can be used in the actual design of a building, but a shorter method is desirable. The writer proposes an approximate method which he believes is sufficiently accurate to be used in the actual design of buildings. For the sake of convenience in reference, this approximate method will be known as the "Proposed Approximate Method" as distinguished from the method used in Section VI, which will be known as the "Slope-Deflection Method."

13. Proposed Approximate Method.—The proposed approximate method is based upon the following assumptions in addition to those used in the slope-deflection method.

1. The changes in slope at the top of a column in the story above and in the story below the one in which the stresses are to be determined, are equal to the change in slope at the top of the corresponding column in the latter story.

2. The ratio of the deflection to the story height of the columns in the story above the story in which the stresses are to be deter-

mined is equal to the ratio of the deflection to the story height in the latter story.

That is, in determining the stresses in the second story, Θ_{A_1} and Θ_{A_3} are assumed to be equal to Θ_{A_2}, Θ_{B_1} and Θ_{B_3} are assumed to be equal to Θ_{B_2} and R_3 is assumed to be equal to R_2. Also, in figuring the stresses in the third story, Θ_{A_2} and Θ_{A_4} are assumed to be equal to Θ_{A_3}, Θ_{B_2} and Θ_{B_4} are assumed to be equal to Θ_{B_3}, and R_4 is assumed to be equal to R_3. This does not mean, however, that the value of Θ_{A_2}, Θ_{B_2} and R_2 used in determining the stresses in the second story are equal to the value of Θ_{A_3}, Θ_{B_3} and R_3 respectively, used in determining the stresses in the third story.

Equations 1, 2, and 3 of Section V, when written for one story, contain the changes in slope in the stories immediately above and below, and the ratio of the deflection to story height in the story immediately above the story for which the equations are written. If Assumptions 1 and 2 are accepted as true, there will be only two unknown slopes and one unknown deflection in the three equations for each story. Therefore the slopes and the deflection can be determined, and after determining these the moments, shears and direct stresses can be computed.

The sum of the moments at the tops and bottoms of all columns of a story is equal to the total shear in the story multiplied by the story height. The distribution of this moment to the ends of the columns depends upon: 1st, the ratio of K of column A to K of column B; 2nd, the ratio of K of column A to K of girder a; and 3rd, the ratio of K of girder a to K of girder b.

The distribution of the moments was determined in a number of bents for which the ratios of K of column A to K of column B, K of column A to K of girder a, and K of girder a to K of girder b had different values. Curves showing the distribution of the moments in these bents also give the distribution of the moments in other bents. The diagrams in Fig. 4, 5 and 6 show the distribution of the moment in symmetrical three-span bents. The diagrams in Fig. 4 show the portion of the total moment in a story, which acts at the top and the bottom of column A. The curves at the left of the figure give the moments in bents for which the K for column A and column B are equal. The abscissae are the ratios of K for girder a to K for girder b; and the ordinates are the moments at the top and bottom of column A in per cent of $W \times h$. The curves are for bents for which the ratio of K for column A to K for girder a equals 0.5, 1, 2, and 4, respectively. The moment in column A of a bent for which the ratio of K for column A to K for girder a has any intermediate value, can be determined by interpolation.

The groups of curves at the right of Fig. 4 give the moment at the top and bottom of column A in bents for which K for column A and K for column B are not equal. Groups I, II, III, and IV are for bents for which the ratio of the K for column

A to the K for girder a equals 4, 2, 1 and 0.5, respectively. Beginning at the left of each group and reading to the right, the curves are for bents for which the ratio of the K for column A to the K for column B equals 0.5, 1, and 2, respectively.

Similarly, the moments at the top and the bottom of column B can be obtained from Fig. 5 and the moment at the end of girder b can be obtained from Fig. 6. It should be noted, however, that the moment in girder b depends equally upon $W \times h$ in the story above and in the story below the girder. This being true, in getting the moment in girder b, the average of $W \times h$ for the two stories should be used.

The moment at the right end of girder a balances the sum of the moments in column A just above and below the girder, and is equal to their algebraic sum. The moment at the left end of girder a balances the sum of the moments at the right end of girder b together with the moments in column B just above and below girder a, and is equal to their algebraic sum. It is therefore possible to obtain the moments at the ends of all members in a bent from the diagrams in Fig. 4, 5, 6, subject, of course, to the error due to the use of assumptions 1 and 2 of this section.

The curves in Fig. 4, 5, and 6 show that a large change in the ratio of the K of one member to the K of another member causes a relatively small change in the distribution of the moments in the bent.

To illustrate further the use of these curves the solution of a problem is presented.

14. Numerical Problem.—The seventh story of a symmetrical three-span bent is 20 ft. high, and is subjected to a shear of 3,000 lbs. The eighth story of the same building is 20 ft. high, and is subjected to a shear of 2,500 lbs. The properties of the members in the seventh and eighth stories are as follows:

$K_A = 30$ in.^{3}; $K_B = 40$ in.^{3}; $K_a = 20$ in.^{3}; and $K_b = 16$ in.^{3}.

It is required to find the moment at the ends of all members in the seventh story.

$W \times h = 2500 \times 20 \times 12 = 600{,}000$ in. lb. in the eighth story.

$W \times h = 3000 \times 20 \times 12 = 720{,}000$ in. lb. in the seventh story.

$$\frac{K_A}{K_B} = \frac{30}{40} = .75$$

$$\frac{K_A}{K_a} = \frac{30}{20} = 1.5$$

$$\frac{K_a}{K_b} = \frac{20}{16} = 1.25$$

To get the moment in column A, use Fig. 4. At the left of the figure trace the ordinate whose abscissa is 1.25 to a point half way between the two middle curves $\left(\frac{K_A}{K_a}=1.5\right.$, which is half way between 1 and 2), and project this point horizontally to a point half way $\left(\frac{K_A}{K_B}=.75\right.$, which is half way between .5 and 1.00) between the two left hand curves of Group II, and also to a point half way between the two left hand curves of Group III. The abscissa of the former point is 9.35%, and of the latter point 9.15%. As $\frac{K_A}{K_a}$ is equal to 1.5 or the average of 1 and 2, the moment at the top and the bottom of column A, in the seventh story, is the average of 9.35% and 9.15% or 9.25% of $W \times h = .0925 \times 720{,}000 = 66{,}700$ in. lb. The moment at the top and the bottom of column A in the eighth story is $.0925 \times 600{,}000 = 55{,}500$ in. lb. Similarly, the moment at the top and the bottom of column B is 15.75% of $W \times h = .1575 \times 720{,}000 = 113{,}500$ in. lb. in the seventh story; and $.1575 \times 600{,}000 = 94{,}400$ in. lb. in the eighth story. The moment at the end of girder b at the top of the seventh story is 13.85% of $W \times h =$

$$.1385 \times \frac{720{,}000 + 600{,}000}{2} = 91{,}500 \text{ in lb.}$$

The moment at the right end of girder a at the top of the seventh story is equal to the sum of 66,700 in. lb., the moment at the top of column A in the seventh sory, and 55,500 in. lb., the moment at the bottom of column A in the eighth story, or 122,200 in. lb. The moment at the left end of girder a is equal to the sum of 113,500 in. lb., the moment at the top of column B in the seventh story, and 94,400 in. lb., the moment at the bottom of column B in the eighth story, less 91,500 in. lb., the moment at the end of girder b; that is the moment at the left end of girder a is 116,400 in. lb.

A comparison of the moments in a bent as obtained by the proposed approximate method and by the slope-deflection method is given in Tables III to VI, inclusive.

IX. COMPARISON OF THE APPROXIMATE METHODS WITH THE SLOPE-DEFLECTION METHOD.

15. Symmetrical Three-Span Bent with Short Middle Span.—For comparison, the moments in the symmetrical three-span twenty-story bent shown in Fig. 1, were calculated by the five following methods:

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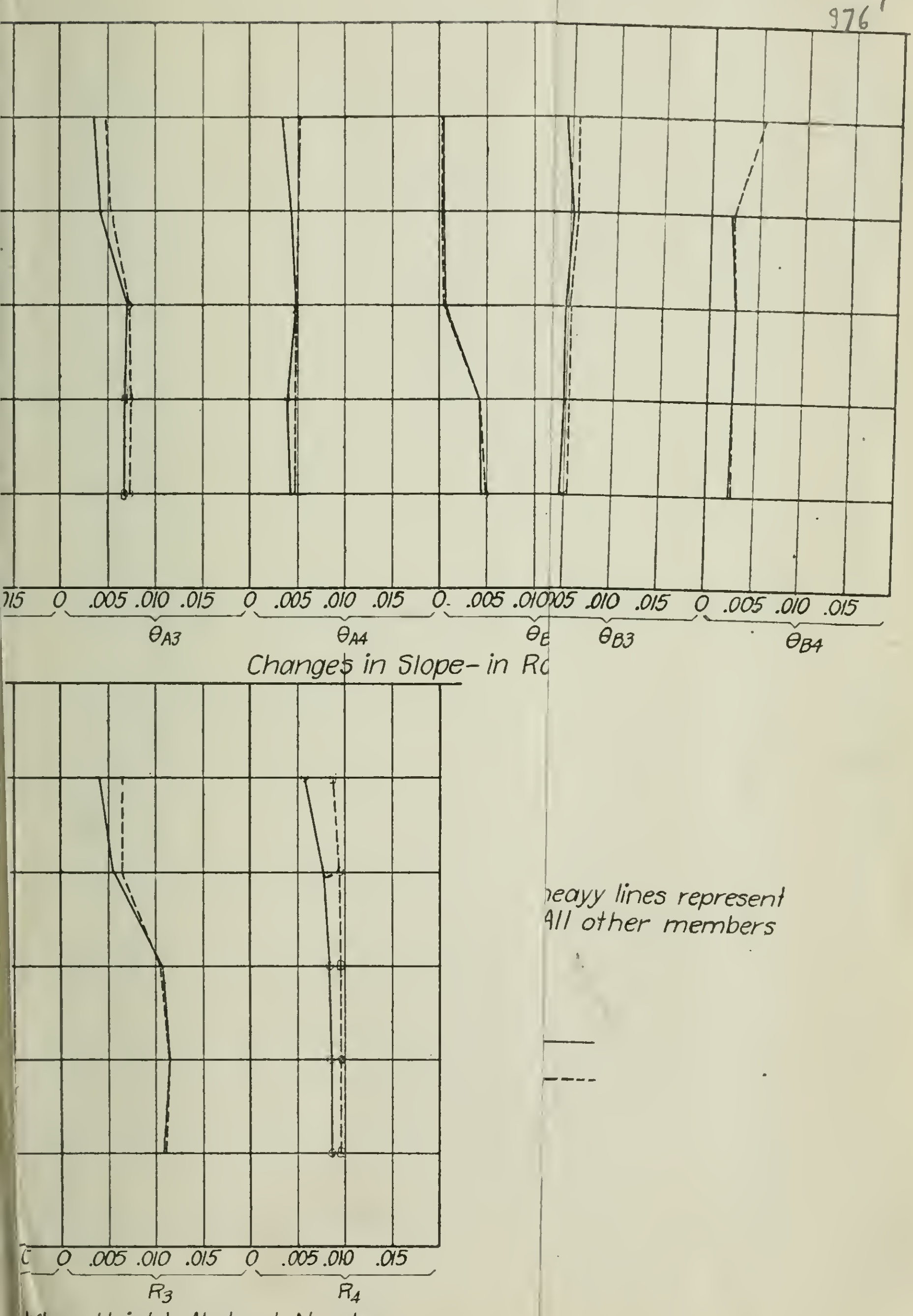
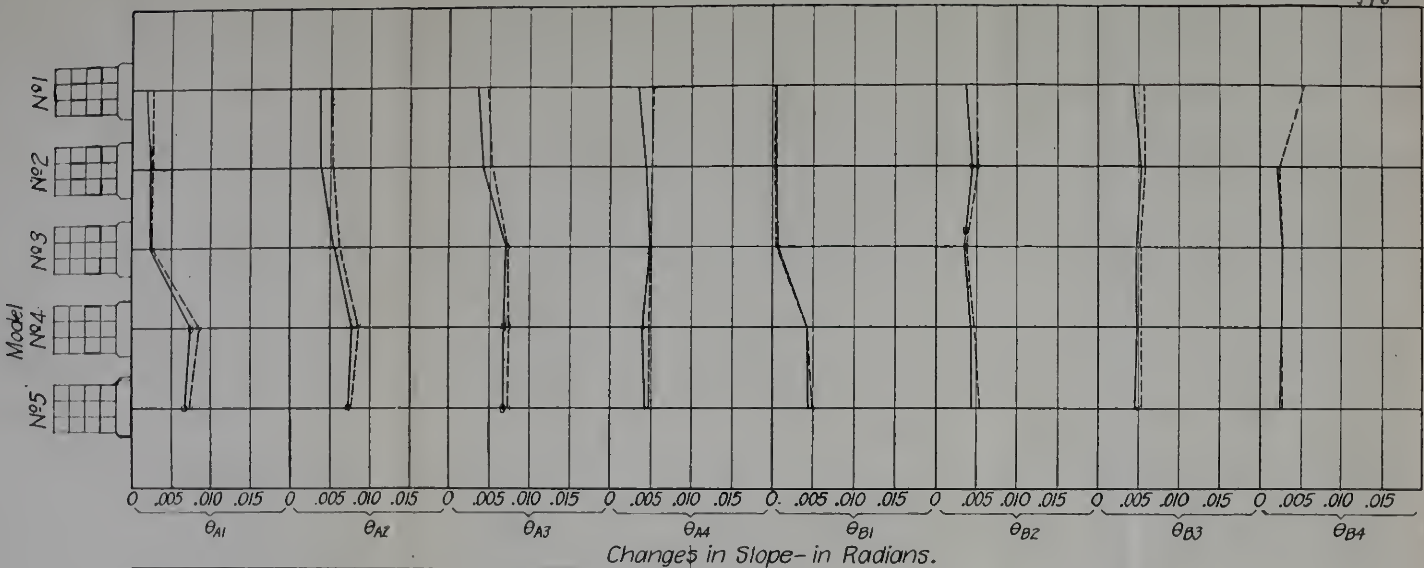
Figure 3.



Sl and the Ratio of Deflection to Story Height sured and as Computed



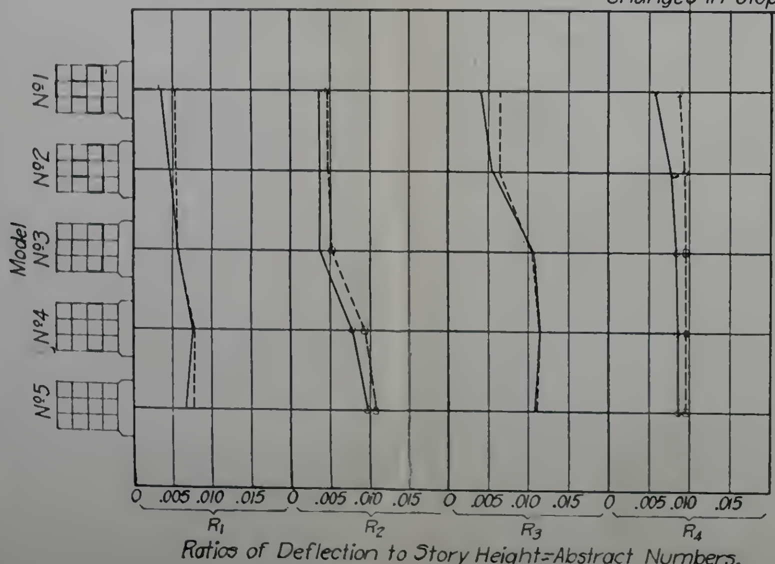


FIGURE 3

Note:—
In models Nº 1 to 5 the heavy lines represent members ½ inch wide. All other members are ¼ inch wide.

Measured quantities ————
Computed quantities - - - - - -

Fig. 3. Showing the Changes in Slope and the Ratio of Deflection to Story Height in a Celluloid Model, as Measured and as Computed

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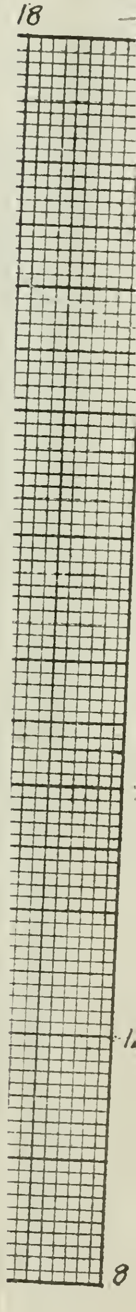
d Stresses
of Office Bu
gure 5.



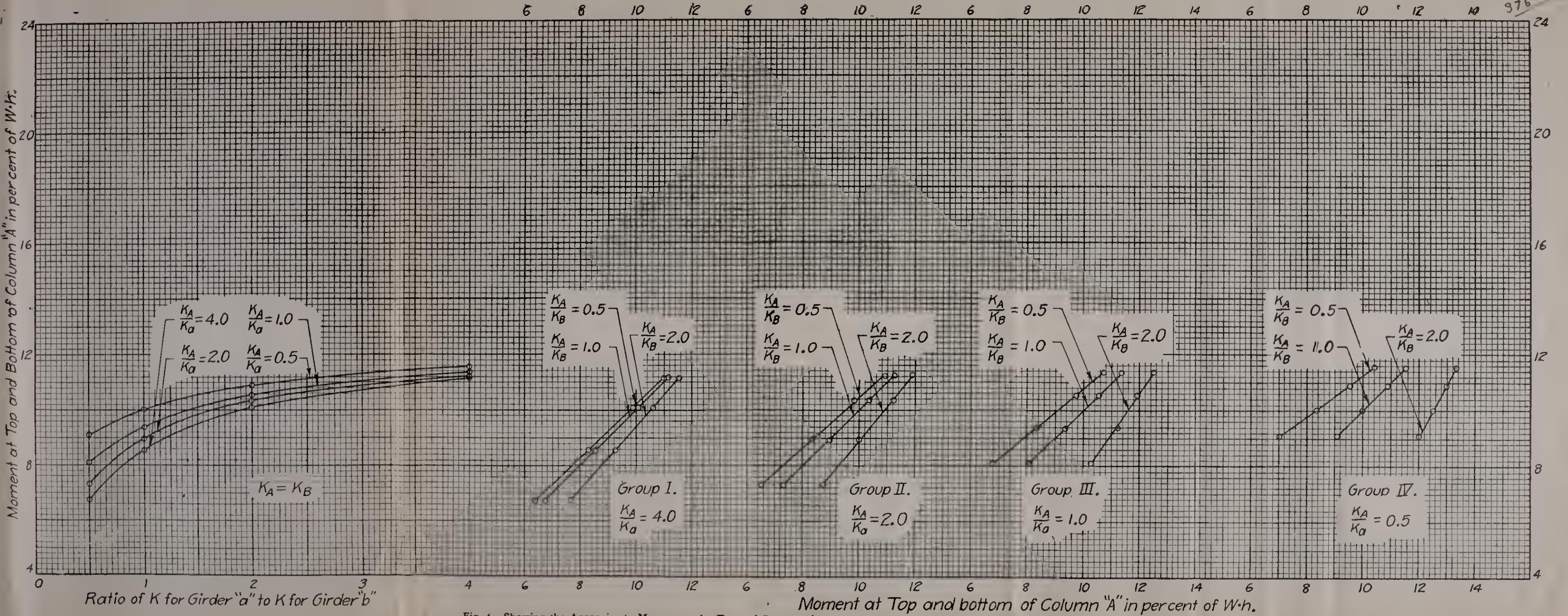


Fig. 4. Showing the Approximate Moment at the Top and Bottom of Column "A" in a Symmetrical Three-Span Bent.

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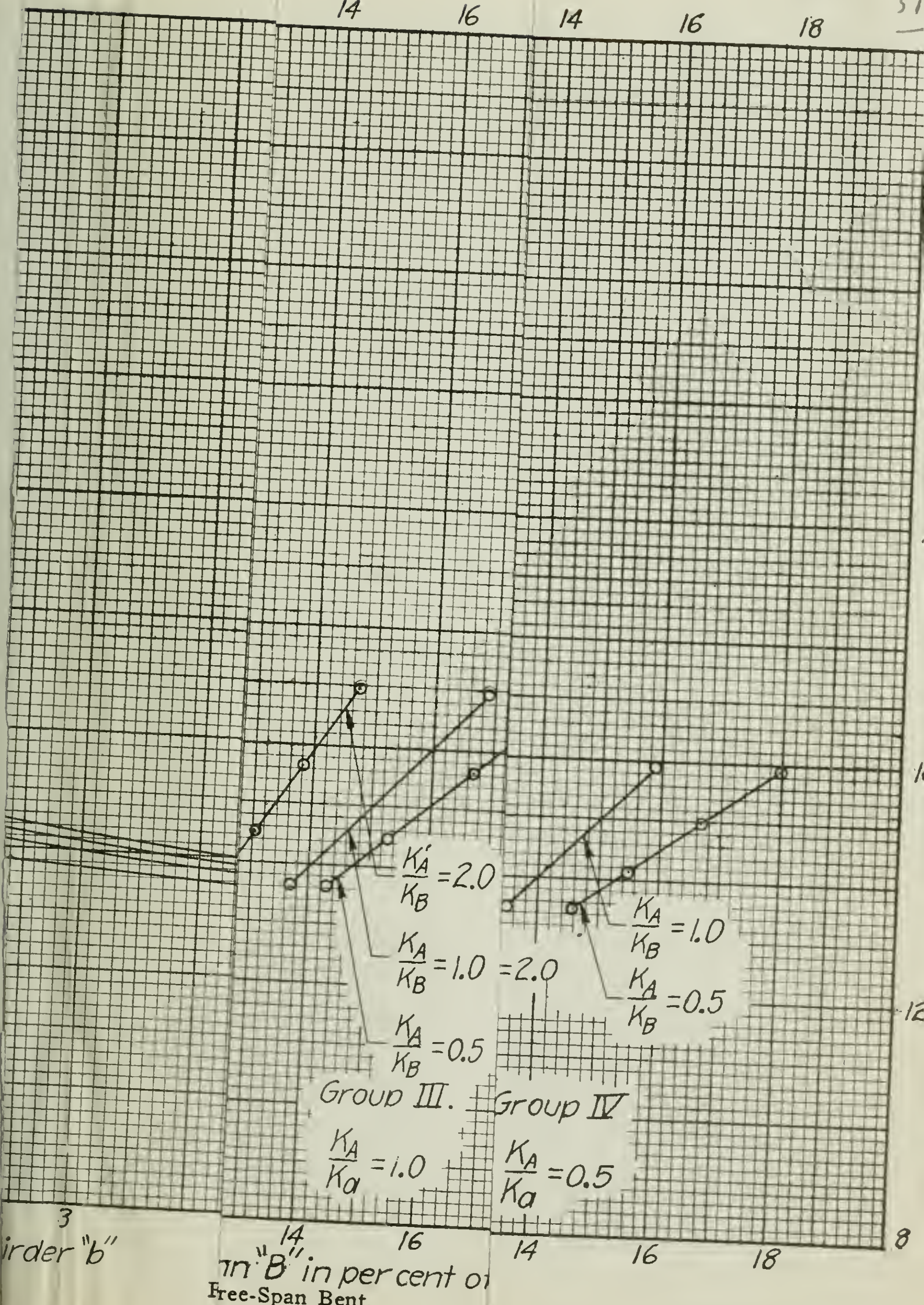
Steel Frames of Office Bui

Figure 5.



Free-Span Bent.

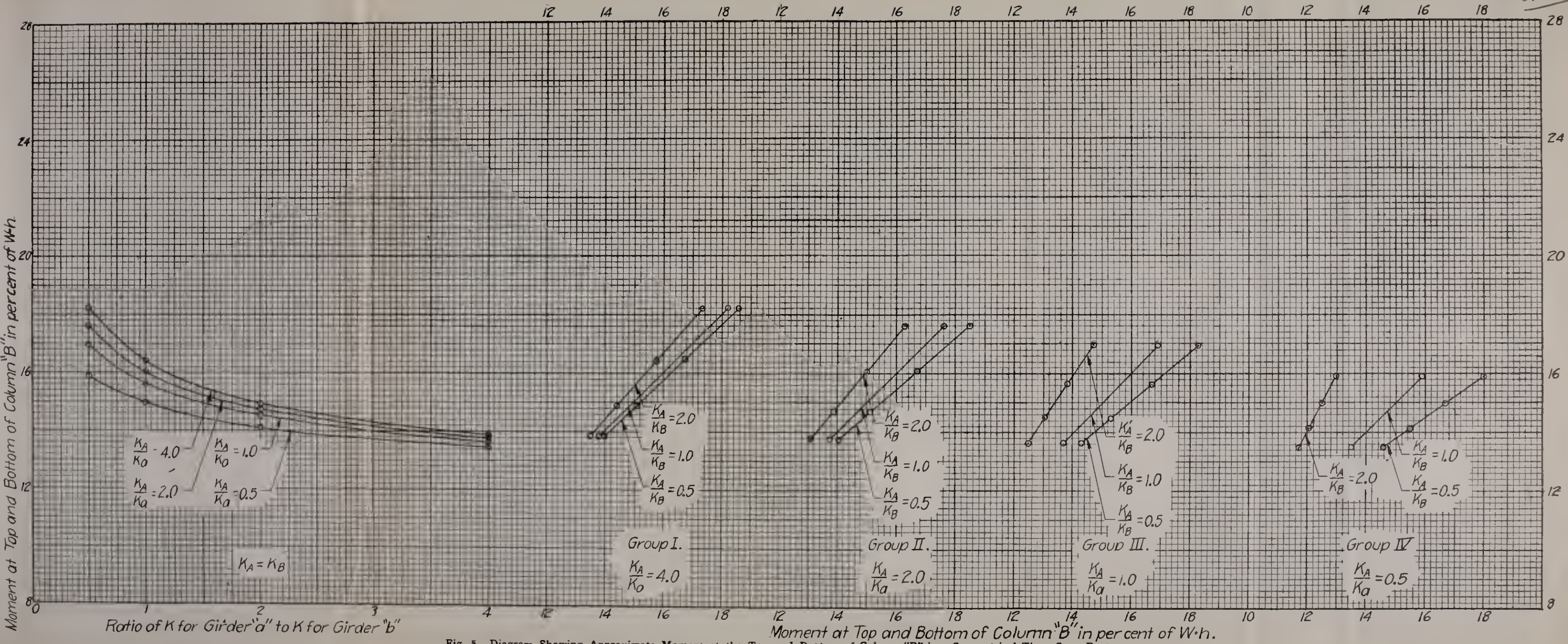
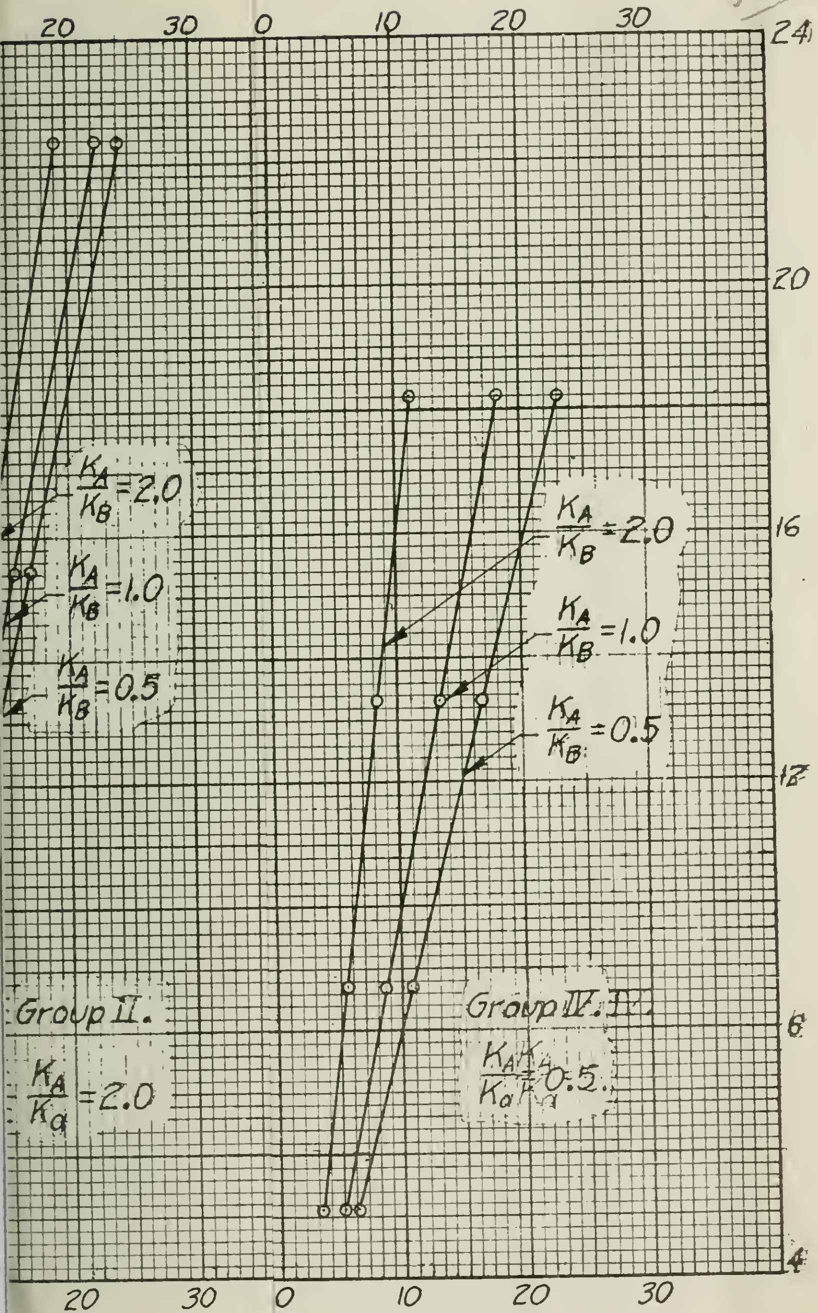


Fig. 5. Diagram Showing Approximate Moment at the Top and Bottom of Column "B" in a Symmetrical Three-Span Bent.

Figure 6.



ent at End of
a Symmetrical Three-S

WESTERN SOCIETY OF ENGINEERS.
Vol. XX. No. 4, April, 1915.
Wilson—Wind Stresses in the Steel Frames of Office Buildings.
Figure 6.

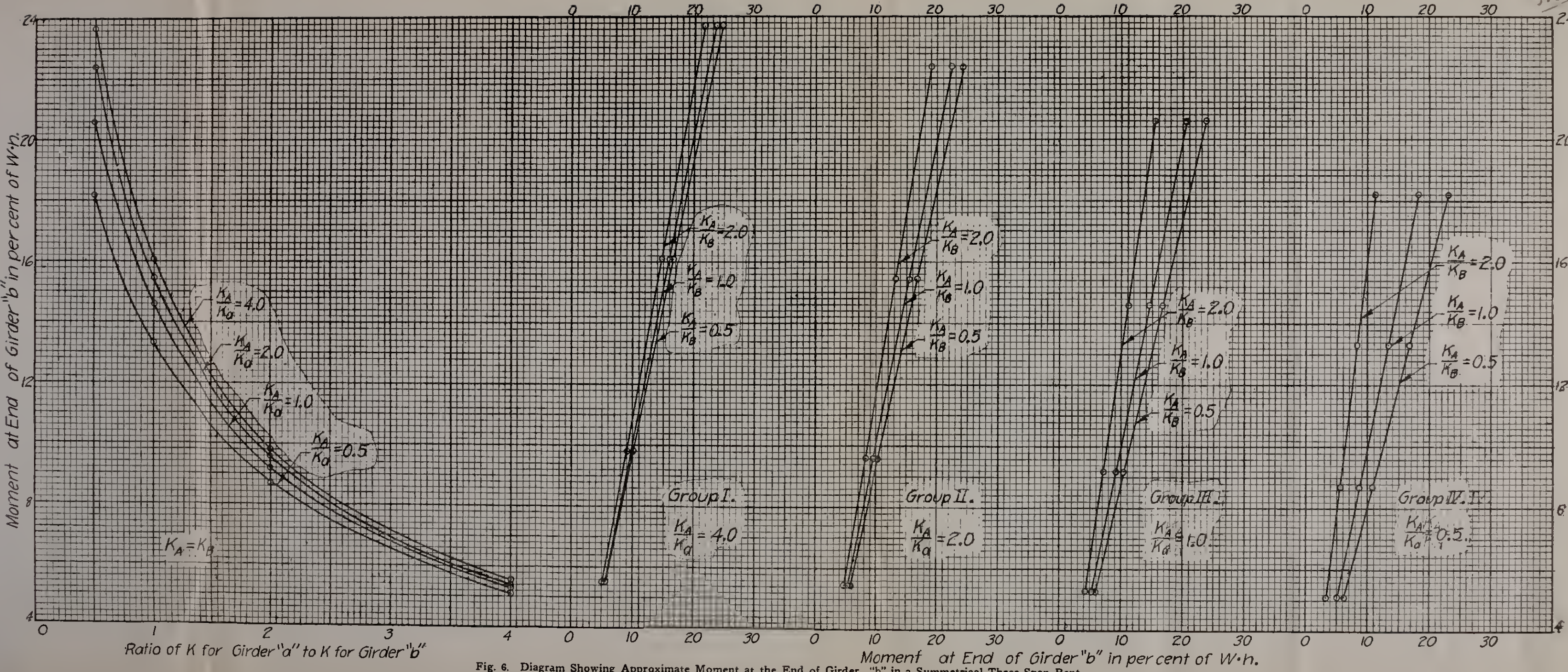


Fig. 6. Diagram Showing Approximate Moment at the End of Girder "b" in a Symmetrical Three-Span Bent.

TABLE I

in the Symmetrical Three-Span, Twenty-Story Bent Shown in Fig. 5

ea of ction ı. in.	Moment of Inertia—in.⁴ Web.	4 Angles Primary	4 Angles Secondary	Cover Plate	Total	Length of Columns = h of Girders = l inches	K for Columns = $\frac{I}{h}$ for Girders = $\frac{I}{l}$ (inches)³
12.80	358	318	2190	3950	6816	264	25.8
12.80	358	318	2190	3950	6816	192	35.6
)3.80	358	318	2190	3080	5946	168	35.4
)2.55	358	318	2190	2060	4926	168	29.4
33.55	358	318	2190	1266	4132	144	28.7
72.42	384	337	2315		3036	144	21.1
54.24	358	299	2050		2707	144	18.8
53.79	308	131	2195		2634	144	18.3
42.26	205	105	1745		2055	144	14.3
38.86	205	96	1590		1891	144	13.1
2.80	358	318	2190	3950	6816	264	25.8
2.80	358	318	2190	3950	6816	192	35.6
)3.80	358	318	2190	3080	5946	168	35.5
)4.80	358	318	2190	2240	5106	168	30.4
35.80	358	318	2190	1459	4326	144	30.0
9.05	358	318	2190	892	3758	144	26.1
57.80	358	318	2190		2866	144	19.9
7.92	358	131	2195		2684	144	18.6
4.39	256	105	1745		2106	144	14.6
1.00	256	96	1544		1896	144	13.2
9.43	2315	13	5730		8058	264	30.5
7.18	1458	13	4170		5641	264	21.4
5.70	1458	13	3690		5161	264	19.5
4.93	844	13	2860		3717	264	14.1
3.45	844	13	2530		3387	264	12.8
1.20	432	13	1580		2025	264	7.7
9.43	2315	13	5730		8058	216	37.3
9.38	1458	15	4830		6303	216	29.2
7.18	1458	13	4170		5641	216	26.2
5.70	1458	13	3690		5161	216	23.8
4.93	844	13	2860		3717	216	17.2
3.45	844	13	2530		3387	216	15.7
1.20	432	13	1580		2025	216	9.4

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TABLE I

Properties of the Columns and Girders in the Symmetrical Three-Span, Twenty-Story Bent Shown in Fig. 5

Member	Story Number	Section of Member: Web Plate	Section of Member: 4 Anglers	Section of Member: Cover Plate	Area of Section sq. in.	Moment of Inertia—in.⁴: Web.	Moment of Inertia: 4 Angles, Primary	Moment of Inertia: 4 Angles, Secondary	Moment of Inertia: Cover Plate	Moment of Inertia: Total	Length of Columns =h, of Girders= l, inches	K for Columns $=\frac{I}{h}$, for Girders $=\frac{I}{l}$ (inches)^3
Column A.	1	17x7/8	8x8x7/8	2-18x1 1/4	112.80	358	318	2190	3950	6816	264	25.8
	2	17x7/8	8x8x7/8	2-18x1 1/4	112.80	358	318	2190	3950	6816	192	35.6
	3 and 4	17x7/8	8x8x7/8	2-18x1	103.80	358	318	2190	3080	5946	168	35.4
	5 and 6	17x7/8	8x8x7/8	2-18x11/16	92.55	358	318	2190	2060	4926	168	29.4
	7 and 8	17x7/8	8x8x7/8	2-18x7/16	83.55	358	318	2190	1266	4132	144	28.7
	9 and 10	17x15/16	8x8x15/16		72.42	384	337	2315		3036	144	21.1
	11 and 12	17x7/8	8x8x13/16		64.24	358	299	2050		2707	144	18.8
	13 and 14	17x3/4	8x6x13/16		53.79	308	131	2195		2634	144	18.3
	15 and 16	17x1/2	8x6x5/8		42.26	205	105	1745		2055	144	14.3
	17 and above	17x1/2	8x6x9/16		38.86	205	96	1590		1891	144	13.1
Column B.	1	17x7/8	8x8x7/8	2-18x1 1/4	112.80	358	318	2190	3950	6816	264	25.8
	2	17x7/8	8x8x7/8	2-18x1 1/4	112.80	358	318	2190	3950	6816	192	35.6
	3 and 4	17x7/8	8x8x7/8	2-18x1	103.80	358	318	2190	3080	5946	168	35.5
	5 and 6	17x7/8	8x8x7/8	2-18x3/4	94.80	358	318	2190	2240	5106	168	30.4
	7 and 8	17x7/8	8x8x7/8	2-18x1/2	85.80	358	318	2190	1459	4326	144	30.0
	9 and 10	17x7/8	8x8x7/8	2-18x5/16	79.05	358	318	2190	892	3758	144	26.1
	11 and 12	17x7/8	8x8x7/8		67.80	358	318	2190		2866	144	19.9
	13 and 14	17x7/8	8x6x13/16		57.92	358	131	2195		2684	144	18.6
	15 and 16	17x5/8	8x6x5/8		44.39	256	105	1745		2106	144	14.6
	17 and above	17x5/8	8x6x9/16		41.00	256	96	1544		1896	144	13.2
Girders in Bay a	1	42x3/8	6x3 1/2x3/8		29.43	2315	13	5730		8058	264	30.5
	2 and 3	36x3/8	6x3 1/2x3/8		27.18	1458	13	4170		5641	264	21.4
	4 and 5	36x3/8	5x3 1/2x3/8		25.70	1458	13	3690		5161	264	19.5
	6	30x3/8	6x3 1/2x3/8		24.93	844	13	2860		3717	264	14.1
	7	30x3/8	5x3 1/2x3/8		23.45	844	13	2530		3387	264	12.8
	8 and above	24x3/8	5x3 1/2x3/8		21.20	432	13	1580		2025	264	7.7
Girders in Bay b	1	42x3/8	6x3 1/2x3/8		29.43	2315	13	5730		8058	216	37.3
	2	36x3/8	6x3 1/2x7/16		29.38	1458	15	4830		6303	216	29.2
	3 and 4	36x3/8	6x3 1/2x3/8		27.18	1458	13	4170		5641	216	26.2
	5	36x3/8	5x3 1/2x3/8		25.70	1458	13	3690		5161	216	23.8
	6	30x3/8	6x3 1/2x3/8		24.93	844	13	2860		3717	216	17.2
	7	30x3/8	5x3 1/2x3/8		23.45	844	13	2530		3387	216	15.7
	8 and above	24x3/8	5x3 1/2x3/8		21.20	432	13	1580		2025	216	9.4

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TABLE III

netrical Three-Span Twenty-Story Bent Shown in Figure 1, as Determined and as Determined by the Approximate Methods.

er line are given in per cent of the moment as determined by the slope-deflection method.

olumn A		Moment at Top of Column B					Moment at Bottom of Column B					
Described ning in the ng News 3, 1913		Slope-Deflection Method	Proposed Approximate Methods	Methods Described by Mr. Fleming in the Engineering News March 13, 1913			Slope-Deflection Method	Proposed Approximate Methods	Methods Described by Mr. Fleming in the Engineering News March 13, 1913			Story No.
I	III			I	II	III			I	II	III	
4.5	254.5	251.0	319.0	343.2	254.5	254.5	308.2	319.0	343.2	254.5	254.5	1
3.6	93.6	100.0	126.8	136.9	101.4	101.4	100.0	103.5	111.3	82.5	82.5	
1.4	171.4	226.5	227.5	225.9	171.4	171.4	239.0	227.5	231.2	171.4	171.4	2
9.4	159.4	100.0	100.4	99.6	75.7	75.7	100.0	95.3	96.7	71.7	71.7	
0.5	140.5	187.5	184.1	190.1	140.5	140.5	182.0	184.1	185.1	140.5	140.5	3
5.0	155.0	100.0	98.3	101.4	75.0	75.0	100.0	101.2	101.8	77.2	77.2	
1.7	131.7	176.1	175.0	172.4	131.7	131.7	173.5	175.0	178.2	131.7	131.7	4
0.0	150.0	100.0	99.4	97.9	74.6	74.6	100.0	101.0	102.9	75.9	75.9	
0.4	120.4	162.3	160.0	165.3	125.3	125.3	162.0	160.0	160.9	125.3	125.3	5
5.3	145.3	100.0	98.5	101.9	77.2	77.2	100.0	98.8	99.2	77.5	77.5	
1.7	111.7	143.3	151.8	152.6	116.3	116.3	155.7	151.8	153.5	116.3	116.3	6
34.2	134.2	100.0	106.0	106.4	81.1	81.1	100.0	97.5	98.6	74.8	74.8	
38.6	88.6	122.0	120.7	122.5	92.8	92.8	124.0	120.7	121.4	92.8	92.8	7
47.6	147.6	100.0	98.8	100.4	76.1	76.1	100.0	97.3	98.0	74.8	74.8	
32.3	82.3	97.2	114.0	112.2	86.2	86.2	127.5	114.0	113.8	86.2	86.2	8
21.8	121.8	100.0	117.2	115.4	88.7	88.7	100.0	89.5	89.2	67.6	67.6	
59.5	69.5	104.2	105.5	105.3	86.0	86.0	103.3	105.5	103.6	86.0	86.0	9
34.0	134.0	100.0	100.8	101.1	82.5	82.5	100.0	102.1	100.0	83.2	83.2	
63.7	63.7	102.0	96.3	97.1	78.8	78.8	94.2	96.3	96.6	78.8	78.8	10
50.4	150.4	100.0	94.3	95.2	77.3	77.3	100.0	102.1	102.7	83.6	83.6	
62.9	62.9	89.0	86.4	87.9	66.7	66.7	81.2	86.4	88.3	66.7	66.7	11
52.8	152.8	100.0	97.1	98.7	74.9	74.9	100.0	106.5	108.7	82.0	82.0	
56.7	56.7	81.5	77.9	79.1	60.0	60.0	75.1	77.9	79.2	60.0	60.0	12
66.4	166.4	100.0	95.6	97.0	73.6	73.6	100.0	103.5	105.4	79.9	79.9	

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TABLE III

Comparison of the Moments in the Columns of the Symmetrical Three-Span Twenty-Story Bent Shown in Figure 1, as Determined by the Slope-Deflection Method and as Determined by the Approximate Methods.

Moments in the upper line are given in 1000 in. lbs.: those in the lower line are given in per cent of the moment as determined by the slope-deflection method.

Story No.	Moment at Top of Column A					Moment at Bottom of Column A					Moment at Top of Column B					Moment at Bottom of Column B					Story No.
	Slope-Deflection Method	Proposed Approximate Methods	Methods Described by Mr. Fleming in the Engineering News March 13, 1913			Slope-Deflection Method	Proposed Approximate Methods	Methods Described by Mr. Fleming in the Engineering News March 13, 1913			Slope-Deflection Method	Proposed Approximate Methods	Methods Described by Mr. Fleming in the Engineering News March 13, 1913			Slope-Deflection Method	Proposed Approximate Methods	Methods Described by Mr. Fleming in the Engineering News March 13, 1913			
			I	II	III			I	II	III			I	II	III			I	II	III	
1	178.8	191.5	166.9	254.5	254.5	272.0	191.5	66.9	254.5	254.5	251.0	319.0	343.2	254.5	254.5	308.2	319.0	343.2	254.5	254.5	1
	100.0	106.8	94.5	145.0	145.0	100.0	70.3	62.3	93.6	93.6	100.0	126.8	136.9	101.4	101.4	100.0	103.5	111.3	82.5	82.5	
2	113.0	113.8	109.8	171.4	171.4	107.5	96.8	112.3	171.4	171.4	226.5	227.5	225.9	171.4	171.4	239.0	227.5	231.2	171.4	171.4	2
	100.0	100.7	97.1	152.0	152.0	100.0	106.0	104.6	159.4	159.4	100.0	100.4	99.6	75.7	75.7	100.0	95.3	96.7	71.7	71.7	
3	100.3	96.8	92.9	140.5	140.5	90.7	113.8	90.0	140.5	140.5	187.5	184.1	190.1	140.5	140.5	182.0	184.1	185.1	140.5	140.5	3
	100.0	96.5	92.8	140.3	140.3	100.0	106.8	99.3	155.0	155.0	100.0	98.3	101.4	75.0	75.0	100.0	101.2	101.8	77.2	77.2	
4	87.8	87.1	87.5	131.7	131.7	87.8	87.1	86.8	131.7	131.7	176.1	175.0	172.4	131.7	131.7	173.5	175.0	178.2	131.7	131.7	4
	100.0	99.3	99.6	150.0	150.0	100.0	99.3	98.9	150.0	150.0	100.0	99.4	97.9	74.6	74.6	100.0	101.0	102.9	75.9	75.9	
5	84.5	85.6	80.2	120.4	120.4	82.8	85.6	81.6	120.4	120.4	162.3	160.0	165.3	125.3	125.3	162.0	160.0	160.9	125.3	125.3	5
	100.0	101.3	95.0	142.3	142.3	100.0	103.3	98.5	145.3	145.3	100.0	98.5	101.9	77.2	77.2	100.0	98.8	99.2	77.5	77.5	
6	75.0	76.8	74.2	111.7	111.7	83.2	76.8	74.4	111.7	111.7	143.3	151.8	152.6	116.3	116.3	155.7	151.8	153.5	116.3	116.3	6
	100.0	102.0	99.0	149.0	149.0	100.0	92.2	89.5	134.2	134.2	100.0	106.0	106.4	81.1	81.1	100.0	97.5	98.6	74.8	74.8	
7	57.6	60.3	59.4	88.6	88.6	60.0	60.3	59.0	88.6	88.6	122.0	120.7	122.5	92.8	92.8	124.0	120.7	121.4	92.8	92.8	7
	100.0	105.0	103.2	154.0	154.0	100.0	100.0	98.3	147.6	147.6	100.0	98.8	100.4	76.1	76.1	100.0	97.3	98.0	74.8	74.8	
8	44.4	54.7	56.6	82.3	82.3	67.7	54.7	55.2	82.3	82.3	97.2	114.0	112.2	86.2	86.2	127.5	114.0	113.8	86.2	86.2	8
	100.0	125.0	127.5	185.5	185.5	100.0	80.7	81.6	121.8	121.8	100.0	117.2	115.4	88.7	88.7	100.0	89.5	89.2	67.6	67.6	
9	52.6	49.8	50.5	69.5	69.5	51.9	49.8	52.3	69.5	69.5	104.2	105.5	105.3	86.0	86.0	103.3	105.5	103.6	86.0	86.0	9
	100.0	94.8	96.0	132.0	132.0	100.0	96.1	101.0	134.0	134.0	100.0	100.8	101.1	82.5	82.5	100.0	102.1	100.0	83.2	83.2	
10	46.5	45.6	45.6	63.7	63.7	42.4	45.6	46.3	63.7	63.7	102.0	96.3	97.1	78.8	78.8	94.2	96.3	96.6	78.8	78.8	10
	100.0	98.0	98.1	137.0	137.0	100.0	107.8	109.3	150.4	150.4	100.0	94.3	95.2	77.3	77.3	100.0	102.1	102.7	83.6	83.6	
11	47.5	43.0	42.3	62.9	62.9	41.5	43.0	41.5	62.9	62.9	89.0	86.4	87.9	66.7	66.7	81.2	86.4	88.3	66.7	66.7	11
	100.0	90.6	89.1	132.3	132.3	100.0	103.8	100.0	152.8	152.8	100.0	97.1	98.7	74.9	74.9	100.0	106.5	108.7	82.0	82.0	
12	41.4	38.7	38.4	56.7	56.7	34.1	38.7	38.0	56.7	56.7	81.5	77.9	79.1	60.0	60.0	75.1	77.9	79.2	60.0	60.0	12
	100.0	93.6	92.7	137.0	137.0	100.0	113.7	111.4	166.4	166.4	100.0	95.6	97.0	73.6	73.6	100.0	103.5	105.4	79.9	79.9	

TABLE IV

**irders of the Symmetrical Three-Span Twenty-Story Bent
mined by the Slope-Deflection Method and as
ned by Approximate Methods.**

lbs., those in the lower line are given in per cent of the moment as
d.

	Moment at Left End of Girder a				Moment at End of Girder b					
	Proposed Approximate Method	Methods Described by Mr. Fleming in the Engineering News March 13, 1913			Slope-Deflection Method	Proposed Approximate Method	Methods Described by Mr. Fleming in the Engineering News March 13, 1913			Story No.
		I	II	III			I	II	III	
0	**274.5** 112.0	**279.3** 114.0	**143.7** 58.6	**130.9** 53.4	**247.5** 100.0	**272.0** 110.0	**295.0** 119.0	**282.2** 114.0	**295.0** 119.0	1
0	**185.6** 100.8	**199.8** 108.5	**104.4** 56.7	**100.7** 54.8	**226.0** 100.0	**226.0** 100.0	**211.2** 93.4	**207.5** 91.9	**211.2** 93.4	2
7	**173.1** 100.8	**178.2** 104.0	**90.7** 52.9	**84.3** 49.1	**189.6** 100.0	**186.0** 98.0	**187.9** 99.0	**181.5** 95.8	**187.9** 99.0	3
6	**152.0** 99.0	**169.2** 110.3	**87.3** 56.9	**84.9** 55.3	**184.4** 100.0	**183.0** 99.0	**172.1** 93.5	**169.7** 92.0	**172.1** 93.5	4
0	**151.8** 99.9	**154.8** 101.8	**83.7** 55.0	**77.3** 50.9	**166.0** 100.0	**160.0** 96.5	**164.4** 99.0	**157.9** 95.0	**164.4** 99.0	5
6	**128.5** 102.6	**133.2** 112.2	**73.0** 58.1	**68.3** 54.4	**141.5** 100.0	**144.0** 102.0	**140.8** 99.5	**136.1** 96.3	**140.8** 99.5	6
0	**110.9** 94.9	**114.5** 98.0	**62.4** 53.3	**57.4** 49.1	**132.5** 100.0	**123.8** 93·0	**121.6** 91.8	**116.6** 88.0	**121.6** 91.8	7
0	**103.5** 112.5	**108.7** 118.0	**64.2** 69.8	**56.0** 60.9	**107.8** 100.0	**116.0** 108.0	**106.2** 95.8	**108.0** 100.3	**106.2** 95.8	8
1	**95.8** 105.0	**96.8** 112.4	**65.5** 71.9	**60.5** 66.4	**106.8** 100.0	**106.0** 99.4	**104.3** 97.6	**99.3** 93.0	**104.3** 97.6	9
0	**85.7**	**87.1** 102.4	**54.8** 64.5	**48.0** 56.5	**98.5** 100.0	**97.0** 98.5	**97.5** 99.0	**90.7** 92.1	**97.5** 99.0	10
6	**77.0** 100.4	**80.3** 104.8	**44.6** 58.2	**40.8** 53.3	**87.5** 100.0	**87.3** 99.8	**85.9** 98.1	**82.1** 94.0	**85.9** 98.1	11
6	**68.5** 100.0	**72.3** 105.5	**38.9** 56.8	**36.4** 53.0	**78.3** 100.0	**78.1** 99.8	**75.9** 96.9	**73.4** 93.8	**75.9** 96.9	12

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TABLE IV

Comparison of the Moments in the Girders of the Symmetrical Three-Span Twenty-Story Bent Shown in Fig. 1, as Determined by the Slope-Deflection Method and as Determined by Approximate Methods.

Moments in the upper line are given in 1000 in. lbs., those in the lower line are given in per cent of the moment as determined by the slope-deflection method.

Story No.	Moment at Right End Girder a					Moment at Left End of Girder a					Moment at End of Girder b					Story No.
	Slope-Deflection Method	Proposed Approximate Method	Methods Described by Mr. Fleming in the Engineering News March 13, 1913			Slope-Deflection Method	Proposed Approximate Method	Methods Described by Mr. Fleming in the Engineering News March 13, 1913			Slope-Deflection Method	Proposed Approximate Method	Methods Described by Mr. Fleming in the Engineering News March 13, 1913			
			I	II	III			I	II	III			I	II	III	
1	287.8	305.3	279.3	425.9	425.9	245.0	274.5	279.3	143.7	130.9	247.5	272.0	295.0	282.2	295.0	1
	100.0	106.1	97.1	148.0	145.0		112.0	114.0	58.6	53.4	100.0	110.0	119.0	114.0	119.0	
2	203.0	210.6	199.8	311.9	311.9	184.0	185.6	199.8	104.4	100.7	226.0	226.0	211.2	207.5	211.2	2
	100.0	103.5	98.5	153.6	153.6		100.8	108.5	56.7	54.8	100.0	100.0	93.4	91.9	93.4	
3	187.1	183.9	178.2	272.2	272.2	171.7	173.1	178.2	90.7	84.3	189.6	186.0	187.9	181.5	187.9	3
	100.0	98.2	95.2	145.8	145.8		100.8	104.0	52.9	49.1	100.0	98.0	99.0	95.8	99.0	
4	170.5	172.7	169.2	252.1	252.1	153.6	152.0	169.2	87.3	84.9	184.4	183.0	172.1	169.7	172.1	4
	100.0	101.0	99.5	148.0	148.0		99.0	110.3	56.9	55.3	100.0	99.0	93.5	92.0	93.5	
5	167.7	162.4	154.8	232.1	232.1	152.0	151.8	154.8	83.7	77.3	166.0	160.0	164.4	157.9	164.4	5
	100.0	97.0	92.4	138.7	138.7		99.9	101.8	55.0	50.9	100.0	96.5	99.0	95.0	99.0	
6	135.0	137.1	133.2	200.3	200.3	125.6	128.5	133.2	73.0	68.3	141.5	144.0	140.8	136.1	140.8	6
	100.0	101.2	98.8	148.2	148.2		102.6	112.2	58.1	54.4	100.0	102.0	99.5	96.3	99.5	
7	125.9	115.0	114.5	170.9	170.9	117.0	110.9	114.5	62.4	57.4	132.5	123.8	121.6	116.6	121.6	7
	100.0	91.5	91.0	135.9	135.9		94.9	98.0	53.3	49.1	100.0	93.0	91.8	88.0	91.8	
8	95.8	104.5	108.7	151.8	151.8	92.0	103.5	108.7	64.2	56.0	107.8	116.0	106.2	108.0	106.2	8
	100.0	109.3	113.3	158.4	158.4		112.5	118.0	69.8	60.9	100.0	108.0	95.8	100.3	95.8	
9	95.0	95.4	96.8	133.2	133.2	91.1	95.8	96.8	65.5	60.5	106.8	106.0	104.3	99.3	104.3	9
	100.0	100.4	101.9	140.3	140.3		105.0	112.4	71.9	66.4	100.0	99.4	97.6	93.0	97.6	
10	89.6	88.6	87.1	126.6	126.6	85.0	85.7	87.1	54.8	48.0	98.5	97.0	97.5	90.7	97.5	10
	100.0	98.9	97.3	141.2	141.2			102.4	64.5	56.5	100.0	98.5	99.0	92.1	99.0	
11	81.9	81.7	80.3	119.6	119.6	76.6	77.0	80.3	44.6	40.8	87.5	87.3	85.9	82.1	85.9	11
	100.0	99.8	98.2	146.2	146.2		100.4	104.8	58.2	53.3	100.0	99.8	98.1	94.0	98.1	
12	73.4	73.1	72.3	108.0	108.0	68.6	68.5	72.3	38.9	36.4	78.3	78.1	75.9	73.4	75.9	12
	100.0	99.6	98.7	147.2	147.2		100.0	105.5	56.8	53.0	100.0	99.8	96.9	93.8	96.9	

ABLE V

etrical Three-Span Bent with Long Middle Span as Determined by as Determined by Approximate Methods.

line are given in per cent of the Moment as determined by the slope-deflection

	Moment at Top of Column B					Moment at Bottom of Column B					
ed the	Slope-Deflection Method	Proposed Approximate Method	Methods Described by Mr. Fleming in the Engineering News March 13, 1913			Slope-Deflection Method	Proposed Approximate Method	Methods Described by Mr. Fleming in the Engineering News March 13, 1913			Story No.
II			I	II	III			I	II	III	
4.4 2.0	**248.0** 100.0	**305.0** 122.8	**370.5** 149.5	**254.4** 102.2	**254.4** 102.2	**302.8** 100.0	**305.0** 100.5	**370.5** 122.0	**254.4** 84.0	**254.4** 84.0	1
1.4 8.2	**212.7** 100.0	**214.0** 100.5	**247.5** 116.2	**171.4** 80.5	**171.4** 80.5	**223.7** 100.0	**214.0** 95.8	**249.5** 111.9	**171.4** 76.8	**171.4** 76.8	2
0.5 8.2	**177.1** 100.0	**174.0** 98.2	**204.8** 115.7	**140.5** 79.3	**140.5** 79.3	**171.6** 100.0	**174.0** 101.5	**203.0** 118.2	**140.5** 82.0	**140.5** 82.0	3
1.7 2.0	**165.3** 100.0	**164.1** 99.5	**191.9** 116.0	**131.7** 79.6	**131.7** 79.6	**163.7** 100.0	**164.1** 100.3	**191.9** 117.5	**131.7** 80.5	**131.7** 80.5	4

TABLE V

Comparison of the Moments in the Columns of the Symmetrical Three-Span Bent with Long Middle Span as Determined by the Slope-Deflection Method and as Determined by Approximate Methods.

Moments in the upper line are given in 1000 in. lbs.; those in the lower line are given in per cent of the Moment as determined by the slope-deflection method.

Story No.	Moment at Top of Column A					Moment at Bottom of Column A					Moment at Top of Column B					Moment at Bottom of Column B					Story No.
	Slope-Deflection Method	Proposed Approximate Method	Methods Described by Mr. Fleming in the Engineering News March 13, 1913			Slope-Deflection Method	Proposed Approximate Method	Methods Described by Mr. Fleming in the Engineering News March 13, 1913			Slope-Deflection Method	Proposed Approximate Method	Methods Described by Mr. Fleming in the Engineering News March 13, 1913			Slope-Deflection Method	Proposed Approximate Method	Methods Described by Mr. Fleming in the Engineering News March 13, 1913			
			I	II	III			I	II	III			I	II	III			I	II	III	
1	193.2	203.5	138.0	254.4	254.4	275.9	203.5	138.0	254.4	254.4	248.0	305.0	370.5	254.4	254.4	302.8	305.0	370.5	254.4	254.4	1
	100.0	105.5	71.4	131.5	131.5	100.0	73.8	50.0	92.0	92.0	100.0	122.8	149.5	102.2	102.2	100.0	100.5	122.0	84.0	84.0	
2	125.9	127.5	92.2	171.4	171.4	123.8	127.5	92.9	171.4	171.4	212.7	214.0	247.5	171.4	171.4	223.7	214.0	249.5	171.4	171.4	2
	100.0	101.3	73.5	136.0	136.0	100.0	102.8	75.0	148.2	148.2	100.0	100.5	116.2	80.5	80.5	100.0	95.8	111.9	76.8	76.8	
3	110.6	108.0	76.2	140.5	140.5	101.6	108.0	75.6	140.5	140.5	177.1	174.0	204.8	140.5	140.5	171.6	174.0	203.0	140.5	140.5	3
	100.0	97.5	69.0	127.0	127.0	100.0	106.5	74.5	138.2	138.2	100.0	98.2	115.7	79.3	79.3	100.0	101.5	118.2	82.0	82.0	
4	99.4	97.8	71.5	131.7	131.7	99.4	97.8	71.4	131.7	131.7	165.3	164.1	191.9	131.7	131.7	163.7	164.1	191.9	131.7	131.7	4
	100.0	98.3	72.0	132.2	132.2	100.0	98.3	72.0	132.0	132.0	100.0	99.5	116.0	79.6	79.6	100.0	100.3	117.5	80.5	80.5	

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ent Top and Column	Moment a Bottom o	
D ior hoc Method I	Slope-De-flection Method	
9 9.62 105.9	15.91 100.0	
7.50 75.00	15.00 100.0	
7 5.00 46.00	14.13 100.0	
9 9.62 19.00	16.91 100.0	15. 90.
38 7.50 9.90	15.62 100.0	17. 11
53 5.00 '.5	14.47 100.0	2 13
32 .62 .3	17.67 100.0	1 8
93 .50 .9	16.06 100.0	1 10
33 00 4	14.68 100.0	2 130.

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TABLE VII

Effect of the Proportios of a Bent Upon the Accuracy of Method I, Described by Mr. Fleming in the Engineering News, March 13, 1913.

All stories of a bent are identicl and the shears on all stories are equal. All column sections are equal, all girder sections are equal, and the column sections are eqal to the girder sections.

For each bent the moments in te upper line are in per cent of W x h, and in the lower line are in per cent of the moment as determed by the slope-deflection metbd.

Bent No.	Proportions of the Bent		Momen t Top and Bottom f Column: Slope-D flectior Methoc	Momen t Top and Bottom f Column: Method I	Moment at Top and Bottom of Column B: Slope-Deflection Method	Moment at Top and Bottom of Column B: Method I	Moment at Right End of Girder a: Slope-Deflection Method	Moment at Right End of Girder a: Method I	Moment at Left End of Girder a: Slope-Deflection Method	Moment at Left End of Girder a: Method I	Moment at End of Girder b: Slope-Deflection Method	Moment at End of Girder b: Method I
1	Height of Story Equals two times the Width of Bay a	Width of Bay a Equals two times the Width of Bay b	9.09 100.0	9.62 105.9	15.91 100.0	15.38 96.5	18.20 100.0	19.24 105.9	13.67 100.0	19.24 140.7	18.20 100.0	11.52 63.2
2		Width of Bay a the Width of Bay b	10.0 100.0	7.50 75.00	15.00 100.0	17.50 116.5	20.00 100.0	15.00 75.0	16.66 100.0	15.0 90.0	13.33 100.0	20.00 150.0
3		Width of Bay a Equals one-half of the Width of Bay b	10.87 100.0	5.00 46.00	14.13 100.0	20.00 141.5	21.70 100.0	10.00 46.1	19.54 100.0	10.00 51.2	8.70 100.0	30.00 345.0
4	Height of Story Equals the Width of Bay a	Width of Bay a Equals two times the Width of Bay b	8.09 100.0	9.62 19.00	16.91 100.0	15.38 90.9	16.18 100.0	19.24 119.3	13.23 100.0	19.24 145.5	20.60 100.0	11.52 55.9
5		Width of Bay a Equals the Width of Bay b	9.38 100.0	7.50 9.90	15.62 100.0	17.50 111.9	18.75 100.0	15.00 80.00	16.66 100.0	15.00 90.0	14.60 100.0	20.00 137.0
6		Width of Bay a Equals one-half of the Width of Bay b	10.53 100.0	.00 .5	14.47 100.0	20.00 138.0	21.04 100.00	10.00 47.5	19.74 100.0	10.00 50.6	9.20 100.0	30.00 326.0
7	Height of Story Equals one-half of the Width of Bay a	Width of Bay a Equals two times the Width of Bay b	7.32 100.0	.62 .3	17.67 100.0	15.38 87.0	14.66 100.0	19.24 131.0	12.93 100.0	19.24 149.0	22.40 100.0	11.52 51.3
8		Width of Bay a Equals the Width of Bay b	8.93 100.0	50 9	16.06 100.0	17.50 108.7	17.84 100.0	15.00 83.9	16.66 100.0	15.00 90.0	15.45 100.0	20.00 129.5
9		Width of Bay a Equals one-half of the Width of Bay b	10.33 100.0	00 4	14.68 100.0	20.00 136.1	20.61 100.0	10.00 48.5	19.92 100.0	10.0 50.1	9.60 100.0	30.00 312.0

1. The slope-deflection method.
2. The proposed approximate method.
3. The three methods described by Mr. Fleming and designated as methods I, II and III.*

The moments as determined by these five methods are given in Tables III and IV (insert). For each story the moments in the upper line are in 1000 in. lb., and those in the lower line are in per cent of the moment as determined by the slope-deflection method. Tables III and IV show: 1st, that the moments as determined by methods II and III are very seriously in error; 2nd, that the moments as determined by method I and by the proposed approximate method agree very closely with the moment as determined by the slope-deflection method except at points where there are sudden changes in the members of the bent; 3rd, that the errors in the moment as determined by the proposed approximate method are less for the girders than for the columns.

16. Symmetrical Three-Span Bent with Long Middle Span.—The distribution of the moments as determined by the slope-deflection method is affected by the ratio of the K of girder a to the K of girder b. As this ratio does not affect the distribution of the moments as determined by methods I, II, and III, the accuracy of the latter methods will depend upon the relative values of K for the two girders.

In the building shown in Fig. 1, K is less for girder a than for girder b, since the girders have substantially the same section and girder a is longer than girder b. To determine the effect of the relative values of K of girders a and b upon the accuracy of the approximate methods, the moments were determined in the four bottom stories of a bent exactly like the one shown in Fig. 1 except that the long and short spans have been interchanged. The results, as determined by five methods, are given in Tables V (insert) and VI. The moments in these tables, as determined by the proposed approximate method, are as accurate as those given in Tables III and IV, whereas the moments as determined by methods I are inaccurate and those determined by methods II and III are very inaccurate. Tables III to VI, inclusive, indicate: 1st, that methods II and III are so inaccurate that they should never be used; 2nd, method I is accurate in some cases but can not be depended upon; 3rd, the proposed approximate method is sufficiently accurate except where there is a sudden change in the sections of the members.

17. The Effect of the Proportions of a Bent Upon the Accuracy of Method I.—In order to determine further the effect of the proportions of a bent upon the accuracy of Method I described by Mr. Fleming, the moments were determined in a number of bents having different proportions, by the slope-deflection method and by

*Wind Bracing without Diagonals for Steel-Frame Office Building, *Engr. News*, March 13, 1913.

TABLE VI

Comparison of the Moments in the Girders of the Symmetrical Three-Span Bent With Long Middle Span as Determined by the Slope-Deflection Method and as Determined by Approximate Methods.

Moments in the upper line are given in 1000 in. lbs.; those in the lower line are given in per cent of the moment as determined by the slope deflection method.

Story No.	Moment at Right End of Girder a					Moment at Left End of Girder a					Moment at End of Girder b					Story No.
	Slope-Deflection Method	Proposed Approximate Method	Methods Described by Mr. Fleming in the Engineering News March 13, 1913			Slope-Deflection Method	Proposed Approximate Method	Methods Described by Mr. Fleming in the Engineering News March 13, 1913			Slope-Deflection Method	Proposed Approximate Method	Methods Described by Mr. Fleming in the Engineering News March 13, 1913			
			I	II	III			I	II	III			I	II	III	
1	**316.9** 100.0	**331.0** 104.5	**230.9** 73.0	**425.8** 135.2	**425.8** 135.2	**277.4** 100.0	**309.0** 111.5	**230.9** 83.3	**138.5** 50.0	**36.0** 13.0	**194.5** 100.0	**210.0** 108.0	**389.2** 200.0	**287.3** 148.0	**389.8** 200.0	1
2	**227.6** 100.0	**235.5** 103.8	**167.7** 73.5	**311.9** 137.0	**311.9** 137.0	**209.4** 100.0	**212.2** 101.9	**167.7** 80.0	**103.0** 49.4	**23.6** 11.3	**174.6** 100.0	**175.8** 100.5	**282.8** 162.0	**208.8** 119.6	**288.2** 165.0	2
3	**210.1** 100.0	**205.8** 98.0	**147.7** 70.0	**272.2** 129.5	**272.2** 129.5	**194.7** 100.0	**194.1** 99.7	**147.7** 75.8	**90.7** 46.6	**23.2** 11.9	**146.4** 100.0	**144.0** 98.2	**249.1** 170.0	**181.4** 124.0	**249.0** 170.0	3
4	**191.0** 100.0	**192.3** 100.8	**138.1** 72.3	**254.5** 136.0	**254.5** 133.0	**175.6** 100.0	**173.3** 98.8	**138.1** 79.0	**84.8** 48.3	**21.7** 12.4	**143.3** 100.0	**143.0** 98.8	**232.9** 162.2	**169.7** 118.1	**232.8** 162.2	4

method I. The moments in the bents, as determined by the two methods, are given in Table VII (insert).

In bents Nos. 1 to 9, inclusive, of this table, all girders and columns have the same section. The relation of the moment of inertia of the columns to the moment of inertia of the girders and of the moment of inertia of the girder in bay a to the moment of inertia of the girder in bay b, affects the moments as determined by the slope-deflection method but does not affect the moment as determined by method I. If the sections of the columns and girders are not the same, the difference between the moments as determind by the two methods might differ even more than Table VII indicates. Any errors in the moments due to sudden changes in the sections of the members are in addition to the errors indicated in Table VII.

The difference between the two methods is due to the fact that, in method I the direct unit stress in a column is proportional to the distance of the column from the neutral axis of the bent, whereas in the slope-deflection method the stress in a column depends upon the shears in the girders and the shears in the girders depend upon the changes in slope at the ends of the girders and upon the moment of inertia of the girder sections.

XII. CONCLUSIONS.

Of the methods described in *Engineering News,* March 13, 1913; method II and method III are so inaccurate that they should never be used; method I is fairly accurate in some cases, but it may give results which are very seriously in error.

The method for determining the wind stresses in the steel frame of an office building presented in Sections V and VI, and known as the slope-deflection method, contains no approximations except those contained in the original assumptions, and it can be shown that the inaccuracies in the assumptions do not materially affect the results. Therefore the stresses in a frame as given by the slope-deflection method will be very accurate.

While the slope-deflection method is long it could be used in the actual design of a building; but it has its greatest value as a standard by means of which the accuracy of the approximate methods may be determined.

The proposed approximate method is short, and except at points where there are large changes in the size of the members, gives results which are accurate enough to be used in the design of a building.

Discussion.

H. J. Burt, M. W. S. E.: The short time that has elapsed since these papers were issued to the members of the Society has not permitted a detailed study so that the discussions must be on general features of the problem. The writer is much impressed with the amount of labor involved in preparing the papers presented to us tonight. The authors have given some idea of the amount of time they have spent on this work, and it is certainly much more than most of us are willing to contribute to the good of the profession.

It seems reasonable to anticipate that some workable methods of computing wind stresses will result from these studies. It is not to be expected that the method of least work or the slope-deflection method will be applied directly to the computation of stresses in the design of a building, but that they will be used in the development of rules or methods easy of application which will closely approximate the correct results.

The writer understands from the statements made that both of the methods are correct. He would ask the authors whether the two methods give identical results when based on the same assumptions.

Prof. Smith: We have not actually compared them. I did not receive Prof. Wilson's paper until this morning, and I presume he is similarly at loss. We did some rough comparing last fall, and Prof. Wilson made some rough calculations as to the relation of the moments in various columns by our two methods of calculation, and found that they differed by about 3½%, but we had to reduce for different widths of bay to do that and in order to get that relation. Therefore we could not say they were within 3½%, but I think there is not the slightest doubt that the methods would check, just as a multiplication table would check.

Mr. Burt: Since the methods lead to the same results, future studies will doubtless be carried on by the slope-deflection method which is very much simpler than the method of least work. The suggestion that a committee of the Society be organized to take up this study is a good one. No doubt many of the members will be willing to assist under the direction of the authors, thus relieving the authors from the burden of the mathematical work involved. Furthermore committee discussions will establish the premises from which the most practicable results can be obtained.

The writer in his practice uses the approximate method designated by Prof. Smith as IV. It is gratifying to note from the values given in his Table I that this method compares favorably with the accurate method. It may be that further investigation will show this approximate method to be accurate enough for practical use. The writer suggests that Prof. Wilson make a comparison with method IV.

Both of the authors criticise the approximate methods. The comparisons made do not seem quite fair because they are not based on the same assumptions. If the accurate method of analysis were applied to a structure actually designed by one of the approximate methods it probably would show much closer agreement in the results. It may show that the resistance to the stress will be effective in whatever way it may be distributed, provided there is a continuous, rigid path from the point of application of the load to the foundation.

Consider a bent made up of any number of panels. It is common to utilize all columns and girders to resist the wind stresses, but it is not necessary to do so. All of the resistance may be in a single panel, or in the two end panels or in any number of panels. The stress will follow the easy path, that is the path of greatest rigidity, or will be divided among the several available paths in proportion to their rigidities. Assuming that the end panels only are braced, there is no reason for believing that the members in the intermediate panels will be overstressed, or even stressed at all (except as to direct compression in the girders).

The investigation should continue with the purpose of developing rules, methods or charts simple and accurate enough for everyday use.

J. G. Giaver, M. W. S. E.: As I received this paper only Saturday noon, less than two days ago, I have not had time to look it over carefully.

I have been engaged for many years in the designing of building structures. The method of figuring wind stresses in buildings has changed materially during these years. The present methods are much more complete than they used to be in earlier days, and if the methods as now used are wrong in some particulars, as pointed out by the authors of this paper, then I will say that in earlier days they were still more wrong; there can be no question about that.

When we look back over the development of building construction, it must be admitted that great progress has been made, especially in figuring wind stresses. So far as the basis of figuring other building stresses is concerned, this is not very new. The method used twenty years ago was very crude, we all know that, and still we find that structures designed in that period have refused to fall down in spite of the fact that the design for wind bracing was imperfect. Therefore, I feel sure that the structures which are built now can be considered perfectly safe.

It appears to me from Professor Wilson's statement that we should have to know the stiffness of each column before we could arrive at some result in regard to these columns' action in resisting wind pressure. In connection therewith we must remember that the columns have other loads to carry than wind loads. They have the direct load resulting from dead and live loads.

Owing to the fact that the New York Building Ordinance allows an over stress of 50% on account of wind, it was not necessary in the Equitable Building, which is thirty-eight stories high, to increase more than a few of the columns on account of stresses resulting from wind action. The New York Building Laws as well as the Chicago Building Laws allow the same amount of over stress from wind action, but there is a difference between the two laws, in that the New York Building Law requires us to figure the building for a wind pressure of thirty pounds per square foot of exposed surface, while the Chicago Building Law requires only twenty pounds per square foot. This lesser amount of pressure per square foot for Chicago was decided on after considerable discussion in a committee of which I was a member, at the time the new Structural Building Ordinance was framed for our city, and after having had information from the Government which indicated that the wind pressure as reckoned heretofore has been very excessive.

In the Equitable Building, as I stated before, there were only a few cases where we had to increase the column section on account of wind loads. Some of these columns were extremely heavy, weighing as much as a ton per lineal foot. The lower columns were up to thirty-four feet long. The area of these columns were determined in most cases by the actual dead and live load contributory to the column.

In the Equitable Building there were four interior wind bracing towers. These wind bracings were composed partly of diagonals and horizontals, and partly of girder bracings. In addition to this interior bracing system, the ends of the building had the girder spandrel bracing system, each of these six systems taking their given proportion of the wind load on the side of the building.

Professor Wilson has raised the question as to what value there was in the horizontal bracing of the columns at the sidewalk level. As a matter of fact I nearly always figure the columns down to the basement floor level, where I consider that all the horizontal forces from the wind action are taken up in the floor system and carried to the surrounding ground.

In the Equitable Building we had two and three story basements and a coffer-dam wall around the outside, this wall extending to the basement floor level. The outside columns were cantilevered over this coffer-dam wall. It therefore became natural to take this point as a fixed point and take up all the horizontal forces resulting from wind at the basement floor level.

Where we have a continuous reinforced steel or concrete wall, as we often have in Chicago, when designing a two or three story basement and these walls are reaching in one length from the lower basement to the sidewalk level, with the first floor beams connected to the same wall, steel to steel, we undoubtedly would be justified in figuring our columns for horizontal stresses, only to the first floor level instead of to the basement floor level. In this case the reaction would be taken up by the ground from the street level down.

I have recently utilized a new method in constructing these area walls, by using steel sheet piling in connection with I-beams of sizes to suit the case. I rivet an I-beam to every second piece of steel sheet piling and drive the combined section, thus forming a continuous steel wall around the entire building area. This steel wall is braced to first floor, basement floor, sub-basement floor, and subway floor, as the excavation is removed, and finally the steel is covered with concrete, presenting in its finished shape a solid concrete wall. Under such conditions also the wind strain in the columns could be figured to the first floor level only.

I wish to thank the authors of this paper for the great amount of work they have done in connection with their investigations and the final papers, and for having undertaken such a huge piece of work. It will undoubtedly lead to situations for which we have all been struggling for some time back, namely, a better understanding of the actions of wind on a building as well as the method of withstanding them.

No doubt the methods presented are a little cumbersome and complicated, as Mr. Burt remarked, for us who have to do this work in a very limited amount of time, which precludes the idea of going into very complicated computations such as these methods indicate. I have no doubt, however, that they can be simplified. Professor Wilson suggests that a shorter method and one which will be fairly accurate can be had and that would be the one which would appeal to me.

O. H. Basquin, M. W. S. E.: In most structures we are in the habit of thinking that a given system of loads will produce some one distribution of stresses in the various members of that structure and that no other distribution is possible. This proposition is not stated in either paper of the evening, but it seems to pervade both of them. In each we have tables that compare the results of different methods of calculation and the conclusion is that there is only one set of stresses that is correct. I do not wish to advocate inferior methods in preference to the accurate methods shown this evening, but I wish to point out the possibility of more than one solution in the case of a structure that is in process of design. This suggestion does not apply to a building that has been constructed or to one whose various members have been determined.

The distribution of wind stresses depends upon the relative stiffness of the various parts of a structure. The stresses may confine a few panels in a large building by making these panels particularly rigid by some method such as the insertion of diagonal bracing. It is evident, therefore, that different distributions of these stresses may be obtained by making different systems of members stiff.

Different methods of design are based upon different assumptions. These assumptions generally look very simple and straightforward. I suspect that one of the principal faults with the present practice in the design of wind bracing is that too little attention is really paid to the actual meaning of the underlying assumptions. It is my impression that these assumptions will be found to define the relative stiffness of the different members of the structure. It is fairly evident that the assumptions of Method IV fit the design of building that Professor Smith has been using. But if he had taken heavier girders in the interior bays, it is possible that the results of one of the other methods would have been nearer his accurate results.

Heretofore we have not been in a position to determine just what these underlying assumptions mean, except in certain simple cases. It strikes me that Professor Wilson's equations may be used to determine their full meaning, i. e., what shall be the relative proportions of the members of a building to give the results assumed in any particular method of calculation?

It seems to me, without having examined the question carefully, that the assumptions of Method IV describe better than those of the other methods the type of building that is most likely to be built. Method II seems to need a stiffer girder in the outside bays to give the extra shear to the outside column. Methods I and III seem to me require extra stiff girders throughout—stiffer than are likely to be built. In using any system, the designer must not only provide for the stresses which he calculates but he must provide for the proper distribution of stiffness in the various members as called for by his assumptions—otherwise the stresses will be quite different from those that he has calculated.

We are greatly indebted to Professor Smith and to Professor Wilson for the results of their scholarly work. It is fairly evident that they mark the beginning of a new day in the design of wind bracing, and I am delighted that this Society has the opportunity of presenting them to the engineering world. Each author has followed a method that is strictly accurate and if both methods were applied to the same building, they ought to give identical results.

Referring to Professor Smith's inquiry, it seems to me that wind stresses should, in general, be carried down to the column bases. The sidewalk reaction seems too uncertain to place any reliance upon. Even a party wall might be taken out at a later date if the adjoining buildings are acquired by the same owner. Attention may be called to the possibility of high bending stresses in basement columns, if the beams connecting them are riveted up when the temperature is very different from the average temperature that will be maintained in the building, thus pushing the end columns out or pulling them in.

Prof. Wilson: Mr. Giaver states that column sections are determined by the dead and live load stresses and not by wind load stresses. I realize that this is true. Wind stresses are important, not because of their effect upon the design of the columns but because of their effect upon the design of the girders and upon the design of the joints which connect the girders to the columns. When the sections of the columns and girders of a bent have been determined, if the joists are perfectly rigid the stresses at all points in the bent can be determined by mathematical laws. The stresses will have the values given by these laws unless the material is over stressed. Therefore, if a girder is put into a structure to resist the wind stress its section should be determined by that stress; and the joint which connects the girder to the column should be strong enough to resist the stress to which it is subjected. If one portion of a structure has a factor of safety that is too small the design is unsafe. If it has a factor of safety that is too large, the design is uneconomical.

Mr. Giaver also stated that while the present methods of designing buildings are much better than the methods which have been used in the past, the buildings designed by the older methods have not failed. That, of course, is true. But I believe that in the future the engineer will have to use more exact methods than have been used in the past. I think that secondary stresses are going to enter more and more in structural design. It is certainly not logical to use a factor of safety of four, and then say that the design is safe because the structure did not fail. If there is a factor of safety of only 1.1 in one member, the structure will not fail. But if a factor of safety of 1.1 is enough for one member it is enough for all members. The trend in structural design must be toward more exact methods. If present methods prevail expenditures must be incurred either to put excess material in members which can not be properly designed or to meet the expense of failure due to such members being made too light. Personally I would much prefer to employ an expert engineer and allow him as a fee a portion of the saving which he could effect.

The question has been raised whether Professor Smith's method and my method will check. Both methods are strictly exact except for errors in the assumptions upon which they are based. Both methods are based upon the same assumptions except that in my method it is assumed that the direct stress in a member does not change its length, whereas in Professor Smith's method the change in length due to direct stress has been considered. In the twenty-story bent shown in Fig. 1, this difference in assumptions will make a difference in the results in the bottom story not to exceed 3% or 4%.

I certainly favor the appointment of a committee to continue this investigation.

J. W. Lowell: Mr. Giaver spoke of factor of safety at the foundation and of disregarding pressure at the sidewalk level as being his method of design. I wonder if he is on the safe side. Would there not be higher stresses above the ground level if there is a force exerted at the sidewalk level than if there was not?

Professor Smith: I am not prepared to say. I suspect there would be. The very high reaction that might come at the sidewalk level (the sum of all the forces in the building above acting upon the sidewalk level as a fulcrum) would cause an enormous force at that point, so that if no reaction were assumed at sidewalk, and the sidewalk beams happened to be stiff and actually delivered a reaction, stresses of a serious nature might be induced in the columns of the first basement story.

Mr. Giaver: I said it could be done. We always go, not to the foundation, but to the basement floor.

Where you have two or three stories below the level of the sidewalk, you have to make your floors below strong enough to resist the earth pressure from one side of the building to the other, and we sometimes do that by making a special floor for that purpose. We make a very heavy concrete floor. Sometimes those stresses from the earth pressure against the basement and sub-basement are much greater than the shear pressure, and we make our floors strong enough to take those forces.

Closure.

Professor Smith: In regard to the tests made at Columbus, which showed stresses due to temperature and no stress from wind, I am in doubt about the temperature stresses. I can not see that such stresses should be present in large amount. Wind stress with low velocities of wind is not to be expected. The partitions and the spandrel walls, thoroughly cemented in place, are of enormous stiffness compared to that of the columns. A light wind should produce no bending in the columns. The strength of these partitions and spandrels is, however, not great, and it seems certain that in a very severe wind their joints would be broken, and that thereafter their resistance would be very small.

Further tests would be likely to result also in negative results from wind, unless we could arrange to have a tornado delivered at the exact moment desired. Even then I do not know how one could determine exactly the wind loads on the building.

I think many designers are already placing more reliance on partitions and spandrel walls than they should, and tests showing negative results from wind would be mischievous in their effect.

Professor Basquin has spoken of the possibility of more than one solution in the case of a structure that is in process of design. This is true, and the necessary preliminary to any computation of the stresses, is an assumption in regard to the stiffness of the members. If then in the course of the design it becomes necessary to make the member so large that its stiffness becomes relatively greater than assumed, its stresses as computed will be in error, no matter how exact the computation.

The closer the assumptions are to the truth the more nearly correct the stresses. That is, the stresses worked out for actual column sections, as in Professor Wilson's computations, are exactly correct for loads as assumed. Now, if the area of one column be made unnecessarily large, and that of another smaller than indicated by the total stresses, the large column will get more than in the ideally correct solution and the smaller one less, but not in proportion to their variation from the ideal. The small column will thus be over stressed. If this departure is sufficient, the overstressing might be serious.

In members receiving very large direct stress in addition to the bending, the error is much more likely to be serious, since overstressing becomes dangerous at a much lower limit. For example, suppose one large and several small columns, receiving the same unit stress from direct load, and deflecting the same amount from wind load. The large column, with a large moment of inertia and a large distance to outermost fibers would receive from wind a much greater unit stress and for the possible maximum wind (which, observe, was not used in its design) would pass the elastic limit long before the smaller column. When the large column did so pass the elastic limit in its outermost fibres, the column would take on permanent set, the deflection of the whole series of columns would be increased, and the smaller columns would take increased load. This relation is not likely to occur in an office building frame because the distance to the outermost fibres is ordinarily about the same in all columns, but the parallel condition of unequal deflections due to inequality in the heights of contraflexure produces the same inequality of unit stress and might lead to similar results.

Prof. Wilson—Author's Closure: Mr. Burt suggests that the comparison of the approximate methods with the slope-deflection method given in Tables III to VII is not fair because the girders are not designed to resist the moment to which they are subjected as determined by the method in question. A second comparison of Method I with the slope-deflection method is given in Table VIII. In the bents of this table the moments of inertia of the girder sections are proportional to the bending moments as determined by Method I; whereas in the bents of Table VII the moments of inertia of the girders sections were fixed arbitrarily without reference to the bending moments to which the girders are subjected. A comparison of Tables VII and VIII shows that when the girders are designed to resist the stress to which they are subjected Method I is more accurate than when the girder sections are determined without reference to the stresses.

A similar comparison of Methods II and III show that they are more accurate when the girders are designed to resist the stresses to which they are subjected than when the girder sections are determined arbitrarily, but that they are still so inaccurate that they should never be used.

At Mr. Burt's suggestion I have compared Method IV with the slope-deflection method. The results of this comparison are given in Table IX. In the bents of this table the moments of inertia of the girder sections are proportional to the stresses to which they are subjected as determined by Method IV. It is very gratifying to note that with bents having certain stated proportions, method IV is quite accurate.

While methods I and IV are quite accurate when applied to

TABLE VIII

Effect of the Proportions of a Bent Upon the Accuracy of Method I.

All stories of A bent are identical and the shears on all stories are equal. All column sections are equal, the moments of inertia of column A and girder a are equal, and the ratio of the moment of inertia of girder a to the moment of inertia of girder b equals the ratio of the bending moment in girder a to the bending moment in girder b, as determined by method I.

For each bent the moments in the upper line are in per cent of W x h, and in the lower line are in per cent of the moment as determined by the slope-deflection method.

Bent No.	Proportions of Bent		Moment: Top and Bottom Column "A"		Moment: Top and Bottom Column "B"		Moment: Right End Girder "a"		Moment: Left End Girder "a"		Moment: End Girder "b"	
			Slope-Deflection Method	Method I	Slope-Deflection Method	Method I	Slope-Deflection Method	Method I	Slope Deflection Method	Method I	Slope Deflection Method	Method I
1	Height Story = 2×Width Bay "a"	Width Bay "a" = 2×Width Bay "b"	9.75 100.0	9.62 98.8	15.25 100.0	15.38 100.5	19.50 100.0	19.24 98.8	16.05 100.0	19.24 120.0	14.45 100.0	11.52 79.6
2		Width Bay "a" = Width Bay "b"	9.6 100.0	7.5 78.1	15.4 100.0	17.5 113.6	19.2 100.0	15.0 78.1	15.6 100.0	15.0 96.1	15.2 100.0	20.0 131.5
3		Width Bay "a" = 1/2 Width Bay "b"	9.45 100.0	5.00 52.9	15.55 100.0	20.00 129.0	18.9 100.0	10.0 52.9	15.10 100.0	10.0 66.30	16.0 100.0	30.0 187.5
4	Height Story = Width Bay "a"	Width Bay "a" = 2×Width Bay "b"	9.05 100.0	9.62 106.2	15.95 100.0	15.38 96.2	18.1 100.0	19.24 106.2	15.7 100.0	19.24 122.5	16.20 100.0	11.52 92.6
5		Width Bay "a" = Width Bay "b"	8.85 100.0	7.50 84.8	16.15 100.0	17.50 108.3	17.70 100.0	15.0 84.8	15.2 100.0	15.0 98.8	17.1 100.0	20.0 117.0
6		Width Bay "a" = 1/2 Width Bay "b"	8.60 100.0	5.00 58.0	16.40 100.0	20.0 122.0	17.20 100.0	10.0 58.1	14.7 100.0	10.0 68.0	18.1 100.0	30.0 165.8
7	Height Story = 1/2 Width Bay "a"	Width Bay "a" = 2×Width Bay "b"	8.55 100.0	9.62 112.5	16.45 100.0	15.38 93.2	17.1 100.0	19.24 112.5	15.8 100.0	19.24 122.0	17.1 100.0	11.52 67.3
8		Width Bay "a" = Width Bay "b"	8.30 100.0	7.50 90.3	16.7 100.0	17.5 105.0	16.6 100.0	15.0 90.4	15.2 100.0	15.0 98.8	18.2 100.0	20.0 110.0
9		Width Bay "a" = 1/2 Width Bay "b"	8.0 100.0	5.0 62.5	17.0 100.0	20.0 117.5	16.0 100.0	10.0 62.5	14.6 100.0	10.0 68.5	19.4 100.0	30.0 154.8

TABLE IX

Effect of the Proportions of a Bent Upon the Accuracy of Method IV.

All stories of a bent are identical and the shears on all stories are equal. All column sections are equal, the moments of inertia of column A and girder a are equal, and the ratio of the moment of inertia of girder a to the moment of inertia of girder b equals the ratio of the bending moment in girder a to the bending moment in girder b, as determined by method IV.

For each bent the moments in the upper line are in per cent of W x h, and in the lower line are in the per cent of the moment as determined by the slope-deflection method.

Bent No.	Proportions of Bent		Moment: Top and Bottom Column "A"		Moment: Top and Bottom Column "B"		Moment: Right End Girder "a"		Moment: Left End Girder "a"		Moment: End Girder "b"	
			Slope-Deflection Method	Method IV	Slope-Deflection Method	Method IV	Slope Deflection Method	Method IV	Slope Deflection Method	Method IV	Slope Deflection Method	Method IV
1	Height Story = 2×Width Bay "a"	Width Bay "a" = 2×Width Bay "b"	9.09 100.0	8.33 91.8	15.91 100.0	16.66 104.5	18.18 100.0	16.66 91.7	13.62 100.0	16.66 122.1	18.20 100.0	16.66 91.5
2		Width Bay "a" = Width Bay "b"	10.0 100.0	8.33 83.3	15.00 100.0	16.66 111.1	20.00 100.0	16.66 83.3	16.66 100.0	16.66 100.0	13.33 100.0	16.66 125.0
3		Width Bay "a" = ½Width Bay "b"	10.89 100.0	8.33 76.8	14.13 100.0	16.66 117.8	21.74 100.0	16.66 76.6	19.56 100.0	16.66 85.20	8.70 100.0	16.66 191.5
4	Height Story = Width Bay "a"	Width Bay "a" = 2×Width Bay "b"	8.09 100.0	8.33 103.2	16.91 100.0	16.66 98.3	16.18 100.0	16.66 103.0	13.22 100.0	16.66 126.0	20.60 100.0	16.66 80.9
5		Width Bay "a" = Width Bay "b"	9.38 100.0	8.33 88.8	15.62 100.0	16.66 106.4	18.76 100.0	16.66 89.9	16.64 100.0	16.66 100.0	14.60 100.0	16.66 114.0
6		Width Bay "a" = ½Width Bay "b"	10.53 100.0	8.33 79.2	14.47 100.0	16.66 115.0	21.06 100.0	16.66 79.1	19.74 100.0	16.66 84.4	9.20 100.0	16.66 181.0
7	Height Story = ½Width Bay "a"	Width Bay "a" = 2×Width Bay "b"	7.32 100.0	8.33 113.9	17.68 100.0	16.66 94.2	14.64 100.0	16.66 113.8	12.96 100.0	16.66 128.7	22.40 100.0	16.66 74.4
8		Width Bay "a" = Width Bay "b"	8.93 100.0	8.33 93.3	16.07 100.0	16.66 103.7	17.86 100.0	16.66 93.3	16.69 100.0	16.66 100.0	15.45 100.0	16.66 107.8
9		Width Bay "a" = ½Width Bay "b"	10.33 100.0	8.33 80.7	14.67 100.0	16.66 113.5	20.66 100.0	16.66 80.6	19.74 100.0	16.66 84.4	9.60 100.0	16.66 173.5

certain bents they may be quite inaccurate when applied to other bents. In all of the bents of Tables VIII and IX columns A and B have the same section. If these column sections are not equal, the methods will not be as accurate as Tables VIII and IX seem to indicate.

HISTORY OF THE BILL FOR A STRUCTURAL ENGINEER'S LICENSE LAW.*

During the year of 1908 there was begun a movement to obtain a law licensing structural engineers in the state of Illinois. Engineers were beginning to realize at that time that their field of endeavor was being limited by a law passed in 1897 licensing the practice of architecture and giving to architects the exclusive right to design and supervise buildings, defined as "structures having foundations, walls and roofs, with or without other parts."

A Legislative Committee was organized and it was determined to make an effort to obtain similar rights for the engineers. Counsel was engaged in 1910 and after thoroughly considering the matter it was decided to introduce two bills as amendments to the Architects' License Law. One of these bills provided for the appointment of structural engineer members to the Architects' Examining Board, and the other bill limited the examination strictly to engineering matters. These amendments were offered on the theory that the state had no right to require any examination except on engineering matters, and that the Architects' Law, if properly administered, would be satisfactory to engineers. The only objection to this lay in the fact that engineers would have to practice under the name of "Architects."

This action met severe criticism and the Architects were very much incensed that amendments to "their law" had been suggested. Of course, through ignorance it was thought that the laws belonged to the people of the state. However, it was made plain at that time that such was not the case and this knowledge has been the basis of action ever since. The principal advantage of this episode was in showing that the professional laws are regarded by the professions and, to a certain extent, by the legislature, as the exclusive property of the professions, and that it is useless to attempt the amendment of a law belonging to someone else.

As a result of this attempt several joint meetings were held with the architects, and they were found willing to consider and, as we thought, to come part way to meet the engineers' ideas and help them obtain a license law of their own. At that time it was decided that the right method would be to attempt to secure a law establishing a State Building Code and codifying the State Building Laws, it being understood that this code should be drawn so as to

*This article has been prepared by Mr. Andrews Allen, M. W. S. E., for the Legislative Committee.

make it possible to introduce an Engineers License Law at the same time.

Therefore, a bill providing for the appointment of a commission to revise and codify the State Building Laws was drafted and submitted to the Legislature. This bill was passed practically through our own efforts. Counsel was employed and the matter taken before a committee at Springfield, and everything possible was done to obtain the passing of this law in accordance with the agreement with the architects, it being understood that they would, at the proper time, help to obtain a license for the engineers. The understanding, however, was reciprocal and the agreement that was made with them was contingent upon the passage of the State Building Code. This is a point that the architects have wholly misstated in their recent propaganda.

The bill was passed at that time but vetoed by Governor Deneen on account of some technical constitutional objections that had been raised by the Attorney General. Therefore, it was necessary to wait two years and introduce it at the next legislature. The same procedure was again employed, and after the passage of the act it was signed by Governor Deneen. During all of this time the engineers did more than their share in carrying out the agreement with the architects.

In the appointment of the commission, Mr. Zimmerman, the State Architect, acted as the Governor's personal representative in the selection of the commission, and the engineers suggested the names of Mr. Armstrong and Mr. Baker, who were appointed by the Governor in connection with two architects, Mr. R. E. Schmidt and Professor Ricker, and a contractor, Mr. Jobst of Peoria. This commission had a preponderance of engineers as will be seen from the fact that Mr. Schmidt is himself an engineer as well as an architect. The commission did not have the results of its labor for submission to the next Legislature, and not until the present session has the Building Code been put in the shape of a bill. Now the architects appear to have entirely lost interest in the matter, partly, it is believed, because they are beginning to realize that a comprehensive Building Code means an end of their monopoly and Governor Dunne, while not opposed to the Building Code, so far as is known, is not committed to it as was Governor Deneen.

An effort was made by the architects during the former campaign to obtain from members of the Legislature pledges that they were in favor of a State Building Code, but the matter has not been carried any further, and the commission itself has had hard work in finding a member of the Legislature to introduce the bill. As a matter of fact, Prof. Baker advises that the work of the commission was practically carried through by its engineering members as the architects appear to have lost interest.

During the time preceding the introduction of the Engineers License Bill and the State Building Code it was understood between the engineers and the architects that the latter would try to make the engineering examination easy, with a view of relieving the conditions under which the engineers are laboring, until they could get a license of their own. This was embodied in a report of our Legislative Committee in which the Western Society was advised to wait until the present session of the Legislature before taking any definite steps.

Now the engineers find themselves facing a condition wherein the State Building Code has practically been dropped by the architects, who are, therefore, in no position to carry out their agreement They are at the same time circulating widely the fact that the engineers agreed with them in writing to a limited license. It is very true that the engineers did agree to a limited license at that time, but it was coupled with an agreement to enact a satisfactory Building Code, and one part of this agreement cannot stand without the other. Without the Building Code it is absolutely impossible to draw up a license law for engineers, limiting the kinds of buildings which they have the right to design.

The work of the Legislative Committee during the present year speaks for itself. It has prepared a License Law, giving engineers the same rights now enjoyed by architects in the design and supervision of buildings. The members of the committee are working hard for the passage of this act and would like to see every engineer in the state get behind the movement and do what he can.

BOOK REVIEWS

THE BOOKS REVIEWED ARE IN THE LIBRARY OF THE SOCIETY.

DESIGN OF STEEL BRIDGES, Theory and Practice, for the Use of Civil Engineers and Students. By F. C. Kunz, C. E. McGraw-Hill Book Co., 1915. Green cloth, 6x9 in., 472 pages, illustrated, 52 plates. Price, $5.00 net.

The first five chapters, including one hundred and sixteen pages, of this book give a discussion of the external forces on different kinds of simple span bridges and the determination of the resulting stresses. The next five chapters, one hundred and twenty-one pages, are devoted to the general as well as the detailed design of these simple structures. Chapter XI treats wholly of the weights of bridges, and throughout the book much attention has been given to this subject. Chapters XII, XIII, XIV, and XV treat of the stresses in and the designing of viaducts, elevated railroads, movable bridges and turntables, and arch bridges, respectively. These four chapters take up one hundred twenty-four pages. Chapter XVI discusses long span bridges in general, giving examples, and Chapter XVII, the closing chapter, is devoted to the stresses in and the design of cantilever bridges. In the appendix, besides many tables and other information, is printed the first part, design of the Specifications of the American Railway Engineering Association.

There are fifty-two plates giving stress sheets, influence lines, elevations of existing bridges, and many detail drawings, but no shop drawings. Most of the plates are large and folded in the back of the book, but a few of them are placed in the body of the book adjacent to the matter that they illustrate. In addition there are many figures, all of them well executed.

The simpler problems in the determination of stresses are treated briefly, and in places the style is much like that of a hand book. Increased space is given to the more complicated problems. In the chapter on arches the theory is fully developed and examples solved. Both algebraic and graphic methods are used in the determination of stresses. Influence lines are used in the graphic solution of stress problems.

The author has used freely in this book a great wealth of information that has been at his command. The information has been so arranged as to be easily accessible, and the book will appeal particularly to the practical engineer and the advanced student as a valuable reference work. M. B. W.

CENTRIFUGAL PUMPS. By R. L. Dougherty, Assistant Professor of Hydraulics, Sibley College, Cornell University. McGraw-Hill Book Co., New York, 1915. Green cloth, 6x9 in., 192 pp., illustrated. Price, $2.00 net.

This book has a special appeal for the practical man who wants to know how rather than why, that is, the construction and operation of centrifugal pumps are treated in such a manner as to be exceedingly valuable to the practical man while only the essential theories are developed. The author undoubtedly knows centrifugal pumps, as is evidenced by the field he has covered under the descriptions of the various types. True enough he admits of considerable reference to trade catalogues, but this too is indicative of the vast amount of work necessary for the production of the volume.

In the introduction the author defines, classifies and gives the conditions of use for centrifugal pumps in their many forms, and also devotes considerable effort to an historical development leading up to the modern high speed, high-head pump of great capacity and power requirements. His descriptions of the different types and their essential parts is excellent, no important point being left uncovered by either text or illustration. Much more could have been said of the installation and operation of this important mechanism, although the author has, in a general way, covered the more important points of these features.

The discussion of the theory is sufficient to give an understanding of the application of moving vanes in imparting energy to a stream of water, and supplies the reader with all the information necessary for the solution of the common problems incident to the design and operation of this type of pump.

Numerous curves and diagrams are used in the chapter devoted to characteristics, and again impress one with the magnitude of the field covered in the collection of data. The author states in his preface that performance tests were made on 174 pumps made by 29 different companies, with an enormous range in number of stages, head, capacity, speed and efficiency.

The comparison of centrifugal pumps vs. displacement pumps, and of the various types of centrifugal pumps is interesting and very valuable to the layman. Costs are considered at some length but must be taken as only approximate and not sufficiently accurate for final estimates.

The volume is closed with chapters on design, application, and testing, with appendices giving methods of tests and tables useful in the solution of problems.

INTERNATIONAL TABLES OF CONSTANTS AND NUMERICAL DATA, PHYSICAL AND TECHNOLOGICAL. By the International Association of Academies and the International Committee nominated by the 7th Congress of Applied Chemistry (London, June 2, 1912). Original edition in German, English, French and Italian. Published by the University of Chicago Press and Messrs. Gauthier-Villars & Cie., Paris, 1914. Gray paper cover, 9x11 ins. Printed in two sections. Price of each section, francs 10:00, approx., $2.00.

Section B, Numerical Data of Electricity, Magnetism and Electrochemie, contains 79 tables divided into three parts: (1) Electricity, Magnetism by Dr. L. Mahlke, Hambourg, Germany; (2) Conductivity of Electrolytes by Prof. P. DuToit, Lausanne;

(3) Electromotive Forces by Prof. W. C. McC. Lewis, Liverpool. Data is given under the following heads: Electric conductivity, Variation of resistance with temperature and other factors, Thermo-electromotive force, Thomson effect, Dialectric constants, Electrostatic rigidity, Electric waves, Photo-electric effects, Magnetism, Ferromagnetism, Hysteresis, Magnetochemistry, Magnetic susceptibility, Magnetic rotation, Kerr effect, Magnetic berefringence, Hall effect, Conductivity of electrolytes, Aqueous solutions, Solvents, Specific and ionic conductivities, Transport numbers, Constants of disassociation, etc.

Section F, Engineering and Metallurgy, Resistance of Materials, and other data, contains 74 tables divided into three parts: (1) Engineering by Ing. G. Freck and Prof. W. Hinrichsen, Royal Testing Dept., Gross-Lichterfelde; (2) Metallurgy by S. L. Archbutt, National Physical Laboratory, Teddington; (3) Mechanical Constants by Ing. E. Nusbaumer and Ing. A. Portevin, Paris. Data is given under the following heads: Mechanical constants, Building materials (wood, cement-mortar, concrete, etc.), Fuels, Metals and alloys, Temperatures, etc.

These tables are of great value to scientists and engineers, containing rare data collected from the technical societies and state departments of the twenty-three nations which are members of the International Association of Academies. By their use much labor and time of research may be saved. An index printed in four languages makes the books universally useful and facilitates the work of locating the required information. C. F. B.

MACHINERY HANDBOOK for Machine Shop and Drafting Room. A reference book on machine design and shop practice for the mechanical engineer, draftsman, tool maker and machinist. Fourth edition. The Industrial Press, New York, 1915. Black leather, 7x4½ in.; 1,400 pp., text and index; drawings, diagrams and tables. Price, $5.00.

This handbook is by far the most complete and extensive that has been produced. In fact that is its one drawback, for in this day of high specialization but few men will find use for its many parts in a life-time of reference. That the data presented is authentic is not to be doubted, as it represents the best work of the entire profession. Practically no problem in the theory or practice incident to the work of mechanical engineer or machinist is left untouched. The tables representing work and calculations of the most exacting character will undoubtedly save the user hours of tedious computation.

The newer departments are for the most part devoted to the machinist's problems and works of allied trades. The heat treatment and machining of steel is especially well covered in a manner easily comprehended by the man of average education. Speeds and feeds are given unusual attention, but make the book all the more valuable, as does the information on gearing with many tables having ready application in the shop and drafting room.

Another subject rarely covered by a handbook except in very superficial manner, is that of chains and sprockets. This handbook, however, goes into the subject with painstaking detail on all phases of the design and use. This information is extremely timely, owing to the increased use of this form of drive.

The mathematical section is almost a text-book, although unnecessary data has been very carefully weeded out. The tables of square, cubes, square roots and cube roots, section moduli, moments of inertia, deflections, logarithms, trigonometric functions, and many others too numerous to mention, are the most up-to-date so far presented in any book of like character. Examples of all problems likely to come up in practice and design are worked out in easy, understandable style, and are a great help to untrained men who are forced to work from a reference book in a short time.

All conversion tables, from metric to English systems, and vice versa, are given in excellent form, and not of least importance is a very complete index, which, through its completeness, makes the handbook especially usable.

PROCEEDINGS OF THE SOCIETY

Minutes of Meeting

April 5, 1915

A regular meeting of the Society (No. 897) was called to order by President Jackson at 8 p. m., Monday, April 5, 1915, with 220 members and guests in attendance.

The Secretary read the following elections to membership:

Harry J. Carton, Chicago........................Associate Member
F. S. Callender, Chicago........................Associate Member
Chas. N. Bainbridge, Chicago....................Associate Member
Chas. A. Jennings, Chicago..............................Member
Herman E. Beckman, Naperville...........................Member
Wm. R. Matthews, Chicago................................Member
Robt. H. Murray, Chicago................................Member
Wharton Clay, Chicago...................................Member
Elmer L. Andrews, Whiting, Ind..........................Member

Fred J. Lamotte, transfer to Junior.

And the following applications:
Albert McWayne, Chicago.
Herman N. Legried, Humboldt, Iowa.
Gardner S. Williams, Ann Arbor, Mich.
Edward Jackson Casse, Chicago.
Chas. U. Freund, Chicago.
Adrian K. Webster, Dawson Springs, Kentucky.
Leigh C. Curtis, Chicago.
Clifford H. Westcott, Chicago.
Le Roy Burrows Fugitt, Cushing, Oklahoma.
Webster D. Corlett, Oak Park.
Stanley E. Bates, Chicago.
Louis Spira, Chicago.
W. F. Hebard, Chicago.

President Jackson then introduced the speaker of the evening, Col. W. V. Judson, U. S. Army Engineer Corps, who had chosen as his subject "Engineering in War." His talk was well illustrated by lantern slides, some of which were from photographs taken during the Russo-Japanese War.

Discussion followed from Messrs. Ernest McCullough, L. S. Marsh, T. Milton, W. B. Jackson, F. H. Wright, Albert Reichmann and E. N. Lake, with answers and explanations by Col. Judson.

Mr. H. S. Baker as Chairman then read a progress report of the Committee on Civilian Military Reserve. That the sentiment of the meeting was in sympathy with the work and purpose of the committee was informally evidenced by a standing vote on important questions.

Two reels of motion pictures were then shown, one of which gave scenes from the present war in Europe; the other illustrated the several phases of U. S. Army life.

After a few announcements the meeting was adjourned at 10:20.

April 12, 1915

An extra meeting (No. 898) in the interests of the Bridge and Structural Section convened at 7:45 Monday evening, April 12, 1915, with 160 members and guests in attendance. Mr. H. C. Lothholz, Chairman of the Bridge and Structural Section, presided.

Following a few announcements regarding the Annual Student's Night to be held April 16th, Mr. Lothholz introduced Mr. W. S. Lacher, Assoc.

W. S. E., who read a paper on "The Pennsylvania Lift Bridge Over the Chicago River," which was prepared by W. L. Smith and W. W. Priest under the direction of J. C. Bland, Engineer of Bridges. Owing to the absence of the authors, there was no discussion.

Mr. Andrews Allen was then introduced and gave an illustrated talk describing the new coal mining plant of the American Coal Mining Company at Bicknell, Indiana. Discussion followed from Messrs. Lothholz, Whittaker, Jones, Smetters and Garcia.

Two reels of motion pictures showing how horse shoes are made, and a short talk by Ernest McCullough explaining some contested points in the work of the Legislative Committee, concluded the meeting at 10:10 p. m.

Minutes of Meeting

Extra Meeting, April 16, 1915

The annual "Student's Night" (an extra meeting, No. 899) was held Friday evening, April 16, 1915.

Mr. Ernest McCullough, First Vice-President of the Society, called the meeting to order at 8:15 with 300 members and guests in attendance.

The following men addressed the meeting on the determining factors of a successful career and other topics of special interest to students of engineering subjects:

B. F. Affleck, President, Universal Portland Cement Company.
Isham Randolph, Consulting Engineer.
E. H. Lee, Vice-President, C. & W. I. R. R.
W. H. Finley, Chief Engineer, Northwestern Railroad.
H. J. Burt, Structural Engineer, Holabird & Roche.
C. F. Loweth, Chief Engineer, C., M. & St. P. R. R.
C. A. Morse, Chief Engineer, Rock Island Lines.
Albert Reichmann, Division Engineer, American Bridge Company.
O. P. Chamberlain, Vice-President Dolese & Shepard Company.
H. S. Baker, Asst. City Engineer, Chicago.
W. W. DeBerard, Western Editor, Engineering Record.

At intervals throughout the program the Armour Institute Musical Clubs gave pleasing vocal selections.

The program was closed with motion pictures of Shooting an Oil Well, and Blowing Up the John Day Rapids, Columbia River.

At 10:45 the meeting adjourned for refreshments.

April 26, 1915.

An extra meeting (No. 900) being a joint meeting of the Electrical Section, W. S. E., and the Chicago Section of the A. I. E. E., was convened at 8:15 Monday evening, April 26, 1915, with Mr. E. W. Allen, chairman of the Chicago Section, A. I. E. E., presiding and 120 members and guests in attendance.

Mr. W. L. R. Emmet was introduced and gave a lantern slide talk on Electric Ship Propulsion.

Discussion followed from Mesrs. King, Adams, Roper, Cook, Taylor, Randolph and others, with a closure by Mr. Emmett.

After motion pictures showing the importance of potash in soil fertilization the meeting adjourned for refreshments at 10:35.

LIBRARY NOTES

The library committee desires to return thanks for donations to the library. Since the last publication of the list of such gifts, the following publications have been received:

NEW BOOKS.

McGraw-Hill Book Co.:

Centrifugal Pumps, R. L. Daugherty. Cloth.
Engineering Economics, J. C. L. Fish. Cloth.
Tunneling, Eugene Lauchli. Cloth.

MISCELLANEOUS GIFTS.

University of Chicago Press:

Annual Tables of Constants and Numerical Data, Chemical, Physical, and Technological. Engineering and Metallurgy; Electricity, Magnetism and Electrochemistry. 2 books, boards.

C. L. Strobel,, M. W. S. E.:

American Legislation Review, Vol. V, No. I, March, 1915. Pam.

F. L. Woodworth, Lansing, Mich.:

Michigan, the Land of Plenty. Paper.

Barclay Parsons and Klapp:

Report on Detroit Street Railway Traffic and Proposed Subway, 1915. Cloth.

EXCHANGES.

Canada Department of Mines:

Report on the Building and Ornamental Stones of Canada, Part III. Pam.

Economic Minerals and Mining Industries of Canada. Paper.

The Physical Properties of the Metal Cobalt. Pam.

Report on the Non-Metallic Minerals used in the Canadian Manufacturing Industries. Paper.

Peat, Lignite, and Coal. Paper.

Preliminary Report on the Mineral Production of Canada in 1914. Pam.

New York Public Service Commission, First District:

Annual Report, 1913, Part I. Cloth.

Western Railway Club:

Proceedings, Vol. 26, 1913-14. Cloth.

Connecticut Public Utilities Commission:

Annual Report, 1914. Cloth.

North Carolina Geological Survey:

Biennial Report of State Geologist, 1913-14. Paper.

City of Portland, Maine:

Annual Reports. Commissioner of Public Works, 1911-12-13. 3 pams.

American Gas Institute:

Proceedings, 1914. 2 cloth.

April, 1915

RULES FOR ESTABLISHMENT OF BRANCH ASSOCIATIONS OF THE WESTERN SOCIETY OF ENGINEERS.

(1) Branch Associations of the Western Society of Engineers may be established by the adoption of a Constitution, which shall be approved by the Board of Directors, and by organization of the proposed Branch Association thereunder.

(2) Said Constitution shall provide:

- (a) That all members of the Branch Association shall be members, in good standing, of the parent body.
- (b) That all fees and dues assessed by the Branch Association against its members shall be in addition to regular fees and dues required by and paid to the parent body.

(3) A copy of the minutes and proceedings of each meeting of the Branch Association shall be filed with the Secretary of the Western Society of Engineers within ten days after the meeting.

(4) The Western Society of Engineers may publish in the Journal such proceedings of the Branch Association as shall be approved by the Publication Committee.

Journal of the Western Society of Engineers

VOL. XX MAY, 1915 No. 5

SOCIETY ACTIVITIES

In each issue of the Journal, under the heading of Society Activities, the membership will be advised of the various new developments in general society affairs, committee work, etc.

MEMBERSHIP.

Since the last report the following additions to membership have been made. The applications for the year now number seventy-six.

ADDITIONS.

Corlett, Webster D., Oak Park, Ill.............Junior Member
Curtis, Leigh G., Chicago............................Member
Freund, Charles U., Chicago................Associate Member
Fugitt, LeRoy B., Coffeyville, Kas...........Associate Member
Hebard, W. F., Chicago......................Affiliated Member
McWayne, Albert, Chicago.................Associate Member
Webster, Adrian K., Dawson Springs, Ky.......Junior Member
Westcott, Clifford H., Chicago.................Junior Member
Williams, Gardner S., Ann Arbor, Mich...............Member

NEW APPLICATIONS.

Edwin G. Birren, Chicago.
Henry C. Wendorf, Chicago.
Thure W. Ingemanson, Chicago.
Ralph G. Culbertson, Ridgeville, Ind.
Harry E. Connors, Chicago.

THE STUDENT INTEREST

Of late years there has been a growing tendency to give more attention to the young engineers and students in engineering courses. In no better way has the value of this work been evidenced than by the interest in the Western Society shown by engineering students of Northwestern University, Lewis Institute and Armour Institute during the past several weeks.

For several years many of the members have urged that a special effort be made to bring the work of the society before engineering students, but the real response seems to have begun with the Annual Student's Night which was held last month. At this meeting nineteen students made application for membership and as many more asked for application blanks for future use. After the meeting several members met with the students and formulated plans for future extension in the universities in and around Chicago, which plans seem to be well started and generally approved.

Concerning the student's opinion as expressed in the April FULCRUM, the Student Publication of Armour Institute, we quote as follows:

"The Western Society has that fortunate ability of making students in college feel at home among their superiors in age and experience, with the result that the student gets an insight into the profession which he has adopted, and due to his contact with men who have made a success in the profession, develops a broader outlook upon his life-work.

The point which is of the most potential interest to Armour men, however, is the fact the student membership in the Western Society of Engineers is open to Junior and Senior undergraduates in engineering schools of recognized standing. A large number of the two upper classes have taken advantage of this fact and have placed their applications for membership. Considering the quickness with which these men have perceived the value of a connection with such an organization as the Western Society of Engineers and the interest which is bound to result from such a perception, it has been proposed by the Western Society, after a serious consideration of the subject, that the men who have placed applications for membership, and any other members of the Junior and Senior classes who do so hereafter, form themselves into a student branch of the Western Society. It was further proposed that the present departmental engineering societies affiliate themselves with this student branch, thus welding the interests of the members, not as mechanicals, civils, or electricals, but as **engineers**, into one organization with one aim, and connected with a firmly established, well-balanced organization like the Western Society. The obvious advantages would be mutual, and, as far as we are concerned at least, would be of utmost value. The proposition was enthusiastically received, and will undoubtedly develop rapidly, now that it has once taken root."

Such a keen understanding and appreciation of this Society's work, if intensified and extended, will be the realization of one of our members' highest ideals. Too often is it difficult to impress the engineering student with the importance of a broad acquaintance in his profession. Too often is it discouraging when the older engineer tries to convince the beginner of the value of the first hand information to be gained from society meetings. But apparently this work is about to become easy, for the student has heeded this wise counsel and now takes it upon himself to carry advice to his fellows.

Without doubt the Western Society has the unqualified support of its student membership. The field for expansion presented by the many technical schools in our vicinity is practically unlimited. The future of the Society lies in its young men and their futures depend upon their environments and connections of the first few years. The time for cooperation is here and the members of the Western Society should make every possible effort to further the move.

MONDAY EVENING DINNERS

On the notices sent out for the meeting of May 10th it was announced that, in accordance with the wishes of several members, those members who so desired would meet at Thompson's Oyster House in the Great Northern Hotel Building and take dinner together before the meeting. About forty members took advantage of this opportunity to get together and talk about society affairs and engineering news in general and to renew neglected acquaintances. Without qualification the event was a success and was a means of bringing a few members to the meeting who otherwise might not have come. So much so was it a success, that another dinner was scheduled for the next week with the result that most of the old and many new faces were seen across the tables.

So far the idea is generally accepted as a good one and promises to grow in popularity. It gives the members a chance to become acquainted outside of the engineering world and to get the other fellow's ideas on society matters. Furthermore it is a pleasant way of spending the otherwise dull period between the close of business and the opening of the meeting.

Each member who possibly can should attend these little dinners. They are absolutely informal and everybody is invited. Bring your friends along and let them get acquainted with the work we are doing. Look for the announcement of the meeting place on the bottom of the weekly notice cards.

PROF. NEWELL'S TALK ON THE RECLAMATION SERVICE

At the meeting of May 17th the spirit was generally that of a welcome to Professor F. H. Newell, the newly appointed head of the Civil Engineering Department at the University of Illinois.

Prof. Newell was scheduled to address the meeting on "Co-operation Among Engineers," but did not limit himself to this subject. Instead, after a few remarks concerning the place of the engineer in the business world and the function of engineering societies in gaining this place for its members, the speaker took up the subject of "Reclamation."

Prof. Newell is eminently well fitted to discuss this important subject, having been consulting engineer for the Reclamation Service for several years. In the development of his subject the speaker described in detail the more interesting features incident to the construction of dams, irrigation ditches and canals, illustrating each point with colored lantern slides.

Owing to the fact that this talk was so interesting pictorially ladies were invited to hear Prof. Newell. Their response was very gratifying and the society is assured that they greatly enjoyed the evening.

APPORTIONMENT OF COST OF HIGHWAY BRIDGES BETWEEN STREET RAILWAYS AND CITIES

By Charles M. Spofford.*

Presented May 10, 1915.

The careful scrutiny of public service corporations exercised by legislative bodies in recent years, with the resulting demand for valuation of the property of many of these corporations for purposes of taxation or rate making, has brought many engineers into active touch with problems of valuation, as is evidenced by the numerous papers dealing with work of this character which have recently appeared in publications of engineering societies. It is with the purpose of bringing before the Western Society of Engineers certain problems of this character that this paper has been prepared. It should be understood, however, that the paper is based entirely upon laws, conditions and practices existing in the State of Massachusetts where the writer's experience in such cases has been gained. That some of the conclusions reached may not apply to other states is obvious.

The transformation of street cars within the last twenty-five years from light-weight horse cars weighing no more than heavy trucks and drays, to large power-driven vehicles, frequently weighing forty or fifty tons and sometimes as much as seventy-five tons, has compelled the strengthening of many existing highway bridges otherwise adequate for all traffic, and has made it necessary to build new bridges of sufficient strength to carry these loads. The necessity of strengthening at their own expense existing bridges to provide for heavy cars was long ago forced upon the street railway corporations of Massachusetts by their inability to operate on some of their important lines, cars of a type which tests upon other lines had proven to be economical. This necessity is well illustrated by the strengthening of various bridges by the Boston Elevated Railway Company, a corporation controlling practically all the street car traffic in the city of Boston.

Perhaps the most important example of this is the repairs to the Boylston Street Bridge across the Boston and Albany Railroad made by the railroad company at a cost of $60,000, following the recommendation of the writer. As the conditions at this structure were somewhat unusual and the solution a novel one, the brief description which follows may prove of interest even if not strictly pertinent to the subject-matter of this paper.

Boylston Street crosses the four-track main line of the Boston

*Hayward Professor of Civil Engineering, Massachusetts Institute of Technology; also of Fay, Spofford & Thorndike, Consulting Engineers, 308 Boylston Street, Boston, Mass.

and Albany Railroad at an angle of 19° between centre lines of highway and railroad location, thereby necessitating a span of 216 feet centre to centre of end pins with such a sharp skew that the easterly end of one truss is only 67 ft. 6 in. from the westerly end of the other truss. This condition is clearly shown by the accompanying figure.

A through bridge with this skew would be impracticable without a central truss owing to the great length of the end portal, and even with a central truss would be unsightly. This difficulty was overcome by building two pairs of trusses—one pair on each side of the roadway. The trusses of each pair were 6 ft. 0 in. centre to centre, and were well braced together, thus giving lateral stability which an ordinary pony truss bridge would not possess, and at the same time avoiding unsightly overhead bracing. The bridge thus constructed was eminently stable, so far as lateral vibration was

Fig. 1. Boylston Street Bridge, Boston, After Strengthening.

concerned, but the trusses were a little too shallow to insure freedom from vertical vibration.

To strengthen the bridge for street railway purposes, an additional truss was built on each side between the original trusses, and new floor beams were inserted carrying the entire load of the street cars for the greater portion of the length of the bridge. The new trusses were so designed as to receive their load from the new floor beams only, the result being in effect that of providing a separate street railway bridge and thereby preventing vertical vibration due to the street cars from being felt on the sidewalks, which continued to be supported by the original trusses.

While street railways have been compelled either to strengthen existing bridges at their own expense or to forego the economies to be gained by operating heavy cars across them, no such compulsion has existed in the case of new bridges and it might seem as if the railways should be relieved from contributing toward their expense. Certainly the claim of the railways that the bridge is but a part of the highway on which they have the same right as others, and for the maintenance of which they pay a reasonable share in the form of taxes, is a legitimate one, and should be given due consideration. The fact, however, that trolley cars are so much heavier than other road vehicles, puts the companies under different obligations than other users of the bridges and makes it seem fair to assess upon them the extra expense required to provide for traffic of this character. This has been recognized by the Massachusetts Legislature, which has adopted in recent years the practice of providing for such assessments either by direct assessment, in advance of construction, of the amount to be charged to the railway, or by providing for its determination by a commission sitting after the bridge has been completed and the actual cost is known.

In examining the various legislative enactments of recent years in Massachusetts, one finds various acts authorizing new bridges and fixing an arbitrary proportion of the cost upon the street railways. Among such acts may be cited the following:

Chapter 359, Acts 1904. Newburyport and Salisbury Bridge (over Merrimac river). Street railway company 10 per cent.

Chapter 354, Acts 1905. "Cut" Bridge, Gloucester. Street railway company 10 per cent.

Chapter 486, Acts 1907. Central Bridge. An act relative to the construction of a bridge over the Merrimac river. City of Lawrence. Street railway company to pay 10 per cent.

Chapter 482, Acts 1909. Improving the bridge over the outlet of Strait's Pond in the towns of Hingham, Cohasset and Hull. County of Plymouth 55-2/3 per cent, County of Norfolk 28-1/3 per cent, Old Colony Street Railway Company 15 per cent. The railway company has only a single track on this bridge.

Chapter 739, Acts 1911. Hingham and Weymouth Bridge (over Weymouth Back River). Construction apportionment, Commonwealth of Massachusetts 45 per cent, County of Norfolk 20 per cent, County of Plymouth 20 per cent, street railway 15 per cent. Street railway now has single track location over said bridge.

Chapter 412, Acts 1913. Winthrop Bridge. Street railway company to pay 15 per cent of the cost of construction for the privilege of using the bridge, provided a location is granted.

Chapter 787, Acts 1913. Bridge over Lake Quinnsigamond between Worcester and Shrewsbury. Street railway to pay 25 per cent of the cost of construction.

Chapter 771, Acts 1913. Granite Avenue Bridge. Street railway company to pay 25 per cent of the original cost of the bridge for the privilege of using same, provided a location is granted. (No street railway has yet applied for location on this bridge.)

It is evident from the foregoing that the assessment by statute of street railways to pay for the cost of new bridges has varied in

Massachusetts from a minimum of 10 per cent to a maximum of 25 per cent, the variation being probably due to the intensity of the desire of the street railway to operate heavier cars or to obtain new locations and to the arguments put before the Legislature by the interested parties. Such a method of determining the proportionate share to the railway may be reasonable in many cases, particularly if the total cost involved is comparatively small, and furnishes an excellent solution if each party agrees in advance upon its share.

The acts and resolves of the Massachusetts Legislature relating to grade crossing abolition specify in the case of the elimination of a crossing involving a street railway that the latter may be assessed an amount not exceeding 15 per cent of the total cost. (Chapter 429, Acts of 1909, Section 34.)

In contrast to the method of determining by legislative enactment the share which the street railway shall pay toward the cost of new highway bridges over which it may wish to operate its cars, may be placed the method which has been adopted in the case of several large bridges in Massachusetts and vicinity, of determining the cost by hearings before a commission appointed by the court to decide upon the just and equitable charge to the street railway company. In cases of this sort, the engineer's services as an expert witness are needed, and the primary purpose of this paper is to present the questions at issue, to consider these questions and to present the decisions reached in certain of such cases. In order to set forth clearly points which may arise in such an investigation, the following list is given in which the writer has attempted to include all the elements entering into the problem which may influence the decision.

1. Type of Structure.
    (a) Temporary bridge.
    (b) Ordinary permanent structure.
    (c) Monumental structure.
2. Additional Dimensions due to Street Railway.
    (a) Width.
    (b) Length.
3. Additional Strength due to Street Railway.
    (a) Superstructure.
    (b) Foundations.
    (c) Impact and future increase in loads.
4. Additional Cost due to Street Railway.
    (a) Variation with increased width.
    (b) Variation with increased strength.
5. Additional Convenience to Street Railway.
    (a) Increased speed of operation of railway.
6. Decreased Cost to Street Railway of Maintenance and Operation.

The various items mentioned in the above list will now be considered in detail.

1. *Type of Structure.*—(a) and (b) Temporary vs. Permanent Bridge. The dead weight of a temporary bridge would ordinarily be much less than that of a permanent structure built to carry the same loads. It may be designed with higher unit stresses; permanent paving can be omitted, and piers and abutments may consist of pile trestles. Its width need be only sufficient for the immediate needs of traffic, and in case other bridges exist within a reasonable distance, very heavy drays and trucks may be prohibited from using it. The influence of heavy street car loads on the cost of such a bridge is evidently much greater in proportion than would be the case on a more permanent bridge, with its heavier dead load.

(c) Monumental Structure. If the structure is to be of a monumental type with towers, carving and other ornamental features, it would seem at first thought as if no part of such ornamental work could be legitimately charged to the railway. Further consideration, however, shows that the scale of the towers, carving and other ornamental features may be a function of the width of the bridge, and if increased width is necessary to provide for street car traffic, additional expense for this purpose may legitimately be incurred. Such a proposition was suggested in the Cambridge Bridge apportionment case which is referred to later.

2. *Additional Dimensions.*—Whether any material increase in width to provide for street car traffic is necessary, depends upon the density of the traffic. If the street car service is infrequent, there would seem to be no reason for increasing the width of the bridge to provide for street cars other than by the slight amount necessary to provide safe clearance for crowded street cars. Ordinary traffic can readily run on the portion of the bridge occupied by the track with little or no delay, and space for extra lines of traffic need not be provided. An example illustrating such a case is the Meridian Street Bridge of Boston. The apportionment of the cost of this bridge to the street railway was referred to a commission. Before the case came to a hearing, however, it was agreed upon both by the city of Boston, which the writer represented, and by the Boston Elevated Railway Company, that the proper distance centre to centre of trusses might be two feet six inches less for a bridge without street cars than for the bridge actually constructed which provided for two lines of street cars.

Another example illustrating the same case is the Chelsea North Bridge of Boston. Provision for four lines of traffic was evidently necessary on this bridge, but it was agreed by both sides before presentation to the Apportionment Commission, that a roadway forty feet wide between curbs, with trusses forty-four feet centre to centre, was required whether street cars were or were not to be operated, this space providing for four traffic lines. In consequence, no charge was made to the railroad for additional width.

In the case of the Cambridge Bridge, a monumental structure providing not only for ordinary street car traffic including surface cars, but also for a double track rapid transit line, a reservation was made along the centre of the bridge to be used exclusively for rapid transit trains. It is quite evident that in this case a marked increase in the width of the bridge was due to the provision for the rapid transit railway. The actual width required for this purpose,

Fig. 2. Cambridge Bridge.

however, was not agreed upon prior to the hearing before the Apportionment Commission, and the railroad argued successfully that while the space out to out of curbs protecting their tracks amounting to twenty-seven feet might be a legitimate increase in the width of the bridge, they should not be charged for the entire space occupied by the curbs, particularly as one curb might have been omitted by placing their reservation to one side instead of in the centre of the structure. A summary of this case giving the finding of the Commission follows at the end of this paper.

In order to determine the proper width of a bridge with or without street car traffic, the following statistics concerning widths of vehicles, bridges and streets may prove useful.

Street Cars.—Ordinary street cars operated in Boston are eight feet wide. The extreme width of the widest car is 8.79 feet. The distance between centres of tracks as specified by the Massachusetts Public Service Commission is 9.71 feet. The clear width required by two lines of the widest cars is, therefore, 8.79 + 9.71 = 18.5 feet.

Horse-Drawn Vehicles.—The width of such vehicles as measured in the streets of Boston is given in the following table in which (a) = distance out to out of hubs; (b) = distance out to out of wheels; (c) = distance out to out of whiffletrees.

	(a)	(b)	(c)
Hay Wagon	7.75	7.00	8.00
Heavy Express	7.65	6.70	7.90
Heavy Express	7.80	6.70	7.60
Ice Wagon	7.40	6.60	7.00
Hack	6.08	5.25	6.83
Coal Wagon (3 horse)	8.50	...	10.83

†Motor Cars.—Maximum width now in use, 10 feet.

WIDTHS OF VARIOUS BRIDGES WITH STATISTICS CONCERNING TRAFFIC.

*Brooklyn Bridge.—Width of roadway. Two roadways at 16 ft. 9 in. each between curbs, with single street car track on each.

Traffic in 1909. Surface cars, round trip, 1,489,364; average per day, including Sundays, 4,080 single trips. Other vehicles, 1,525,262; average per day of twenty-four hours, including Sundays, 4,179.

*Manhattan Bridge.—Width of roadway. One roadway at 35 ft. without street car tracks.

Total roadway vehicle traffic in 1910, 918,535; average per day, including Sundays, 2,516.

*Williamsburg Bridge.—Width of roadway. Two roadways 19 ft. 11¼ in. each between curbs, without street car tracks.

Total roadway vehicle traffic in 1909, 1,673,333; average per day, including Sundays, 4,584.

*Queensboro Bridge.—Width of roadway. One roadway 35 ft. 1½ in. clear with space for street cars on either side, giving a total width of 53 ft. 2½ in.

Traffic in 1910. Surface cars, round trip, 296,301; average per day, including Sundays, 812 single trips. Other vehicles, 768,865; average per day, including Sundays, 2,107.

*Willis Avenue Bridge, New York.—Width of roadway, 42 ft. 0 in. between curbs, without street cars.

Total vehicle traffic in 1911, 1,980,490; average per day, including Sundays, 5,426.

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†See "Motor Truck Loading on Highway Bridges," Engineering News, Vol. 72, 1914, page 492, et seq.

*These statistics are taken from the Annual Report for 1912 of the Department of Bridges of the City of New York.

Northern Avenue Bridge, Boston.—Width of roadway. Two roadways each 18 ft. 9 in. and one roadway at 18 ft. 6 in. between curbs. without provision for street cars. Traffic on February 27, 1913, between 7 a. m. and 6 p. m., 3,644 vehicles. The accompanying photograph shows traffic conditions on this bridge on a typical day in April, 1915.

Congress Street Bridge, Boston.—Width of roadway. One roadway 44 ft. 0 in. between curbs on fixed spans; 31 ft. 4 in. between curbs on draw-span. This bridge, including draw-span, is used regularly by three lines of vehicles. No street cars. Traffic on September 11, 1908, 7,362 vehicles.

Malden Bridge Draw-Span, Boston.—Width of roadway. Two

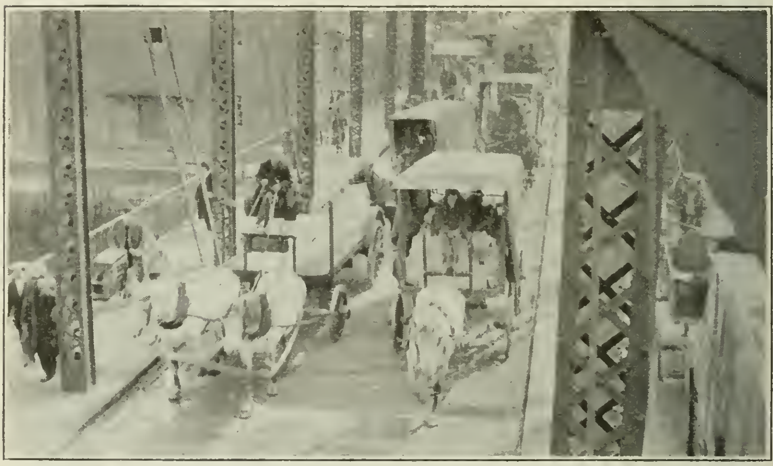

Fig. 3. Northern Avenue Bridge, Boston.

roadways each 19 ft. 6 in. between curbs, with street car track on each roadway. One line of traffic on each roadway in addition to street cars.

Broadway Bridge, Boston.—Width between curbs 40 ft. 0 in. with double track street railway. Traffic on March 8, 1915, from 6 a. m. to 10 p. m., 398 cars, 1,925 other vehicles. Four lines of traffic.

Meridian Street Bridge, Boston.—This bridge is a comparatively narrow structure, having a distance between trusses of 25 feet and between curbs of 21 ft. 3 in. The traffic across this bridge on September 10, 1912, between 6 a. m. and 10 p. m. consisted of 1,145 vehicles, including street cars.

Chelsea North Bridge, Boston.—Width between curbs, 40 ft. 0 in. The traffic across the bridge on September 5, 1912, between the hours of 6 a. m. and 10 p. m. consisted of 1,307 street cars and 2,018 other vehicles.

The following figures are from the 1911 Report of the London Traffic Branch of the Board of Trade and refers to traffic on one day in 1911 between 8 a. m. and 8 p. m.

Westminster Bridge, London.—Width of roadway in the clear, 54 feet. 14,618 horse and motor vehicles, including 2,975 electric tram cars.

Waterloo Bridge, London.—Width of roadway in the clear, 27 ft. 6 in. 10,192 horse and motor vehicles. No street cars.

Blackfriars Bridge.—Width of roadways in the clear, 73 ft. 6 in.

Fig. 4. Congress Street Bridge, Boston.

14,067 horse and motor vehicles, including 1,829 electric tram cars.

London Bridge.—Width of roadway in the clear, 37 feet. 13,771 horse and motor vehicles. No street cars.

Tower Bridge, London.—Width of roadway in the clear 35 feet. 9,552 horse and motor vehicles. No street cars.

In order to accurately measure the capacity of a bridge or street in relation to traffic, it is evidently necessary to consider the character of the vehicles and their speed as well as their number. For the purposes of making such a comparison, the London Board of Trade sets up as a unit a motor cab or carriage, and assigns the following numbers to other classes of vehicles.

Trade Vehicles.		*Passenger Vehicles.*	
1 Horse (fast)	3	Electric Trams	10
1 Horse (slow)	7	Omnibuses (horse)	5
2 Horse (fast)	4	Omnibuses (motor)	3
2 Horse (slow)	10	Cabs (horse)	2
Motor (fast)	2	Cabs (motor)	1
Motor (slow)	5	Carriages (horse)	2
		Carriages (motor)	1
		Barrows	6
		Cycles	½

The Board lays down the following definitions:

"Traffic Volume" at a point is the average aggregate number of traffic units attributable to vehicles which pass it per minute during the twelve hours from 8 a. m. to 8 p. m.

"Average Traffic Density" is the aggregate number of traffic units attributable to vehicles which pass the point during the twelve hours, per minute, per ten feet of available carriageway.

"Greatest Traffic Density" is the average density per minute, per ten feet of available carriageway, during the busiest hour, expressed in traffic units.

With the above units and definitions in mind, the following comparison of traffic on London Bridges is clear.

	Westminster Bridge	Waterloo Bridge	Southwark Bridge	Blackfriar's Bridge	London Bridge	Tower Bridge
Traffic volume	91.4	60.5	105.9	16.6	89.2	84.7
Average traffic density	20.3	22.0	14.4	5.8	24.1	24.2
Hour of greatest density	6-7	5-6	6-7	....	11-12	11-12
Density of that hour	23.8	22.5	15.3	....	27.4	27.9
Average vehicles	4.2	3.9	5.0	4.1	4.0	6.0

In connection with the width of bridges it should be remembered that the capacity of a bridge in vehicles per hour is considerably greater than that of the ordinary city street due to the freedom from interruption by traffic on intersecting streets and by vehicles stopping at the curb to discharge and receive freight or passengers.* It is evident that the width of bridges on curves may have to be increased greatly to provide proper clearance for street cars.

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*For example, the effective width of the roadway of Boylston Street, Boston, by actual measurements is not more than 36 feet, the vehicles standing at the curb requiring at least 14 feet. See Fig. 8.

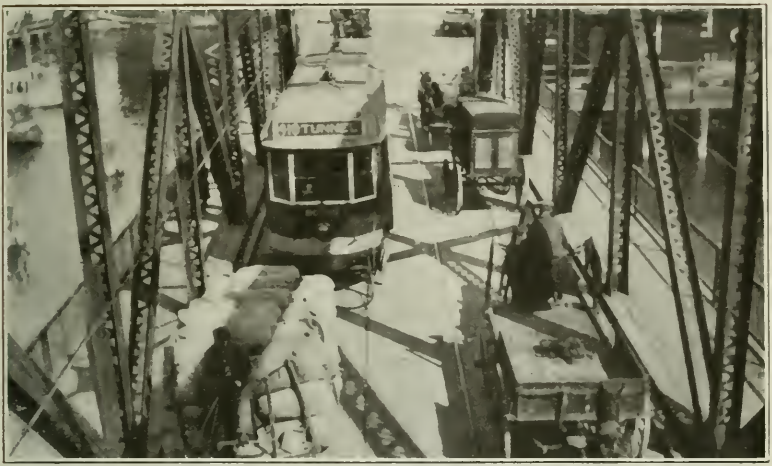

Fig. 5. Meridian Street Bridge, Boston.

Fig. 6. Chelsea North Bridge, Boston.

WIDTHS OF VARIOUS STREETS WITH STATISTICS CONCERNING TRAFFIC.

New York—*Fifth Avenue, south of 59th Street. Width of roadway, 55 feet between curbs. No street railway. Six lines of traffic possible in addition to vehicles standing at curb.

New York—Broadway at Rector Street. Width between curbs, 35 feet, with double track street railway. Four lines of traffic possible, but with no room for vehicles to pass between car and truck standing at the curb.

Fig. 7. London Bridge.

London[1]—Piccadilly. Width of roadway, 37 feet. No street car traffic. Traffic between 8 a. m. and 8 p. m., 15,284 vehicles.

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*Information concerning present width of Fifth Avenue was furnished the writer by Clarence D. Pollock, Consulting Engineer, Park Row Building, New York City, formerly Assistant Engineer in the Department of Highways, Manhattan, who also adds the following statement:

"Fifth Avenue was formerly 40 feet between curbs, permitting two lines of vehicles to move in each direction, in addition to vehicles standing at the curb. This increase in width of 15 feet has increased by 50% its capacity for moving vehicles."

Traffic Statistics before the Avenue was widened are given by Clifford Richardson in article referred to below. This article states that in 1904 the total number of vehicles passing between 7 A. M. and 6 P. M. was 12,068.

1. These figures are from an article entitled "Street Traffic in New York City," by Clifford Richardson. Associate Member, Am. Soc. C. E., Vol. LVII. of the Transactions of that Society.

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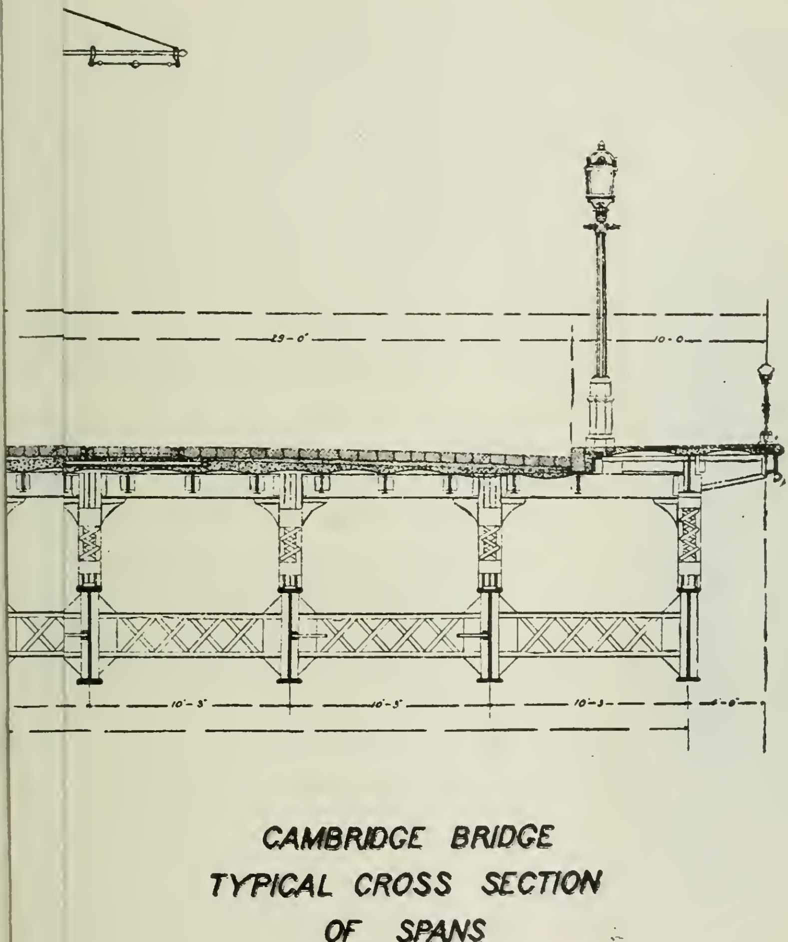

CAMBRIDGE BRIDGE
TYPICAL CROSS SECTION
OF SPANS

Scale of Feet

Fig.

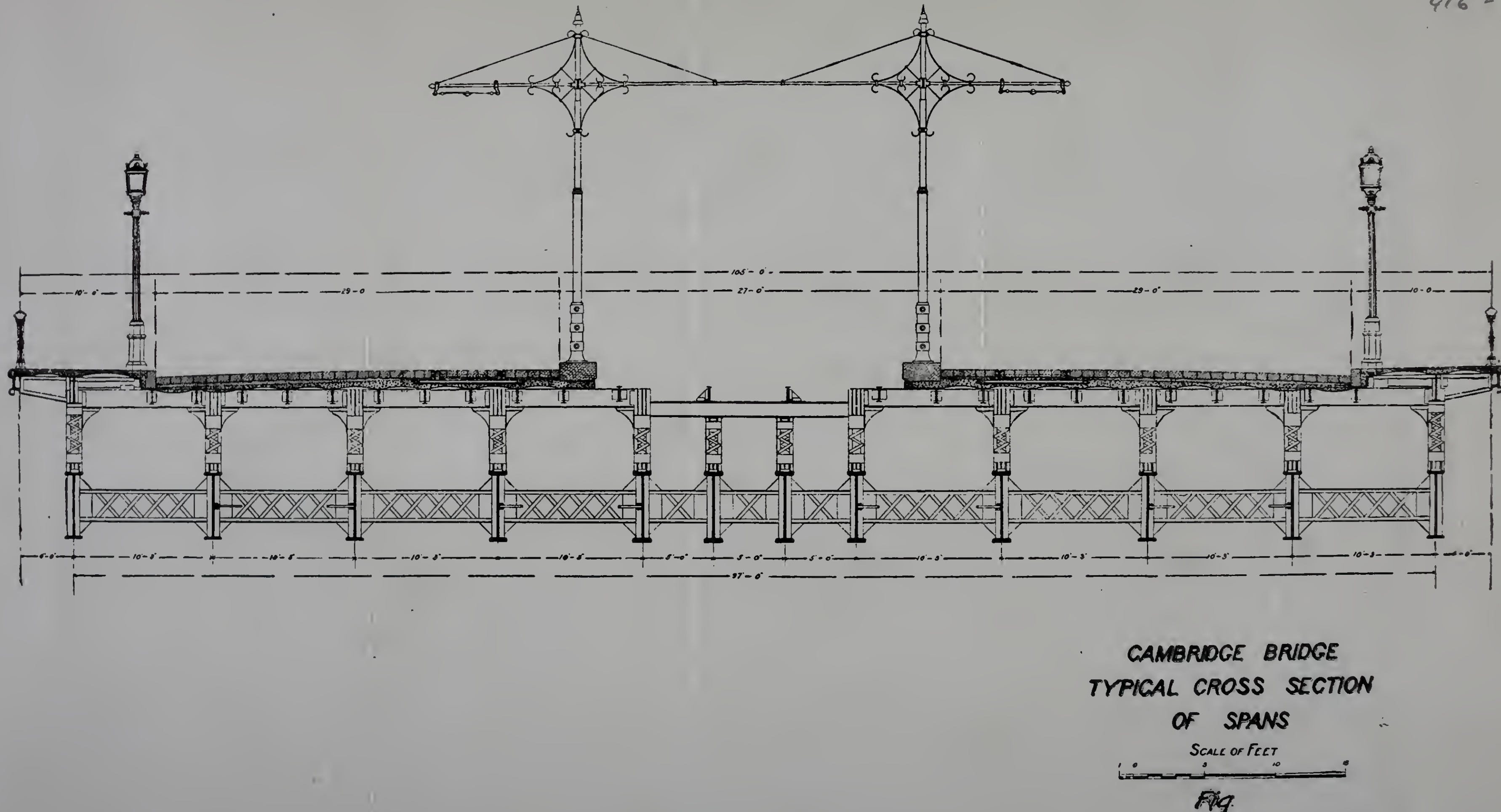

Fig. 10. Cambridge Bridge.

Boston—Washington Street, south of Summer Street. Width between curbs, 32.5 feet, with double track railway. Four lines of traffic in all, with just room for a vehicle to pass between a car and the curb.

Boston—Boylston Street, between Berkeley and Arlington Street. Width between curbs, 50.2 feet, with double track railway; room for six lines of traffic in all or for four lines of traffic with ample room for a vehicle to pass between a car and another vehicle standing at the curb.

Berlin—Leipzigerstrasse. Width of roadway, 42.5 feet.

Fig. 8. Boylston Street, Boston.

Berlin—Friedrichstrasse. Width of roadway, 26.25 feet. (Narrowest part.)

Paris—Rue de Rivoli. Width of roadway, 39 feet. (Narrow part.)

Paris—Avenue de l'Opera. Width of roadway, 52.5 feet.

Vienna—Praterstrasse. Width of roadway, 36 feet.

It is seldom that the length of the bridge is a function of the street railway. Such a condition may, however, occur in the case of a bridge on a curve where the curve must be made flatter than would otherwise be necessary in order to provide proper clearance. The writer is familiar with two bridges where this has occurred. One of these is the temporary Chelsea North Bridge, Boston, which is illustrated in the accompanying figure.

3. *Additional Strength.*—The additional strength required to provide for street car traffic depends primarily upon the differences in weight and allowances for impact between ordinary vehicles and street cars. The specifications of the Massachusetts Public Service Commission require that all bridges in the state carrying street railways are to be designed for electric cars weighing fifty tons, and

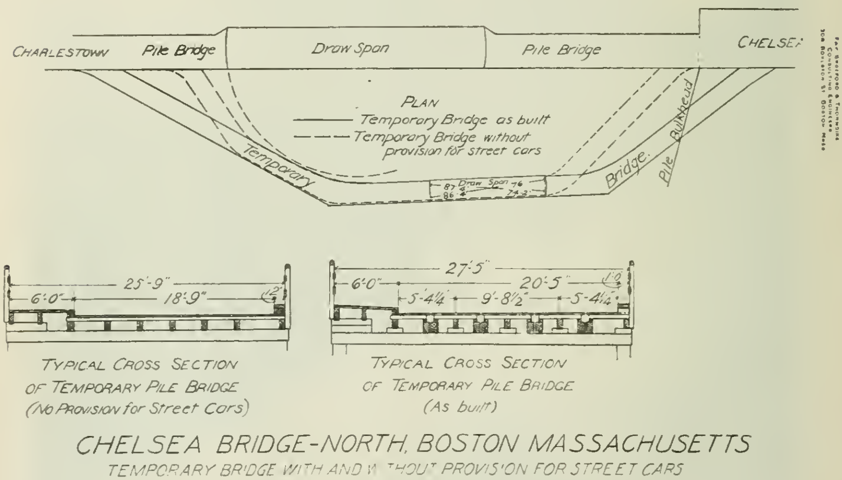

Fig. 9. Chelsea Bridge; Temporary Bridge Plans.

recommend that the following concentrated loads shall be assumed on the highway in addition to the uniform live load:

(a) City bridges, carrying heavy loads, 20 tons on two axles, 12 feet apart.

(b) Suburban or town bridges, 12 tons on two axles, 8 feet apart.

(c) Light country highway bridges, 15 ton road rollers, with three wheels, or rollers—the weight on the 4-ft. wide front roller to be 6 tons, and on each 20-inch wide rear roller to be 4½ tons.

These specifications are under revision and the writer is informed by Mr. Lewis E. Moore, Member of the Western Society of Engineers, and Engineer of Bridges and Signals for the Public

Service Commission of Massachusetts, that the following loadings will hereafter be specified. Two 50-ton trolley cars, with trucks 20 feet centre to centre, wheels 5 feet centre to centre, with impact varying from 25% to 10% depending upon the loaded length required to give maximum stress; if the road wishes to operate standard freight cars, above weights to be increased 50%. One 20-ton motor truck, occupying a space 10 feet wide, 32 feet in length; axle loads 14 tons and 6 tons, respectively; axles 12 feet centre to centre; impact 50% on steel stringers, floor beams and hangers. Uniform live load is to be used with these loadings.

The increase in strength necessary to provide for street cars is most marked in the floor systems. It is less noticeable in trusses and girders, and least of all in foundations. In the case of foundations, the additional strength (size) depends largely upon the character of the bridge. In the case of heavy city bridges with paved floors, where no increased width is necessary to provide for street car traffic, the difference between the live loading of the street cars and that due to ordinary roadway traffic would not materially affect the foundations.

The allowance for impact and future increase of street car loads must be carefully considered in determining the additional strength of the structure. So far as the foundations are concerned, it is doubtful if any allowance for impact need be made.

The question of future increase in loading due to the street railway is a difficult one to satisfactorily adjust. An interesting example of a somewhat unexpected increase in this respect is noted in the Cambridge Bridge case summarized later.

4. *Increase in Cost.*

The best plan to pursue in determining the difference in cost of bridges with and without street cars seems to the writer to be that of comparing two designs, one the detailed design of the structure, the other a stress sheet design with the cross-sections of all members carefully determined. The two designs should be similar in type. Allowance for the weight of the details of the second structure may be made by considering the details of each individual member to vary in weight in proportion to the variation in the cross-section of the main member, this relation being obtained from the detailed design of the first case, or if the structure has been completed, from the gross shipping weights reduced by the computed weight of the main sections. The same unit prices should be used in both computations.

In the case of a reinforced concrete barrel arch bridge, it would seem as if the additional cost would ordinarily be dependent entirely upon the increased width, since for such a bridge the effect of the concentrated wheel loads would be largely distributed by the dirt fill. For such a bridge it might be possible to estimate the increased cost by determining the cost of a strip of the bridge, using for this purpose the same unit prices as for the remainder of the bridge.

The question has arisen in some cases with which the writer has been connected, as to whether the cost of engineering, insurance, etc. should be assumed to vary directly with the cost of construction. This is perhaps open to legitimate discussion. It would seem to the writer as if these items should vary directly with an increase in width, since such increase would certainly involve additional engineering and inspection, and would prolong the time of construction. Whether the increase should vary directly with an increase in strength is not quite so obvious. Little additional engineering cost is required to provide for heavier sections in floor beams, stringers and trusses. On the other hand, it is probable that no better unit actually exists for determining the difference in these items than the total cost of the completed structure, and it would seem as if it would usually be proper to adopt this basis for determining additional charges for engineering, etc. In the cases of the Chelsea and Meridian street bridges summarized later, the percentage charged for these items was the same for bridges both with and without street cars, and this was agreed upon by the railways as a proper charge before the case came up for hearing.

5. *Convenience.*

In determining the proportion which a street railway should pay towards the cost of a given bridge, the question of greater convenience to the railway is one which deserves careful consideration. The advantage to the railway company of having a new bridge of ample size and strength to allow for unrestricted traffic running at a reasonable speed, and to provide for any probable increase in weight of rolling stock is a factor which may possibly result in economy of operation far in excess of the actual expenditure necesary to provide for increased width and strength. In the case of a new bridge providing an opportunity for a contemplated new line of railway traffic, it is quite conceivable that the railway might afford to pay a very considerable proportion of the cost. In fact, if the line is to be built, at all events it would seem as if the railway company could afford to pay towards the construction of the bridge an amount equal to the cost of a new structure plus the capitalized cost of maintenance less salvage, provided the bridge is to be owned and maintained by the municipality and equitable arrangements are made for reimbursing the railway if its franchise is taken away by no fault of its own.

That street railways have often agreed in advance of construction to pay a very considerable proportion of the cost of the bridge in some cases, is doubtless due to reasons such as this. Similar instances of great and immediate convenience to street railways, due to the reconstruction of an existing bridge, may readily occur. Such, for example, was the condition in the case of the Meridian Street Bridge referred to later. In this bridge some of the timbers of the existing structure had actually begun to crush under the heavy cars operated by the railway, and for some time prior to the reconstruction, car traffic was not allowed across the draw-span, passengers being required to change cars and walk across the draw. This naturally imposed an undue inconvenience upon passengers and an extra expense upon the railway. In such a case it would seem quite clear that the railway might well pay toward the reconstruction of the bridge an amount in excess of the additional cost of the structure to provide for their loads. Another factor under this heading might well arise in the case of a draw-span over a stream with much traffic. The increased rapidity of operation which might conceivably occur with a new bridge would certainly be of value to the street railway in preventing traffic interruption.

6. *Decreased Cost to Street Railway of Maintenance and Operation.*

The fact that the cost of maintenance and operation of a highway bridge would ordinarily be borne by the municipality should be considered in apportioning the cost to the street railway. This would be particularly pertinent in the case of swing bridges, where it would seem as if a fair arrangement would be for the railway company to furnish the current necessary to open and close the bridge, and for the municipality to maintain the draw-tenders and other attendants. In general, it would appear that the street railway company might reasonably be charged as its portion of the capitalized cost of maintenance, a share proportionate to its contribution to the cost of construction.

Franchise Taxes and General Taxation.—All of the above discussion should be considered with due regard to the fact that the railway company is ordinarily subject to heavy taxes, and in consequence, should be entitled to operate across the bridge with vehicles of weight equal to that of the heaviest motor trucks. The only equity in charging the railway more than the ordinary transportation company is because of the heavy loads which it operates.

SUMMARY OF CASES.

The following brief summaries are intended to set forth the essential features of several cases presented before the Massachusetts Commissioners to determine and adjust an equitable charge to the street railways.

Cambridge Bridge, Boston.—The Legislative Act under which this case was argued is found in Chapter 500, Acts and Resolves of Massachusetts Legislature, Section 15, 1897.

> "Said corporation shall join with the city of Boston and the city of Cambridge in a petition to the Legislature for the year eighteen hundred and ninety-eight or the year eighteen

hundred and ninety-nine, as said cities may elect, for an act authorizing the construction and maintenance of a bridge across the Charles River, at or near the present site of the West Boston Bridge, suitable for the use of the elevated and surface cars of said corporation, and also for all the purposes of ordinary travel between said cities; and said corporation shall pay towards the construction of said bridge such portion thereof as shall be rendered necessary by reason of its being of additional size and strength for the use of the elevated railroad of said corporation, and shall also itself construct or shall pay for constructing its railway, both elevated and surface, across said bridge, and the balance of such cost beyond that paid by said corporation shall be paid one-half by the city of Boston and one-half by the city of Cambridge."

This Act was further qualified by a later Legislative Act given in Chapter 467, Acts of 1898, Sections 4 and 8.

"Section 4. Said bridge shall be suitable for all the purposes of ordinary travel between said cities, and for the use of the elevated and surface cars of the Boston Elevated Railway Company, shall be built not less than one hundred and five feet in width, and with masonry piers and abutments, and a superstructure of iron and steel, or both."

"Section 8. The cost of the laying out and construction of said approach in the city of Boston, and of all other work on the Boston end of said bridge, not including any part of the construction of the abutments or other parts of said bridge, shall be paid by the city of Boston, and the cost of the laying out and construction of said approach in the city of Cambridge, and of all other work on the Cambridge end of said bridge, not including any part of the construction of the abutments or other parts of said bridge, shall be paid by the city of Cambridge, and the cost of construction of the abutments and other parts of said bridge, including the cost of the temporary highway bridge, the removal of shoals, and the salaries of the commissioners and of all employees of said Commission, and including all other expenses incurred in carrying out the provisions of this act not hereinbefore required to be paid by said cities severally, shall be deemed the cost of construction of said bridge, and shall be paid as provided in section fifteen of chapter five hundred of the acts of the year eighteen hundred and ninety-seven. . . . ."

The bridge as actually constructed as shown in Fig. 5 provided space for rapid transit trains on the surface in a reservation instead of on an elevated structure as originally contemplated by the Act. The total cost of the bridge up to March 1, 1908, this covering practically the entire cost of construction, was as follows:

CONDENSED SUMMARY BY SCHEDULES.

Schedule and Description.	Cost of 105 ft. Bridge	Estimated Cost of 75 ft. Bridge
A Ten Piers	$ 889,417.97	$ 614,411
B-C Two Abutments	332,816.99	232,829
D Steel Superstructure	629,001.47	410,973
E Roadways, etc.	201,031.29	159,150
F Towers and Carvings	187,276.11	187,276
Total Cost of Construction	$2,239,543.83	$1,604,639
G Engineering	147,982.83	106,030
H Inspection	33,486.65	23,994
I Architectural Work, etc.	40,914.89	29,316
J Printing and Stationery	717.17	514
K Advertising	957.63	687
L Commission Expenses	33,715.59	24,158
New Bridge—Total Cost Without Maintenance	$2,497,318.59	$1,789,338
M Maintenance of New Bridge	10,296.70	....
N Temporary Bridge	113,615.30	103,615
O Channel Dredging	30,683.50	30,683
Total without Miscellaneous Payments	$2,651,914.09	$1,923,636
P Miscellaneous Payments	2,981.57	2,982
Total	$2,654,895.66	$1,926,618

The fact that the width of the bridge was established by Legislative Act rather than by engineering study resulted in the roadway being made a little wider than ordinarily would have been the case. As a matter of fact, it would have been better had additional space been given to the elevated railway, as the company finds the distance between tracks rather small for its purposes; this distance, however, was determined by the railroad company itself rather than by the city. In presenting the case to the Commission, it was decided by the city that a bridge 75 feet in width would be ample for all purposes of ordinary heavy traffic. Such a bridge was designed with great care along the same lines as the existing structure by Mr. Frederic H. Fay, Member Am. Soc. C. E., and partner of the writer. Mr. Fay, who was designing engineer of the original structure, determined the cost of the new bridge as accurately as possible, basing his unit prices on the cost of the actual construction. His estimate of the cost of this bridge is shown in the column adjoining that for the cost of the 105 ft. bridge. By Mr. Fay's figures, the saving on account of a narrower bridge amounted to $728,277.

The railway company argued that in view of the wording of the Legislative Act it should be compelled to pay for increasing the width of the bridge only by the amount necessary to construct upon it an elevated railroad, that is a width of 10 feet for columns and wheel guards, regardless of the fact that by being located on the surface, the expense to the company of an elevated structure about

1,750 feet in length was entirely saved, and that no opposition was offered by the company to the plan actually adopted. It also contended that none of the items in the summarized schedule previously given, except those from "A" to "D" inclusive, should be charged to the company. The railway also claimed that the railroad loading used in the design, which included an allowance of 75% for impact and possible future increase, was excessive, even for a monumental structure of this character intended to last for a long period, and in the design of which the somewhat high unit stress of 17,500 lbs. was used. Estimates by the company were furnished for bridges of the following widths, without provision for railway traffic, and with a paved roadway over the entire width of the bridge between curbs, the estimates referring to items "A" to "E" inclusive.

(a) Width 105 ft. (that of actual bridge). Estimated cost, $1,940,999—reduction of $111,277 from the actual cost of the structure.
(b) Width 95 ft. Estimated cost, $1,812,595—reduction of $239,671 from the actual cost of the structure.
(c) Width 81 ft. Estimated cost, $1,613,969—reduction of $438,297 from the actual cost of the structure.
(d) Width 78 ft. Estimated cost, $1,575,312—reduction of $476,954 from the actual cost of the structure.
(e) Width 75 ft. Estimated cost, $1,535,723—reduction of $516,543 from the actual cost of the structure.

These estimates were not made by making actual designs for bridges of these widths, but by starting with the 105 ft. bridge as actually built, and eliminating such portions as the railway expert thought proper. A comparison of the differences in the estimates of the two 75 ft. bridges shows that most of the difference occurred in the piers and abutments. Other estimates provided by both sides tended to show the reasonableness of the foregoing estimates.

The following quotations are made from the ruling of the Commission upon some of the important matters argued by the parties, and includes its findings:

"The Commission finds that the additional width of the bridge necessary for the use of the elevated railway is substantially 24 feet, and that all the remaining portion of the bridge is devoted to the ordinary forms of surface travel, including the surface electric cars. This conclusion of the Commission attributes to the elevated railway all the space on the bridge that it can be said actually to occupy. (i. e., it does not allow for curbs.—Author.

"As to the additional strength, for the use of the elevated railway, the Bridge Commission contends that the assumption of its engineers as to what that strength should be adopted as a preliminary to their work of designing the bridge, and which determined to a large extent its strength as built, is binding upon the Commission. On the other hand, it is the contention of the Elevated Railway Company that it should pay only the cost 'rendered necessary' by reason of the additional strength in fact required for the use of its elevated railroad, that the assumptions of the engineers of the Bridge Commission were excessive, and that it is the duty of the Commission to determine what additional strength was properly and necessarily required in the bridge as constructed, and to base its findings as to cost on the findings as to the proper and reasonable strength. The issue is important, for the Engineers of the Bridge Commission assumed as the basis for their design very heavy loads for the elevated cars, much greater than seem to the expert witnesses for the Elevated Railway Company to be reasonable and proper. For example, the figure assumed by the engineers of the Bridge Commission for the 'live load' of the elevated cars when passing over the bridge was 9,000 pounds to the linear foot. The Railway Company's expert witnesses, all of whom are eminent engineers, assert that this 'live load' should properly be taken at about 5,000 pounds per linear foot and no more.

"It is the conclusion of a majority of the Commission that the assumptions of the engineers of the Bridge Commission are not controlling, but that it must determine the cost rendered necessary by such additional strength in the bridge as was, in fact, reasonably and properly required for the use of the elevated railroad.

"It is hardly conceivable that the Legislature introduced an elaborate procedure for ascertaining what portion of the cost of the bridge should be paid by the Elevated Railway Company, if the sole function of the Commission appointed to determine this amount is to audit the accounts of the Bridge Commission, accepting as final and conclusive the preliminary views and theories of the engineers of the Bridge Commission as to additional size and strength.

"It is clear to the Commission that architectural and aesthetic considerations and a reasonable and proper intention to make the bridge a massive and striking monument, which would give satisfaction outside of any question of its practical efficiency, as a bridge, were influential in determining the way in which the type of bridge designated by the Act under which it was constructed and meagerly defined therein, should be developed. With this underlying thought prominently in their minds, it was but natural that large allowances should be made in every portion of the work where a 'margin of safety' was required. The extent to which such allowances are made in any case depends only in part upon exact principles."

"After a careful study of all the evidence, the Commission has arrived at the following conclusion and makes the following findings:

"The aggregate cost of the bridge was $2,654,895.66. In presenting its case, the Bridge Commission divided the total cost into items marked respectively 'A' 'P.'

"Items 'A' to 'E' inclusive relate to the piers, abutments, steel superstructure and roadways of the bridge.

"The cost of so much of the bridge as is covered by those items was $2,052,266.

"The Commission determines that the portion of the cost of this part of the bridge (items 'A' to 'E' inclusive), which the Elevated Railway Company shall pay as representing that part of the entire cost 'rendered necessary' by the presence of additional size and strength for the use of the elevated railway is $420,000.

"It is not contended that the Railway Company should pay any part of the cost of the towers and carvings which make up item 'F.'

"Items 'G' to 'L' inclusive relate to the cost of engineering, inspection, architectural work, printing and stationery, advertising and expenses of the Bridge Commission.

"The sum of these items is $257,774.76.

"The Commission determines that the Elevated Railway Company should pay $45,000 as its part of the portion of the cost of the bridge represented by items 'G' to 'L' inclusive.

"The Commission determines that the Railway Company should pay $10,296.70 under item 'M' for maintenance of the new bridge, and $10,000 under item 'F,' a portion of the cost of maintenance of the temporary bridge which was in use during the construction of the new bridge. It is not contended that the Railway Company should pay any portion of items 'O' or 'P' relating to channel dredging and miscellaneous payments.

"The Commission therefore determines that the portion of the cost of the new bridge 'rendered necessary by reason of its being of additional size and strength for the use of the elevated railway' is $485,296.70, and that that amount with interest from the date of the filing of the petition should be paid by the Elevated Railway to the Cities of Boston and Cambridge, one-half to each city.

"It was suggested to the Commission that the Elevated Railway Company has already paid the sum of about $8,000 with which it is to be credited. Counsel can undoubtedly adjust this matter.

"The cost of the proceedings before this Commission should be paid one-half by the Boston Elevated Railway Company and one-half in equal parts by the Cities of Boston and Cambridge."

It should be added that before the commission had made its final report the chief engineer of the Boston Elevated made inquiries as to the possibility of replacing the open floor designed for this bridge by a solid ballasted floor in order to reduce noise, thereby increasing its weight by 2,150 lbs. per foot per track. Upon receipt of these inquiries the city immediately asked for a rehearing before the Commission. At this rehearing the railroad counsel stated "that the company had no desire and no intention of putting any flooring whatever on the bridge," and again succeeded in convincing the Commission that the loading used by the city in designing the portion of the bridge carrying the railway was excessive. As a matter of fact, after the decree was made final, the railway immediately began the construction of a solid floor, thus bringing the total load up to 12,079 lbs. per linear foot in place of 11,919 lbs. assumed by the city. This furnishes an interesting example of the possibilities of future increase in weight of railway loads in a somewhat unexpected manner and confirms the excellent judgment of the city engineers in making a liberal allowance for the future. It also, in the writer's opinion, indicates the wisdom of appointing at least one engineer upon a commission dealing with such questions in order to secure independent judgment.

It is interesting to observe that a few years after the completion of the Cambridge Bridge, the Boston Elevated Railway Company constructed a reinforced concrete viaduct across the same river. This viaduct was made with a width of 32 feet, providing room not only for two tracks, but also for foot walks on either side for access to the various portions of the viaduct, and for the convenience of passengers in case cars should be stalled. In the Cambridge Bridge, such means of access and accommodation for passengers were provided by the roadway and sidewalks of the bridge and were not charged to the railway company. It differs from the high level Cambridge Bridge by including a bascule span with moderate opening. The fact that the bridge adjoins a park and was subject to the approval of the Park Commissioners required the railway company to design a structure of pleasing appearance, and in that respect it is fully equivalent to the Cambridge Bridge. So far as I can ascertain, the cost of this viaduct was about $900,000, or much more than the railway's share of the Cambridge Bridge. Its length is 1,740 feet or practically the same as the Cambridge Bridge. In addition to the greater initial cost, the railway must maintain the bridge and operate the draw-spans, all of which expense is saved in the case of the Cambridge Bridge.

Chelsea Bridge and Meridian Street Bridge, Boston.—The Chelsea Bridge which lies on one of the main arteries of travel leading from Boston to the north, consists of three sections, extending respectively across the south channel, the flats between the south and north channel, and the north channel of the Mystic river. The

Bay State Street Railway Company has a double track location over the Chelsea Bridge, and the Boston Elevated Railway Company has a similar location over the Meridian Street Bridge. As the result of an order of the Secretary of War, a new swing bridge has been recently constructed across the north channel of the Mystic river with a total length of 363 ft. 0 in. center to center of draw-span cracks, and a total width of 60 ft. 0 in. center to center of railings, with a roadway 40 feet clear between curbs. Legislative authority has been granted for a new structure to replace the obsolete bridge across the south channel, and construction has proceeded to the extent of building a new temporary bridge to serve during the construction of the permanent structure across this channel. Plans and estimates have also been made for a permanent bascule span with two approach spans, the bridge having a total length on center line of 368 feet. The proposed bascule span has a movable leaf of a length of 110 feet center to center of end pins, and two roadways 21 ft. 3 in. in the clear, with provision on each leaf for a single track trolley line.

The Meridian Street Bridge lies across the Chelsea creek between East Boston and Chelsea. It consists of a new swing bridge with a total length between draw-span cracks along the center line of bridge of 273.5 feet, and a total width of 37 ft. 0 in. center to center of railings, with a roadway with a clear width of 21 ft. 3 in. between curbs.

To determine the proportion which the various municipalities concerned and the street railways should pay towards the cost of these bridges, a Commission was appointed by legislative act, Chapter 581, Acts of 1911, to apportion among the cities and towns which received special benefits from these bridges, a just and equitable share of the cost of construction, reconstruction, repairs and maintenance of said bridges, and to assess upon street railways having a location on the bridges, a just and equitable share of the construction and repairs of the bridges.

The Commission found that the expenditures on these respective bridges had been, or would be, as follows:

CHELSEA BRIDGE NORTH—REBUILDING.

Total payments to January 1, 1914	$380,293.55
Payments due on completed construction	22,510.46
Additional construction to be done	9,950.00
	$412,754.01
Incidental expenses, etc., allow	12,245.99
Total estimated cost	$425,000.00

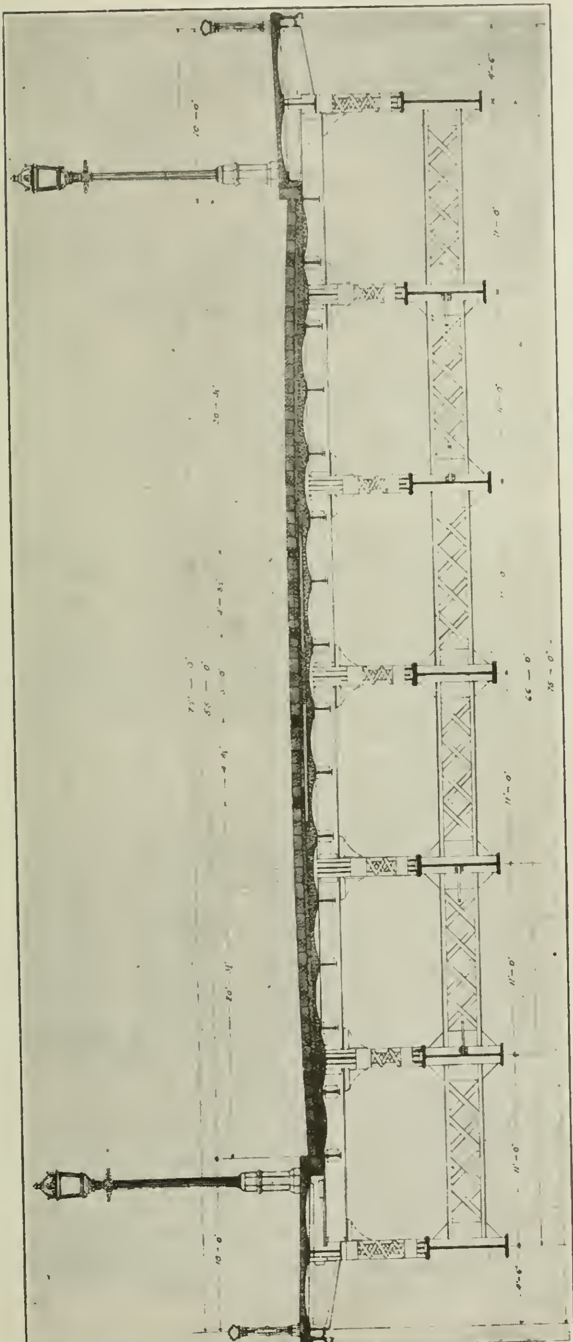

Fig. 11. Typical Cross Section Showing Proposed Cambridge Bridge Without Elevated

CHELSEA BRIDGE SOUTH—TEMPORARY BRIDGE.

Total payments to January 1, 1914	$ 20,645.35
Payments due on work done and estimated cost of work to be done	53,123.75
Total	$ 73,769.15
For incidental expenses allow	1,230.85
Total estimated cost	$ 75,000.00

PERMANENT DRAW-SPAN.

Estimated cost of permanent bridge	$403,015.00
Total cost of south draw	$478,015.00

MERIDIAN STREET BRIDGE.

Total payments to January 1, 1914	$169,532.20
Payments due on completed work	1,229.73
Additional construction work to be done	1,300.00
	$172,061.93
For incidental expenses, including proportionate part of cost of apportionment expenses, contingencies, etc., allow	2,938.07
	$175,000.00

The engineers and various parties interested agreed in advance of hearings upon the differences in width and cost of these respective structures due to the presence of the street railway. These differences may be summarized as follows:

Bridge	Width of Roadway in clear between curbs		Cost		Percentage Reduction
	(With tracks as built)	(Without tracks as designed)	(With tracks as built)	(Without tracks as designed)	
Chelsea North	40 ft.	40 ft.	$425,000	$396,500	6.7%
Chelsea South	*21 ft. 3 in.	20 ft. 0 in.	478,015	450,500	5.75%
Meridian Street	21 ft. 3 in.	18 ft. 9 in.	175,000	161,308	7.6%

The percentage of reduction for the Chelsea South Bridge includes an allowance of 20% of the cost of the temporary structure due to the presence of the street railway.

The Commission ruled that the street railway should, in each case, pay 15% of the cost of construction for all these bridges.

The following decisions are in answer to requests for rulings made by the railway companies to the Commission and are interesting as bearing upon its decision concerning certain cases at issue:

"So long as the street railway is rightfully using a public high-

*For each leaf of bascule span.

way, including the bridge forming a part thereof, and has no property rights therein, it has the same rights therein as the general public so far as any payment for such is concerned. *Refused.*

"The only case in which the street railway may be justly and equitably assessed any portion of the expense of the construction or repair of the bridge is where additional expense is caused solely because of the presence of the street railway upon said bridge. *Refused.*

"In the present proceeding it is to be assumed that a bridge is to be constructed adequate for the travel which the evidence shows may be expected to cross it, and the street railway should be assessed only for such cost as exceeds that necessary to provide for all other traffic. *Refused.*

"The method of computation, of taking as a basis the requirements of the Massachusetts Public Service Commission relating to bridges with and without street cars and assessing the difference upon the street railway, applies only when there are no facts in connection with the bridge under consideration which require variation of the rule. *Refused.*

"Upon the evidence the Commission cannot assess upon the Bay State Railway Company any greater portion of the cost of altering and reconstructing the Chelsea Bridge than represents the difference between what said work should have cost if said bridge had been altered and reconstructed without reference to its use for street car traffic and the actual cost of said work. *Refused.*

"As a matter of law the portion of the cost of altering and reconstructing the Chelsea Bridge which may be assessed upon the Bay State Street Railway Company is only such as represents the additional cost, if any, of so reconstructing said bridge that it could be safely used for street car traffic. *Refused.*"

The motion to recommit this case was made by the street railway, and as a preliminary to the presentation of the case to the courts, the Commission was ordered to state the facts upon which the findings against this company were based.

In this supplementary report the following statements, giving reasons for its decision, appear:

Meridian Street Bridge.—"The standard of bridge engineering in the city of Boston requires, with respect to bridges intended for all kinds of travel other than street cars, that such bridge shall be capable of sustaining a load of 20 tons. The evidence showed that it was the practice of the board of railroad commissioners to withhold its approval of plans for city bridges intended to be used by street cars unless designed for strength capable of sustaining a street car weighing 50 tons."

From the testimony of the engineers it appeared that the Meridian Street Bridge was constructed at a cost of 7.6 per cent (of the whole cost) more in consequence of its being intended to accommodate street cars; or, in other words, a bridge of sufficient strength and dimensions to safely take care of all other kinds of ordinary traffic could have been built at an expense of 7.6 per cent (or $13,692) of the whole cost less than the bridge which was constructed to meet the engineering requirements of a bridge to be used by street cars of the size, character, frequency and loads of those operated by said street railway company and intended to pass over this bridge.

At the time of the passage of Chapter 581 of the Acts of 1911, and for some time prior thereto, the old Meridian Street Bridge was impassable for street cars. Certain timbers of the trusses of the bridge were actually crushing under the weight of the cars and their loads, and the bridge was closed to street cars. During this time the cars could only run over the fixed portion of the bridge up to the draw, and the passengers were required to walk across the draw, the bridge being in use, however, for ordinary team and foot travel.

"The waterway traffic requires the opening and closing of the draw of this bridge on an average of about forty times a day, and the mechanism of the new draw is such that less time is required for the opening and closing of the same than was required for the old draw. The said street railway company operates cars ordinarily under seven or eight minutes headway over this bridge, it being on the direct line from Chelsea, by way of the East Boston tunnel, to Boston proper, and they are subject to less delay in consequence of the new draw openings. There was evidence that this draw was opened more times a year than any other bridge in the city of Boston."

Chelsea South Bridge.—"The temporary bridge for the south draw, for use while the permanent structure was being erected, was made stronger, of greater width of roadway, and was made longer, to provide for suitable curves for operating street cars, than it otherwise would have been had there been no street cars to provide for, at an extra cost of 20 per cent, which extra cost, however, is included in the above total percentage of 5.75 per cent.

"For some years prior to the new construction only one car was allowed on the south draw span at a time, and if another car was coming on another track in the opposite direction the first car had to wait until the other had crossed before it was allowed to proceed.

"The roadway on this south draw span has been increased in width by 10 feet, and the road bed for the car tracks improved.

"A large area lying northerly of the Mystic river is served by the Bay State Street Railway Company. A record kept by the company for one week during the progress of the hearings showed an average of 42,000 passengers per day as being carried in the cars of the company over the Chelsea bridge. Less time is required in operating the new draw than of the old, and consequently there is less delay in the passage of cars."

A hearing upon the ruling of the Commission is to be held before the full bench of the Supreme Court of Massachusetts at some future date.

Huntington Avenue and Massachusetts Avenue Bridges Over the Boston and Albany Railroad in Boston.

These bridges are in the central portion of the city and are of the same width as the city streets crossing them; hence, no question of extra width to accommodate street cars is involved. They were rebuilt because of their dangerous condition, under an agreement between all the parties interested, i. e., the City of Boston, Boston Elevated Railway Company and the Boston and Albany Railroad Company. The following is the decision of the Commission of the apportionment of cost between these parties under date of October 8, 1910.

"By virtue of the Decree of the Court appointing us Special Commissioners in the premises, we have heard the parties in interest and report as follows, viz:

"The city laid out and built Huntington Avenue and the bridge in question over and across the railroad in 1872, and Massachusetts Avenue and the bridge referred to in 1875, but no other changes were made in either until the present action was taken.

"Under an agreement between all the parties.
the city has done the work required upon the two bridges, completing the Huntington Avenue bridge in October, 1909, and the Massachusetts Avenue bridge in December, 1908.

"We have, upon the request of all the parties, treated the action taken under the contract as therein agreed and determined that the city is the party to carry the decision of the railroad commissioners into effect. What the cost of doing the same shall be, and whether interest upon the same may be allowed the city, we refer to the determination of the court.

"The new structures are of the same length and width upon the ways as the old bridges were, but as rebuilt they are strengthened and improved and are of greater cost to properly carry out the order of the railroad commissioners. The railroad structure and the use of its way remains the same at these crossings as before the bridges were built.

"The Boston Elevated Railway Company and the West End Street Railway, lessees, have two tracks upon each bridge, and their use of the same required the bridges to be built, in certain particulars, of stronger and more expensive materials than otherwise would be necessary. The Massachusetts Avenue bridge was kept open for the use of the company during its construction and thereby added to the expense of building it, while the company acting under Chapter 266, Acts of 1908, took a temporary location upon Huntington Avenue bridge during its reconstruction. It claimed that, besides this temporary use, we would only consider, so far as its liability was concerned, the extra cost due to the necessity of building the bridge stronger in certain particulars so that its cars could be safely run over its tracks. But we determined that, to make a just distribution of the cost and expense in the premises, the railway company should be assessed a somewhat larger amount than involved in its claims and have so ordered.

"It appeared that the city, to protect the Huntington Avenue bridge from the gases arising from the locomotives used by the railroad, which gases have the effect of depreciating and wearing out the structure as directed by the Railroad Commission, caused its under part to be covered with cement and other materials, which materially increased the cost of its construction. The Massachusetts Avenue bridge was not so treated on account of the difficulty of doing so at a season of the year when it was built. A majority of the commission determined that this element of cost is not alone a sufficient reason for charging the railroad and, inasmuch as the railroad gains no benefit from the rebuilding of the bridges, and as it was under no prior legal obligation to build or maintain the bridges, it should not contribute toward the cost and expense of rebuilding and maintaining the same.

"The railroad also claims (which the city disputes) that under a certain contract made between it and the city of Boston, a copy of which and another instrument relating thereto are hereto annexed, it is exempt from any liability in the premises, but inasmuch as we have found that the railroad is not liable, we have not made any further ruling on this question, and refer the same to the court for its determination.

"Thereupon our award and finding is and we DETERMINE AND DECIDE

"1. That the city of Boston shall make the alterations, rebuild the bridges and carry the decision of the Board of Railroad Commissioners into effect.

"2. That the cost and expense of making such alterations and rebuilding said bridges, the cost of the application to the Board of Railroad Commissioners and the Hearings before the Special Commissioners shall be borne and paid as follows:

"3. The Boston and Albany Railroad, the New York Central & Hudson River Railroad, lessee, shall pay the costs of the application to the Board of Railroad Commissioners and the hearings before the Special Commission.

"4. The West End Street Railway, the Boston Elevated Railway, lessee, shall bear and pay the expense of laying the temporary tracks for the use of the railway during the construction period, which is made a part of the expense of rebuilding the bridges, and shall also pay 10% of the remainder.

"5. A majority of the Commission shall determine that the city of Boston shall bear the remainder, 90%.

"6. The future charges of maintaining and keeping the bridges and the approaches thereto in repair shall be borne as follows: The West End Street Railway, the Boston Elevated, lessee, shall keep in repair so much of the surface of each bridge, and the approaches thereto as shall be occupied by its tracks, including the space between the rails of its tracks, and the city of Boston shall maintain and keep in repair the framework and the surface of each bridge, except so much of the surface as shall be occupied by the tracks of the West End Street Railway, Boston Elevated, lessee, including the space between the rails of its tracks."

Conclusions.—The conclusions which the writer has drawn from his experience in apportionment cases of this character are as follows:

(a) Additional width to provide for street cars is ordinarily necessary only in the case of bridges with narrow roadways, providing for no more than two lines of traffic.

(b) The extra expense involved in strengthening heavy city bridges of permanent type to provide for 50-ton trolley cars would not ordinarily be greater than 10% of the total cost, and may be as low as 6%. This percentage will be greater for light country highway bridges without paved floors, but if such bridges are designed for heavy motor truck traffic, as they should be, the additional expense will not be excessive.

(c) To apportion the cost equitably, and with credit to the engineering profession, the engineers on the two sides should try to agree upon the additional cost of provisions for street cars before the case is presented to an apportionment commission. This can ordinarily be done if both sides are reasonable.

(d) It is doubtful if the railroad company should ordinarily be charged for additional convenience due to the reconstructed bridge. This, however, is a matter the settlement of which hardly comes into the province of the engineer.

The author wishes to extend his acknowledgment to the following gentlemen, who have assisted him in obtaining photographs and data:

Frederic H. Fay, Consulting Engineer, 308 Boylston St., Boston, Mass.

Clarence D. Pollock, Consulting Engineer, Park Row Building, New York City.

Lewis E. Moore, Bridge and Signal Engineer, Mass. Public Service Commission.

John E. Carty, Designing Engineer, Bridge and Ferry Division, City of Boston.

Clarence D. Fernald, Assistant Engineer, Boston Elevated R. R. Co., Boston, Mass.

May, 1915

DISCUSSION.

C. F. Loweth, M. W. S. E.: The paper which has just been read is excellent. It contains information of value, and the speaker regrets that he is not at this time prepared to discuss it in detail.

It would hardly seem that there was room for any question of the principle that street railways should bear some portion of the cost of street bridges: clearly the occupation of the street by a street railway is an added burden of which the beneficiary (the street railway), should assume the cost.

Structures intended to carry streets on which there are street car tracks, must be built much wider and heavier than for the same streets without street railways. If the street is in a subway it must be wider and higher, and the depression of the street greater, and the inclines or approaches must be much increased in length in order to provide the desired clearance for electric cars. This greater depression of the street in subways, together with the lesser gradients of approaches to subways or viaducts in order to provide the better operating conditions asked for by street railways, both involve a very considerable disturbance of existing conditions, and add enormously to the consequential damages for grade changes.

Street railways have, at times, taken the position that their franchises required of them only the maintenance of a portion of the street paving, and that it devolved upon the city to provide the streets for their tracks. The fallacy of this is indicated by the fact that where street railway traffic has become unduly burdensome on the streets, street railways have been required, at their own expense, to elevate or depress their tracks, and thus has come about the elevated railroads in New York, Chicago and Boston, and the subways in New York, Philadelphia and Boston. In the two latter places the street railways have been taken off the street surface, and elevated at some places and depressed at others, in order to relieve the congestion in the streets, and the cost has devolved entirely upon the street railways.

The speaker knows of many instances where street railways have, at their own expense, entirely replaced or added to existing bridges, where these bridges were not of sufficient capacity or strength to take care of the street railway traffic. One case which might be cited is that of the bridge over Mississippi river between St. Paul and Minneapolis, where, if the speaker's memory serves him rightly, the bridge was largely rebuilt by the street railway company before it could operate its cars over it. This bridge was a very large structure, 130 feet or more above the surface of the water, and comprised two large steel arch spans.

The determination of the proportion of cost of the elimination of grade crossings which should be borne by street railways is in process of evolution, and cannot be decided on precedent. It is only within recent years that street railway cars have become so large and heavy as to greatly exceed the size and weight of other highway vehicles. When street railway traffic was largely horse-drawn cars, of weights and dimensions not much, if any, exceeding ordinary vehicles, there could not be much liability of street railways for sharing in the cost of street improvements. Their cars at that time had the speed of other vehicles, and bridges of ordinary construction were safe for their passage. But today the conditions are radically different, and street railway cars are very much larger and heavier than other vehicles, and they move at a speed which practically results in their exclusive use of that portion of the streets occupied by their tracks. In size and weight they are much nearer the ordinary steam railway car than the old time street car.

The Railway Commission of Wisconsin has repeatedly recognized the justice of placing upon the street railways a portion of the cost of street bridges and of grade separation. At La Crosse, Wis., a street grade crossing with a steam railroad is being eliminated by order of this commission, and the cost was proportioned:

60 per cent to the steam railroad,
25 per cent to the city, and
15 per cent to the street railway.

In a quite recent order, involving the separation of the grades of seven or eight streets, the commission's order placed five per cent of the total cost upon the street railway, notwithstanding the fact that only about one-half the streets involved were occupied by street railways.

F. H. Cenfield, ASSOC. W. S. E.: During the years 1913, 1914 and 1915 a census was made of the traffic passing over the bridges crossing the Chicago river by the division of bridges and harbors, bureau of engineering, Department of Public Works, City of Chicago. These counts have been made for the purpose of properly routing traffic during the replacement of a number of the old type center pier swing bridges with the bascule type of bridge. The census in 1914 included Lake Street bridge and Jackson Street bridge, which are not included in 1915 on account of construction of new bridges. The term trucks includes all pleasure and commercial motor drawn and horse drawn vehicles.

The data pertaining to the various bridges is given as follows:

Bridge—	No. of Street Car Tracks	Roadway		Sidewalks	
		No.	Clear Width Each	No.	Clear Width Each
Rush Street	0	2	17 ft. 4 in.	2	7 ft. 7 in.
State Street	2	1	37 ft. 0 in.	2	9 ft. 10 in.
Dearborn Street	2	1	36 ft. 0 in.	2	9 ft. 11 in.
Clark Street	2	2	18 ft. 0 in.	2	6 ft. 7 in.
Wells Street	2	2	18 ft. 0 in.	2	6 ft. 7 in.
Randolph Street	2	2	22 ft. 3½ in.	2	8 ft. 8 in.
Washington Street	0	1	36 ft. 0 in.	2	7 ft. 0 in.

Bridge—	No. of Street Car Tracks	Roadway No.	Roadway Clear Width Each	Sidewalks No.	Sidewalks Clear Width Each
Madison Street	2	1	34 ft. 0 in.	2	5 ft. 7 in.
Adams Street	2	2	18 ft. 0 in.	2	6 ft. 3 in.
Van Buren Street	2	2	17 ft. 3 in. S. 17 ft. 5 in. N.	2	6 ft. 8 in.
Lake Street	2	2	18 ft. 0 in.	2	6 ft. 7 in.
Jackson Street	0	2	18 ft. 0 in.	2	6 ft. 7 in.

E. H. Lee, M. W. S. E.: We are fortunate to have Professor Spofford with us tonight, and to be given the facts relative to the scientific apportionment of costs for bridge construction as between the Public, Steam Railroads and Street Railways, with all three interested in a particular structure.

There can be little doubt that it is desirable from every angle that the apportionment of the cost in such cases be worked out in this manner, and engineers are especially well equipped to determine the facts and make the apportionment.

The facts which are developed relative to the widths of roadway required for traffic of various densities are exceedingly interesting and valuable. These lead me to wonder how much traffic can be carried on a bridge having a width of 118 feet over all, including roadways and sidewalks, such as recently planned for construction here in Chicago.

We are not so fortunate in the apportionment of the expense here in Chicago as is apparently the case in the region with which Professor Spofford is familiar. Here steam roads are generally required to bear all the expense for bridges over their tracks or carrying their tracks over streets.

It seems probable that an apportionment of the expense between the public, the street car companies and the steam railroads upon some fair and scientific basis would result, in the long run, to the advantage of the public as well as the railroads, because expenditure needlessly incurred and really unwarranted by conditions might sometimes be avoided, and it is true that needless expenditure, even if required by the public authorities, usually is eventually borne in some form by the public itself.

I. F. Stern, M. W. S. E.: There were two points brought out by Professor Spofford which interested me greatly:

1st. The work to be done on a structure for putting it in shape to carry heavier traffic.

2nd. Estimating the difference in cost of two structures spanning the same opening, but of different designs, one of which is to be constructed while the other would have been built ordinarily if some special considerations had not arisen.

The repair or reinforcement of existing structures to carry heavier traffic, and the consideration of whether the old structure

Traffic Statistics of Bridges and Tunnels between Rush St and Van Buren St Chicago, Ill. 1915.

Taken from 7 A.M. to 7 P.M.

BRIDGE	Traffic	7-8	8-9	9-10	10-11	11-12	12-1	1-2	2-3	3-4	4-5	5-6	6-7	Totals
Rush St. Feb. 4, 1915	Pedestrians	1061	1167	818	732	728	1302	859	755	616	772	1226	450	10486.
	Trucks	397	920	1211	1511	1008	878	850	1004	983	1075	1296	661	11594
State St. Feb. 5, 1915	Pedestrians	1091	1072	664	1027	1023	1136	978	1169	1224	1276	1444	1079	13183
	Cars	90	114	83	84	78	73	76	68	74	87	115	109	1051.
	Trucks	222	313	314	398	294	197	284	309	341	277	279	65	3293.
Dearborn St. Feb 8, 1915	Pedestrians	474	556	755	802	667	775	701	626	608	555	799	196	7514.
	Cars	55	46	40	54	34	36	38	36	41	46	64	47	537.
	Trucks	91	105	140	161	123	88	118	124	125	140	140	45	1400.
Clark St. Feb. 9, 1915	Pedestrians	1087	1201	1571	2212	2522	2802	2719	3044	2606	2188	5144	3825	30921.
	Cars	67	69	66	63	72	59	67	68	68	70	58	63	790.
	Trucks	230	303	327	335	414	216	253	334	309	333	321	171	3546.
Wells St. Feb. 10, 1915	Pedestrians	1178	1061	1044	1030	1063	1525	1491	954	931	1205	2702	713	14897.
	Cars	93	84	66	53	59	57	57	56	59	70	100	73	827.
	Trucks	306	331	411	432	387	271	311	328	432	407	394	135	4145.
Randolph St. Jan. 27, 1915.	Pedestrians	786	1610	1389	1435	1260	1741	1337	1004	910	923	1877	449	14721.
	Cars	229	269	189	168	143	179	121	125	127	165	227	146	2088.
	Trucks	317	663	713	680	1063	353	520	595	663	627	522	195	7111.
Washington St. Jan. 25, 1915.	Pedestrians	957	1429	635	760	659	792	644	605	475	723	1882	355	9916.
	Trucks	147	325	312	337	325	255	288	338	291	373	396	183	3570.
Madison St. Jan. 29, 1915.	Pedestrians	4106	8964	5423	5840	5243	2853	2951	2652	2445	3176	10877	2477	57007.
	Cars	143	157	105	93	92	108	94	95	114	130	164	104	1399.
	Trucks	184	298	348	397	321	215	283	346	310	382	300	146	3530.
Adams St. Feb. 1, 1915	Pedestrians	4265	5139	3149	1625	3328	1691	1329	992	923	1278	5100	885	29704.
	Cars	60	62	49	56	58	43	49	50	50	61	69	64	671.
	Trucks	376	695	709	653	528	273	300	362	314	349	390	185	5134
Van Buren St. Feb. 2, 1915.	Pedestrians	1328	1196	1232	1420	1446	1255	865	739	734	855	1656	482	13208.
	Cars	65	61	63	38	50	40	38	41	48	48	77	53	622.
	Trucks	291	495	557	551	455	305	327	642	750	330	400	199	5302.
La Salle St. Tunnel	2/11/15.	112	184	79	81	101	73	70	67	88	105	198	104	1262 Cars
Washington St Tunnel	2/3/15	143	129	105	72	77	70	74	78	88	106	162	127	1231 Cars
Van Buren St. Tunnel	2/11/15.	63	51	33	27	26	30	30	34	37	44	66	41	482 Cars

Fig. 1.

Traffic Statistics of Bridges between Lake St. and Van Buren St

Taken from 7 A M to 7 P.M

Washington St. Tunnel.
Van Buren St Tunnel

BRIDGE	Traffic	7-8	8-9	9-10	10-11	11-12	12-1	1-2	2-3	3-4	4-5	5-6	6-7	Totals.
Lake St. Feb. 10. 1914.	Pedestrians	860	550	460	500	390	640	600	560	440	630	1740	630	8000.
	Cars	136	161	107	84	90	93	96	85	103	102	182	120	1359.
	Trucks	198	247	368	332	293	189	218	250	288	281	236	82	2782
Randolph St. Feb. 11. 1914.	Pedestrians	880	920	530	470	380	1040	710	470	490	520	1610	440	8460
	Cars	88	104	56	49	27	56	46	46	71	75	100	78	796
	Trucks	313	391	400	491	461	285	407	516	498	233	376	162	4533.
Washington St Feb 12. 1914.	Pedestrians	650	1040	470	380	320	500	400	320	330	365	1130	340	6245.
		Taken on Lincoln's Birthday					Trucks are over 80% Automobiles							
	Trucks	46	121	206	143	113	130	150	124	158	168	220	102	1681.
Madison St. Feb. 9. 1914.	Pedestrians	3450	6020	2420	2020	1630	2630	3020	2580	2520	2790	6410	3140	38630.
	Cars	112	163	105	95	91	92	88	89	104	128	133	112	1312
	Trucks	148	272	301	366	272	220	314	356	332	309	298	171	3359.
Adams St. Feb. 13. 1914.	Pedestrians	5630	4810	1280	1080	1200	3080	1510	1280	1260	1690	5020	850	28690.
	Cars	64	74	64	50	56	80	67	61	63	65	86	58	778.
	Trucks	137	215	443	375	307	413	400	462	421	459	501	262	4355.
Jackson St. Mch. 26. 1913	Pedestrians	1912	1141	537	609	776	2569	845	629	543	702	2971	1690	14924.
	Trucks	226	454	456	558	508	440	456	529	525	655	672	463	5942.
Van Buren St. Feb. 14 1914.	Pedestrians	1540	750	440	500	410	1450	980	550	433	850	420	250	8573.
	Cars	68	56	57	52	47	52	67	46	46	57	68	57	673.
	Trucks	229	307	441	411	403	249	326	385	343	245	161	79	3579.
Washington St. Tunnel. 2/17/14		89	121	65	50	52	51	48	71	72	89	148	85	941 Cars
Van Buren St. Tunnel 2/17/14		66	42	36	30	31	49	36	58	53	59	67	45	572 Cars.

Fig. 2.

can be reinforced, or an entirely new structure is necessary requires a large degree of high class engineering ability.

A great amount of money is annually wasted in trying to make repairs to bridges that should really be rebuilt. On the other hand, a great many bridges have been taken out and replaced when a small amount of money, comparatively speaking, judiciously expended, would have enabled many of the structures to be carried for a great many years under the additional loads imposed. The Boyleston Street bridge mentioned in the speaker's paper is a good illustration of the latter case.

While it is notoriously true that lack of proper engineering advice has resulted in allowing loads that should never have been permitted, to run over some structures, with, at times, resulting failures, causing loss of life and much property and operating damage, the opposite error is quite as likely to take place.

I know of one particular case on a street railway where heavier power was put into service, the electrical engineer of the railway decided it was necessary to keep traffic off of a bridge over a certain stream, and built a trestle alongside for the operation of the street cars. I happened to be in his office one day, while the matter was being considered, and was asked to give my opinion. The plans were quite complete. After studying them over, I came to the conclusion that the bridge, if in proper physical condition, could carry the heavier loading, for a great many years, upon which I was informed that unlike civil engineers, the electrical engineer never took any chances. As previously stated, a pile trestle was built alongside to carry the street car traffic, and I have always considered it a foolish waste of money. The sequel is interesting. Some time later, a street car bridge in another part of the country collapsed under its loading, and several people were killed. At the next meeting the board of directors of the electric road that built the pile trestle, they officially thanked their electrical engineer for having been wise enough to "properly" safeguard their interests.

Street car companies are, however, not the only offenders in this respect. Some years ago, I was called in by a steam railroad to report on a line several hundred miles long on which it was desired to run heavy Mikado engines. Up to that time, as a measure of economy, this railroad had saved bridge engineers' fees and had called in bridge companies to do their designing, as part of their construction contract. The bridge company had sent one of their draftsmen over the line and had enumerated certain bridges which would have to be rebuilt before the Mikado engines could safely be used.

My report on this line was adopted and I am certain that I did not take any "chances" on the safety of the structures. The cost of doing the work was about what we estimated, which amounted to about twenty per cent of what it would have cost if the

Bridge Company had been allowed to follow its own inclinations in the matter.

I have recently been in conference with the chairman of this section, regarding the costs of two bridges at the same location, one of which was called for by an early contract between an Electric railway company that I represent and the railroad that he represents. The electric line crosses the steam railroad. It was decided to change the type of structure on account of the necessity of providing for a different grouping of the railroad company's tracks. We made more or less detailed plans and estimates for both structures to agree on a basis for a different apportionment of costs. We finally decided that it would not be equitable to take the actual costs of the structure to be built, after it was completed, and compare it with an estimate of cost of a structure that was never built, but that the only proper thing to do was to take the estimate of cost of both structures. Mr. Loweth's instructions in this matter, which were followed, were to the effect that while we should make close estimates in as great detail as possible, we should not go to such a refinement that it would cost a dollar to develop one dollar's difference between the two comparative estimates.

Ernest McCullough, M. W. S. E.: Street car lines are required to pay a legitimate part of the cost of paving and repairing street surfaces because of the greater concentration of traffic caused by the presence of the tracks. Similarly when special provision must be made to carry street cars on bridges the companies should be charged with a fair share of the cost of such bridges. It would seem to be difficult to decide in advance whether this cost should be a per cent of the whole cost or be decided by a study of each case. When a commission is called on to decide an engineering question it is necessary to have a careful estimate made and the question decided on merit, the technical and other sides of the question being given due weight. At times there may be cases arising when the street railways will be of such great benefit to a district served by a bridge that the entire cost could be borne by the community and the street railway company be charged a rental, or be merely charged with a proportion of the upkeep.

James N. Hatch, M. W. S. E.: I was very much interested in Professor Spofford's paper and it would seem to me that the branch of engineering which he has discussed is one that has many possibilities for the engineer. My experience in this line of work has been very limited and I do not know that I could add anything that would be of special interest.

I recall to mind, however, a report that I made, some years ago, where an interurban railway was carried by a joint bridge. The interurban railway had constructed its bridge by building one truss outside of a highway bridge and arranging its track so that about two-thirds of the load came on the new truss and about one-third on one of the old trusses of the highway bridge. The question was raised as to whether the loads thus brought on the highway bridge were safe for the structure to carry.

After figuring this over, I reported that the cars of the railway brought an excessive load on the old truss of the bridge which I found to be stressed practically up to its limit with the highway traffic only. My report raised considerable discussion, both with the city and with the railway company, and I do not know just what would have happened were it not for the fact that very fortunately the extreme high water, of two or three years ago, came on at this time and washed the pier out from under the old bridge and let it down into the river.

This ended all controversy over the matter and I have not heard from my report since.

H. S. Baker, M. W. S. E.: The new bridges being built by the city at the present time are paid for by the City of Chicago, except that the Oak Park Elevated Railroad Company bears one-third of the cost of the double deck bridge in Lake street. In general, the viaducts carrying streets above railroad tracks are built and maintained by the railroad companies at their expense. The expense of track elevation work, including bridges and subways beneath them, is paid for entirely by the steam railroads, except the damages to abutting property, which are paid by the city. The street railway companies pay only the cost of their own tracks and the paving between the rails.

Closure.

The Author: The writer regrets that the verbal discussion of the evening has brought forth no definite figures concerning the actual additional cost of providing for street railway traffic on highway bridges. Mr. Baker has mentioned that the Chicago Elevated Railway Company is to pay one-third of the cost of the Lake Street Bridge, but does not state how this figure, which seems rather high in the light of the examples given, was obtained. It is evident from the other discussion that the speakers are in agreement as to the reasonableness of charging some proportion of the cost of a highway bridge to any railway which may cross it.

Mr. Loweth cites the bridge at LaCrosse, Wisconsin, where the street railway was charged 15%, which agrees with the amount charged in the case of several Massachusetts bridges.

In conclusion, the author wishes to express the hope that members of the Western Society of Engineers who may become engaged upon cases of this character will publish the methods used and the conclusions reached.

THE FLOW OF ENERGY THROUGH TRANSMISSION LINES

By Robert A. Philip, Member A. I. E. E.*

Presented at the Joint Meeting of the Chicago Section of American Institute of Electrical Engineers and the Western Society of Engineers, March 22, 1915.

The flow of a material fluid, such as water or air, through the pipes which transmit it may be shown as a ribbon whose varying width represents the variations of the current.

A similar picture may be drawn of the transmission of power.

It is, however, more exact to consider that it is energy rather than power which is being transmitted, because power means a flow of energy. The relation between power and energy is similar to that between a current of water and the water itself. That is, power is a name for a current of energy.

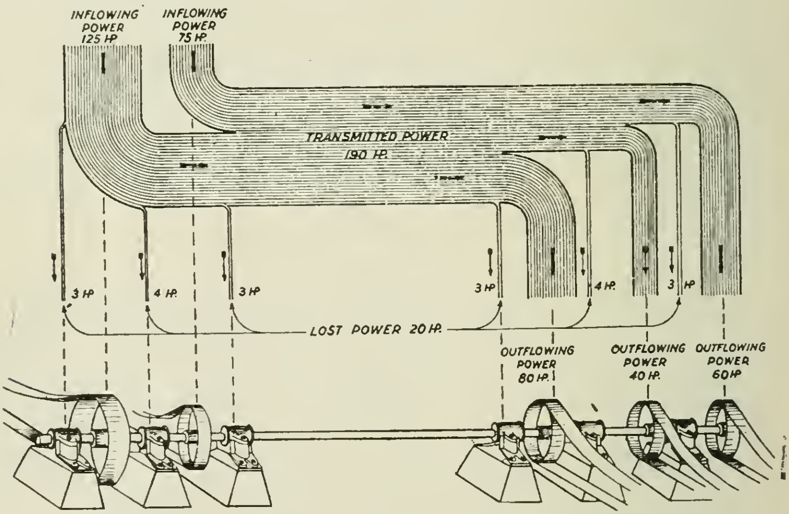

Fig. 1. Flow of Energy Through a Shaft.

Energy, like matter, can be transported or changed in form, but can be neither created nor destroyed. Therefore in the distribution of energy as in the distribution of a material fluid the total quantity supplied to the distributing system, plus or minus storage in the system itself, must at every instant equal the quantity delivered, including leakage. This fundamental similarity allows a distribution of energy to be pictured as though it was a distribution of matter.

Fig. 1 is a picture, on this basis, of the flow of energy into, through and out of a rotating shaft. Along the route of the shaft

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a ribbon is drawn, the width of the ribbon at each point being proportional to the flow of energy, that is the power, at that point. Evidently, if there is no storage in the shaft the width of the ribbon can only increase at points where energy flows in and only decrease where it flows out, and a change in width of the ribbon representing the main stream of energy must be exactly equal to the width of a branch at that point. The flow of energy may be measured in any convenient unit, horsepower, foot-pounds per second or kilowatts, and the width of the ribbon may be drawn to any desired scale. At each point the flow has two elements, amount and

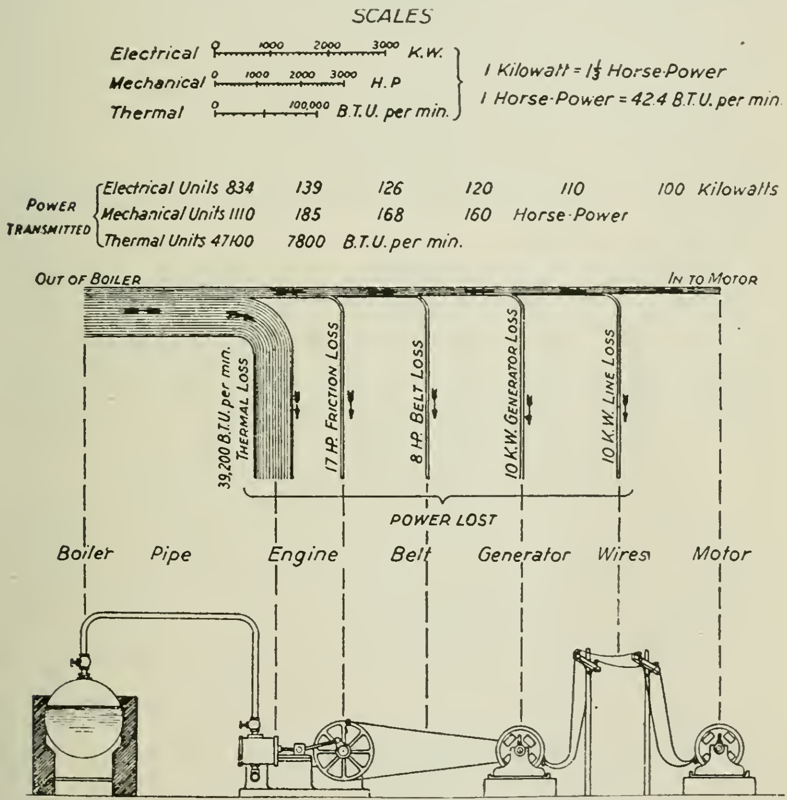

Fig. 2. Thermal, Mechanical and Electrical Transmission.

direction, the former being represented by the width of the ribbon and the latter indicated by arrows marked on the ribbon.

This first illustration is based on the transmission of energy through a rotating shaft where the energy comes in and goes out over moving belts and is lost in bearing friction. A similar illustration may be used for the hydraulic and pneumatic transmission of energy by currents of water and of air and for the electric transmission by electric current.

The picture drawn is a general one and may be used to represent the transmission of any kind of energy in any manner.

Energy may be transmitted in one form, transformed and transmitted further in another form and the several transmissions may be grouped together to form a single picture.

Fig. 2 shows energy transmitted thermally from a steam boiler through a steam pipe to an engine, thence mechanically through a belt to a dynamo, and finally electrically to a motor. The diminution of the stream of energy is indicated as due to separate thermal and mechanical losses of transformation in the engine, mechanical losses in the belt, combined mechanical and electrical losses of transformation in the dynamo and electrical losses in the wires.

This picture may be extended by tracing each branch forward or back to its furthest ascertainable end, and it may be amplified by analyzing the losses into more elementary streams and by tracing the flow in greater detail; showing, say, the flow of energy through the reciprocating parts of the engine on its way from the steam pipe to the belt.

While this is a general method of picturing the transmission of power it is especially useful in illustrating the meaning of terms used in electrical power transmission by alternating currents, such as wattless current, synchronous condenser and induction generator, therefore the electrical use of the method will be chosen for amplification, although it will be indicated that the same things may be found in mechanical transmission.

The Direct-Current Generator and Motor.

In Fig. 3 the varying widths and directions of the ribbon of energy flow show the operating characteristics of generators and motors. The width of the outgoing energy stream is, of course, exactly proportional to the load, but is electrical power from a generator and mechanical power from a motor. The width of the loss stream is a maximum at full load and decreases slightly down to a minimum at no load. The input stream is exactly equal to the output stream plus the loss stream; that is, the losses are necessarily drawn from the inflow, so are supplied mechanically for a generator and electrically for a motor. The main current of energy tapers down as it passes through the machine. The efficiency is equal to the outflow divided by the inflow. The illustration shows clearly one important point: the efficiency increases from no load to full load, not because of a decrease in losses, but in spite of an increase in losses.

The series of pictures may be considered as a moving picture film of the operation of a direct-current generator. It is first running in multiple with other sources of electric power and carrying full load. The operator turns the rheostat handle increasing the resistance of the field circuit and the outflow drops perhaps to half load; he turns the handle further and the outflow drops to zero, the reduced load on the engine being indicated by showing the engine as proportionally smaller. If the operator continues to turn in resistance the flow of electric power reverses. There is

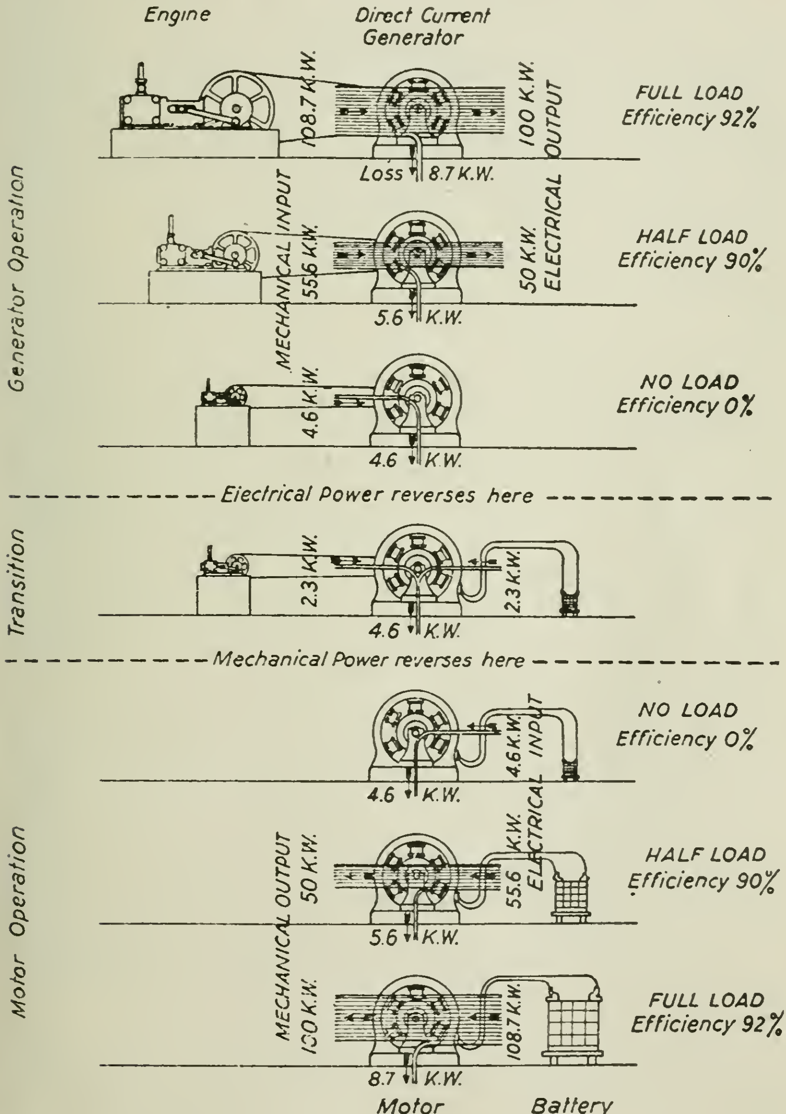

Fig. 3. Direct-Current Generator and Motor Operation at Varying Loads.

here a narrow transition stage where the losses, which are now at a minimum, are supplied both mechanically and electrically. When further resistance is turned in, the mechanical power also reverses and operation as a motor follows at no-load, fractional load, full load and overload in successive steps.

The series illustrates the meaning of the terms generator and motor. They describe, not the construction of an electric machine, but the two ways of using it. The electric machine is reversible in function. It is a generator only so long as the outflowing energy is electrical and a motor so long as it is mechanical. When it is known whether a machine is operating as a generator or as a motor two elements of the ribbon picture have been determined. First, which way the arrows of flow should point, and second, as a consequence of this, which way the main flow tapers off.

TRANSMITTING MEDIUM.

While a current of energy may be transmitted by using a current of water or a current of electricity the energy itself is neither water nor electricity. The water or electricity is but a medium of transmission. Similarly the motion which constitutes the flow of the water or other mediums is not the motion which constitutes the flow of energy. The medium may be, and often is, used over and over again. The moving belt goes forward on the slack side and returns to the driving pulley on the tight side; the water goes out in the pressure pipe, leaves the engine through the exhaust pipe, and may return to the pump through the suction pipe; the electricity goes out on the positive wire and returns to the generator on the negative wire, just as much belt, water or electricity comes back as goes out, but the transmitted energy moves forward only. In fact, the direction in which the belt, water or electricity moves can be reversed without reversing the direction in which energy is transmitted, or vice versa.

Therefore if energy is transmitted by a flow of water or of electricity a picture of the flow of energy will not be at all identical with a picture of the flow of the transmitting medium, even though the same principles may be used in representing each kind of flow.

It will be understood that a representation of a flow of electrical energy is not at all a representation of a flow of electricity.

That the motion of energy and the motion of the transmitting medium are practically independent is also shown by the fact that shafts, belts, water and electricity may be in active motion and yet transmit no power, and that the same mediums may transmit more power at times when they move slowly than when they move rapidly.

This is because the mediums transmit no power unless they move under pressure or tension. Power, whether mechanical or electrical, is considered as consisting of two equally important components, one of motion and one of pressure. The amount of power is the product of the two components. For hydraulic transmission the power in foot pounds per second is the product of the flow in cubic feet of water per second by the pressure in pounds per square foot and similarly, for electric transmission, the power in watts is the product of the current of electricity in amperes by the electrical pressure (potential) in volts.

Alternating Currents.

Where power is transmitted mechanically by shafts, belts or fluids, or electrically by direct currents, the motion and pressure each has its own fixed direction. However, power is also transmitted both mechanically and electrically by motions and pressures which alternate in direction periodically. The pistons, piston rods, connecting rods and other reciprocating parts of a steam engine transmit mechanical power in virtue of their motion, although this motion alternates in direction instead of being uniformly forward. In these cases it is important to note that the pressure as well as the motion also alternates. The pressure is on one side of the piston on the forward stroke and on the other side on the backward stroke.

Energy is the product of motion and pressure; therefore, if motion and pressure both reverse the flow of energy is not reversed, on the principle that the product of two negatives makes a positive. The reversal of the motion of the reciprocating parts of a steam engine does not reverse the motion of the energy which flows forward from steam pipe to shaft during the backward as well as forward stroke.

With uniform motion or flow the amount of energy transmitted is equal to the product of the motion by the pressure. The same formula holds for reciprocating motion and alternating flow provided it is understood that by motion and pressure is meant mean motion and mean pressure. The mean is found by squaring the instantaneous values of the quantities averaging these squares over a complete cycle and extracting the square root.

The transmission of power by electric current which alternates in the direction follows the same principle as the transmission by reciprocating mechanical motion, namely, the reversal of the direction of the electric current does not reverse the flow of energy because the pressure is simultaneously reversed. An alternating current of electricity, or of water for that matter, will transmit just the same amount of power as a direct current of the same mean magnitude, at the same mean pressure, provided, however, that the current and potential reverse at exactly the same time.

When the motion and pressure reverse simultaneously they are said to be in phase. Alternating motions or currents when in phase with their corresponding alternating pressures are practically equivalent to uniform motions or direct currents for the transmission of power.

Under these conditions the ribbon picture of power may be used for alternating current transmission. However, it is to be remembered that the flow represented is not the instantaneous flow, which fluctuates, but the mean flow over one or more complete cycles.

Accelerating Power.

It may happen that while the motion and pressure are both reciprocating or alternating, and at the same rate, they fail to reverse simultaneously.

The difference in time of reversal may be very small, but it cannot be greater than a quarter of a cycle. When motion and pressure reverse a quarter of a cycle apart any further change in either direction brings the times of reversal closer together. For example, two cranks on the same shaft have their respective dead points as far apart as possible when set, like the cranks of a locomotive, a quarter of a revolution apart. Motion and pressure are then said to be in quadrature, and each reverses when the other is at a maximum.

Under these conditions motion and pressure, instead of being positive and negative, simultaneously thereby always giving a positive product, are of the same sign, but half the time so that their product is half the time positive and half negative. This change in sign of the product, that is of the power, indicates a reversal of its direction of flow. Where motion and pressure are in quadrature the energy flows forward and backward instead of moving uniformly forward. The average of the forward and backward flow is zero, so that such an alternating flow of energy does not constitute a transmission of power in the ordinary sense.

The phenomena of motion and pressure in quadrature occurs wherever a mass moves with a reciprocating motion. The motion is that of the mass and the pressure that required to accelerate it. The power corresponding to their joint effect may be called accelerating power.

The power transmitted by reciprocating motion is equal to the product of the mean velocity and mean pressure when motion and pressure are in phase. The rule may be extended to apply to accelerating power.

The product of the mean velocity by the mean pressure, where motion and pressure are in quadrature, is an amount of power equal to the maximum value which the accelerating power attains during a cycle. The momentary flow at all times is proportional to this maximum. As the flow alternates in direction, giving an average value over the cycle of zero, it is convenient to use the maximum value as a measure of the flow where considering it in connection with the associated flow of energy over one or more complete cycles.

For reciprocating motion, the product of mean velocity by mean pressure is the transmitted power if the two quantities are in phase, but is the accelerating power if they are in quadrature.

Accelerating power is evidently always necessary where reciprocating motion is maintained. On the whole the accelerating power neither adds to, nor subtracts from, the true power transmitted. It may exist where there is no true power transmitted, and for a given amount of true power the accelerating power may be greater or less. Finally, it may be said that accelerating power is a peculiar form of power fundamental to reciprocating motion, and that it may be considered as transmitted independently of the true power and according to its own laws.

The steam engine, containing reciprocating parts, furnishes an example of the transmission of accelerating power.

Consider a steam engine with steam shut off and running due to the momentum of the flywheel. Aside from any effects of friction or of compression in the cylinder the reciprocating parts, the piston for example, must be accelerated from the rest to a maximum velocity, then retarded (accelerated negatively) and brought to rest again in each stroke. These accelerations require forces which must be transmitted to the piston from the flywheel through the intervening parts such as the piston rod, as pressures (or tensions, which are negative pressures). The reciprocating parts are, therefore, transmitting accelerating pressures and at the same time are in active motion. However, it will be found that the motion of the rod reverses at the time when the pressure in it is a maximum, and that the pressure reverses when the velocity is a maximum. That is, motion and pressure are in quadrature.

The flywheel is giving out power and accelerating the piston during half the time, and during the other half the process is reversed. It may be said that the flywheel and the piston are interchanging accelerating power which alternates in direction.

At the instant that the reciprocating parts are passing their dead point the flywheel has a maximum velocity which is the same as though it were running freely unconnected to the reciprocating parts. At all other times the velocity of the flywheel is more or less reduced. Consequently, if reciprocating parts are connected to a flywheel previously running freely the number of revolutions per minute will thereby be reduced.

The flywheel contains a store of energy by virtue of its velocity. This reduction in the mean velocity results in a corresponding reduction in the average energy stored in the flywheel, but, on the other hand, the reciprocating parts acquire an equal amount of average energy due to their mean velocity.

From this point of view it may be said that the reciprocating parts have been energized at the expense of the flywheel which has been deenergized. The total stored energy of the system has not been changed, but it has been redistributed.

In a steam engine, whether a simple engine with a single cylinder and crank, or a compound engine with several cranks, the motion of all the reciprocating parts, pistons, piston rods, connecting rods, valves, valve rods and eccentric rods, is in proportion to a single angular velocity, the speed of revolution of the engine. The distribution of accelerating power in one engine may form a complex system, all, however, based on a single angular velocity. In this respect it is similar to an alternating-current distributing system, which, however large, has a single frequency.

Where the mean angular velocity is constant the energizing of the reciprocating parts and the deenergizing of the rotating parts is directly proportional to the amount of accelerating power which flows. For example, if the weight of a reciprocating part is doubled, the energy it contains and the accelerating power it receives are both doubled, while if the stroke is doubled the energy and accelerating power are each quadrupled. At constant angular velocity the amount of accelerating power may be used as a measure of the transfer of energy, and it may be said that each reciprocating part takes a flow of accelerating power proportional to the amount to which it is energized while each rotating part is deenergized in proportion to the flow of accelerating power which it gives out.

Pictures of Accelerating Power.

To make a picture of the flow of accelerating power a second ribbon may be drawn of width equal to the accelerating power; that is, to the product of the mean force by the mean velocity. To distinguish between the two ribbons, that for energy transmission will be shaded longitudinally and that for accelerating power laterally.

Accelerating power may be measured in the same units as other power; that is, foot pounds per second, horse power, watts or kilowatts.

Arrows have been placed on the energy flow ribbon to indicate that energy is continually passing a given point in one direction. With such a flow the total quantity of energy passed increases cumulatively with the time. The flow of accelerating power alternates in direction so that arrows to represent the successive instantaneous flows would point equally in both directions. However, in picturing the transmission of power by reciprocating motion we are not attempting to show the instantaneous values which fluctuate throughout the cycle, but only the effect over one or more complete cycles.

While the accelerating power has no direction of flow it is associated with the transfer of energy from the rotating flywheel to the reciprocating piston which is in a determinate direction. As the deenergizing of the flywheel and the energizing of the piston are each proportional in magnitude to the width of the stream of accelerating power it is a useful convention to mark on this ribbon arrows to indicate the direction of the transfer of energy. It is to be remembered that this transfer is a process not cumulative with time, so that accelerating power of a constant amount may flow indefinitely from a flywheel without depleting its energy supply. The arrow on this ribbon represents a transfer of energy which occurs at the time when the flow from flywheel to piston first begins, and which may be described as unstable. The transfer can only be maintained as long as the flow of accelerating power continues, and in an amount proportional to the flow. Any increase or decrease of flow is accompanied by a corresponding transfer of energy.

It is further to be remembered that the direction of these arrows is determined by making the assumption that the rotating parts are the primary reservoirs of stored energy; therefore, that the flow of accelerating power (transfer of stored energy) is from the rotating parts to the reciprocating parts. This assumption is natural in the simple case used for illustration, but is not essential. That is, the direction of the arrows results from a convention, and could be reversed by adopting a different convention. It is, of course, desirable to adhere always to one convention, though it is useful to know that the arrows on the ribbon of accelerating power represent but one of two possible views. The conclusions are, of course, the same whichever view is adopted, the language in which they are clothed being alone affected.

Fig. 4 shows the distribution of accelerating power from a flywheel to the reciprocating parts of an engine.

The speed of the engine is 150 rev. per min. The stroke of the engine is two feet, giving the pistons a mean velocity of $\pi/\sqrt{2} \times 150$ rev. per min. $\times$ 2 feet or 667 feet per minute. The mean acceleration of the pistons is $\sqrt{2} \times \pi^2 \times 150^2$ rev. per min. $\div\ 60^2$ seconds per minute $\times$ 2 feet, or 175 feet per second per second. The high pressure piston weighs 120 pounds and takes a mean accelerating force of 120 pounds $\times$ 175 feet per second per second divided by 32.2, or 652 pounds. The accelerating power is therefore 652 pounds $\times$ 667 feet per minute divided by 33,000, or 13 horsepower.

The low-pressure piston weighs four times as much and requires 52 horsepower acceleration. The valve weighs one-sixth as much and has one-fourth the travel and requires 1/96 the power, or 0.14 horsepower.

The high-pressure piston is energized to an amount equal to one-half its weight multiplied by the square of its mean velocity, or $1/2 \times 120$ pounds $\times\ 667^2$ feet per minute divided by 60^2 seconds divided by $32.2 = 230$ foot-pounds. The low pressure piston contains 920 foot-pounds energy and the valve 2.4 foot-pounds. These quantities of energy are exactly proportional to the accelerating power taken by the parts, the ratio being 33,000 foot-pounds per minute divided by $4 \times \pi \times 150$ rev. per min., or 17.5. That is, a reciprocating part is energized by 17.5 foot-pounds for every horsepower of accelerating power which flows into it.

Magnetizing Power.

What has been said of mechanical motion and pressure when in quadrature applies also to electric currents and pressures. As

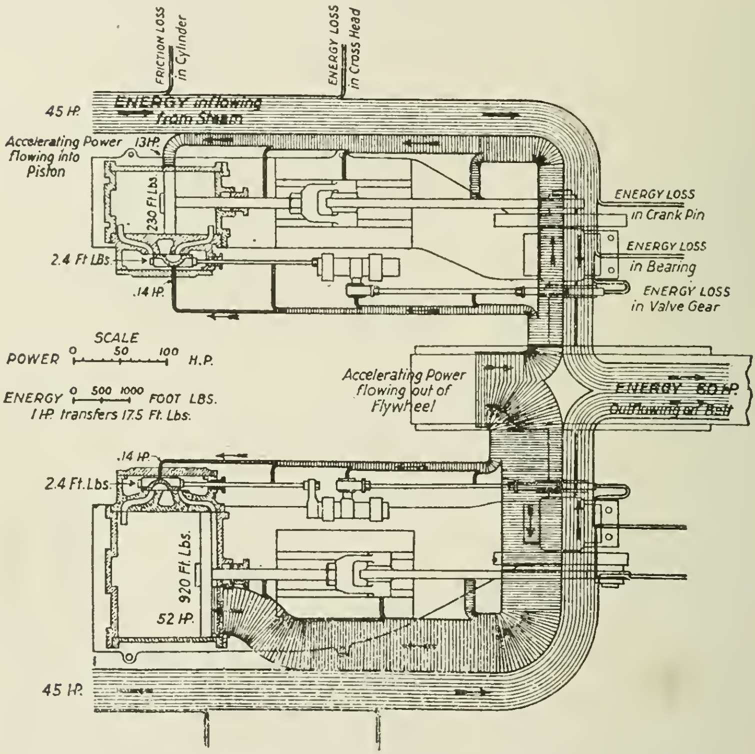

Fig. 4. Flow of Energy and Accelerating Power Through Engine.

reciprocating motion necessitates acceleration of matter and that requires the application of accelerating power, so alternating electric currents necessitate the acceleration of electricity, and that also requires a similar kind of power. Mechanically, the accelerating power is stored intermittently as kinetic energy in the reciprocating mass, while electrically the power is correspondingly stored in the alternating magnetic field of the moving electricity. Wherever there is reciprocating matter there must be mechanical accelerating power, and wherever there is alternating electricity there must be electric magnetizing power.

Electric currents in quadrature with the electrical pressure have been called idle or wattless currents because they transmit no power in the ordinary sense, and the product of these currents by the pressure has been called wattless power for the same reason. As the power taken by reactive coils is almost wholly "wattless" the power is also called reactive power, with the advantage that there is no implication that it is not really power. As the "idle" currents produce magnetization they are also called magnetizing currents, and the name magnetizing power seems to give the simplest view of the function of reactive power. All of these electrical terms describe a special form of power which alternates in direction and is otherwise identical with mechanical accelerating power which exists in all reciprocating machines.

Magnetizing power, it should be noted, is necessary to produce magnetism alternating in direction, just as accelerating power is necessary to produce reciprocating motion.

When the magnetism is uniform in direction the magnetization is produced once for all at the beginning, and no further magnetizing power is required. The same distinction occurs in mechanics; uniform motion, say of a flywheel, requires accelerating power only at the time of starting; after reaching speed it will run indefinitely without further acceleration.

A permanent magnet or an electromagnet excited by direct currents may be regarded as a reservoir of magnetism just as a uniformly moving flywheel is a reservoir of energy.

The magnets used in direct-current electrical machinery are of this type, therefore, except at the instant of starting, no magnetizing power is used.

A permanent magnet may be compared to a frictionless flywheel which will run indefinitely when once started. Flywheels in general cannot be frictionless, but must have shaft and bearings. To keep such a flywheel running uniformly energy must be continually supplied equal to the bearing friction. But it should be noted that *such energy adds in no way to the stored energy of the flywheel.* A direct-current electromagnet is similar to such a flywheel. The field current or exciting current merely overcomes electrical friction, that is resistance, and conserves the magnetization put in at the first instant.

The magnetizing power flowing into an alternating-current magnet is like the accelerating power flowing into a reciprocating piston, while the exciting power flowing into a direct-current magnet is like the mechanical power flowing into the bearings and overcoming the friction of a flywheel.

In practically all commercial machines for interchanging mechanical and electrical power, that is, generators and motors, the mechanical forces are due to the attraction and repulsion of magnets. With alternating-current machines the magnetism of these magnets is produced in whole or in part by this magnetizing power.

An ordinary alternating-current generator also has magnets excited by direct current. These magnets serve a similar purpose to the flywheel of a reciprocating engine. As the flywheel is a reservoir of mechanical energy which is drawn on to accelerate and retard the reciprocating parts so the magnet of the alternator is a reservoir of magnetization which magnetizes and demagnetizes the alternating-current magnets of the circuit.

As we may picture mechanical accelerating power flowing out from the flywheel to each reciprocating part of an engine so may we picture magnetizing power flowing out from the generator to each motor, transformer or other part containing an alternating-current magnet.

The alternating-current magnets are magnetized at the expense of the direct-current magnets. The gain of magnetization of one exactly equals the loss of magnetization of the other.

A displacement of magnetization in a determinate direction is then associated with the flow of magnetization, which being alternating, is itself directionless. Furthermore, the frequency being the same throughout the system, the amount of magnetization displaced is proportional to the magnetizing power.

Electric machines absorb or give out mechanical energy because of attraction or repulsion of their constituent magnets. Alternating-current machinery such as ordinary generators, synchronous motors and synchronous converters contain both direct- and alternating-current magnets, while other important electric machinery such as transformers, induction motors, induction regulators and induction generators contain alternating-current magnets only.

A machine containing both direct- and alternating-current magnets may either give out or absorb magnetizing power. A machine containing alternating-current magnets only can also give out or absorb magnetizing power if provided with a suitable commutator. The use of such a commutator is, however, still unusual, and the ordinary induction motor and most other machinery containing alternating-current magnets have no commutators. A machine containing alternating-current magnets only, and without a commutator, can absorb, but cannot give out magnetizing power.

Most alternating electric machinery is designed to have an approximately constant magnetization, therefore the magnetizing power is also approximately constant. The flow of magnetization to a transformer, induction motor or other non-commutating machine containing alternating-current magnets only can be pictured as being constant at all loads for an ideal, perfect machine. For a practical machine the flow of magnetization will increase slightly with increasing load, although the useful magnetization decreases slightly, the voltage being assumed normal at all loads. Increased voltage at any load increases the flow of magnetization, and decreased voltage decreases it.

Pictures of the Flow of Magnetizing Power.

Magnetizing power being but an electrical variety of accelerating power, its flow may be shown by a similar picture. A ribbon may be drawn for it with a width equal to the product of the mean current by the mean potential.

Magnetizing power may be measured in the same units as accelerating or other power, though in electrical work magnetizing power is measured in kilovolt-amperes instead of in kilowatts. The two units are of the same dimensions, a kilowatt being the same as a kilovolt-ampere, except that its application is limited by an additional convention that the current and pressure are in phase. It may be pointed out that it is equally important to distinguish between kilovolt-amperes of magnetizing power where current and pressure are in quadrature and kilovolt-amperes of apparent power where no determinate phase relation is implied.

Arrows may be placed on the ribbon to show the direction in which magnetization has been displaced. The demagnetizing of the field magnets of an alternator and the magnetization of the fields of an induction motor being proportional to the magnetizing power, and due to its flow, there is a natural basis for describing the flow as being from the point where demagnetizing takes place, and to the point where the magnetism reappears. The displacement of magnetization, like the transfer of energy from flywheel to piston, is a transient change which occurs when the flow begins, but the displaced magnetization is only prevented from returning to its original state of equilibrium by the continuance of the flow of magnetizing power. The flow of magnetizing power is, therefore, not a cumulative flow, and if constant, does not further deplete the magnetization of the source from which it springs nor build up an indefinite amount of magnetization at its terminus.

The Induction Motor and Induction Generator.

Fig. 5 shows the flow of energy through an induction motor at varying loads. As previously mentioned, an induction motor contains alternating-current magnets only, and, therefore, must receive magnetizing power from some external source. The motor receives from the generator two independent kinds of power. The ordinary flow of energy through it is similar to that through a direct-current motor, and requires no further comment.

The magnetizing power which flows into the motor and goes no further is the peculiar feature. The width of this power ribbon does not vary much from full load to no-load. Motors of different sizes take magnetizing power approximately in proportion to their horsepower rating, though small motors take a somewhat greater proportion due to less perfect design. Slow-speed motors take more than high-speed motors of the same rating, because the speed being low, the maximum torque must be high, and as the diameter of the armature is not increased sufficiently to maintain the same surface

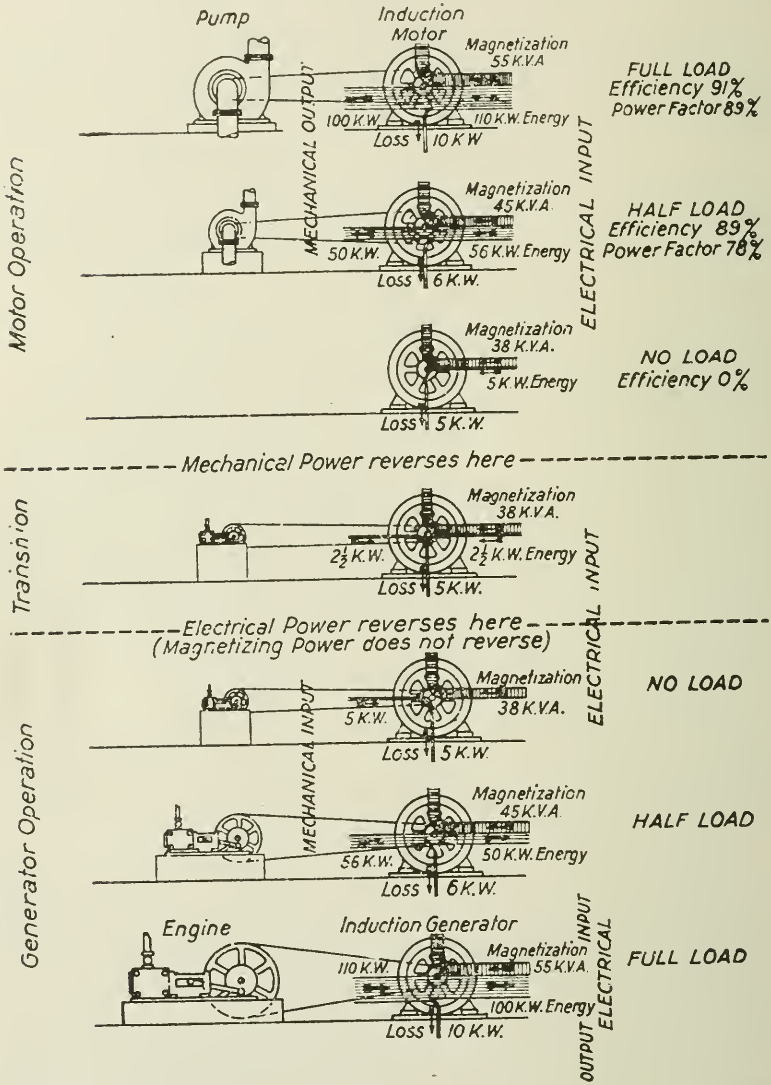

Fig. 5. Induction Motor and Induction Generator Operation at Varying Loads.

speed, a high torque requires more magnetic attraction, and consequently more magnetism. Subject to considerable variation due to such causes, the figures shown may be taken as typical of any induction motor.

An induction motor, like other motors, is reversible in its function and may operate as a generator, and is then called an induction generator.

Fig. 5 is extended to show the transition from motor to generator action. The operation of the motor as a generator amounts to a reversal of the flow of energy, precisely as with a direct-current machine.

However, *the flow of magnetizing power does not and cannot reverse.* An induction generator cannot produce magnetizing power. The induction motor is a reversible machine as regards the flow of energy, but not as regards the flow of magnetization. This explains why one induction motor operated as a generator cannot operate another as a motor unless some other machine is also connected which is capable of furnishing the magnetizing power for both machines It also shows why it may be advantageous to forego the simplicity of the ordinary induction motor and add a commutator so that the inward flow of magnetization may be reduced, eliminated or reversed.

Synchronous Motor and Alternating-Current Generator.

An alternating-current generator can operate as an alternating-current motor, and is then called a synchronous motor. The synchronous motor differs from the induction motor in being completely reversible; that is, reversible as regards the flow of magnetization as well as of energy. Where an alternator transmits power to a synchronous motor there are three cases, as shown in Fig. 6.

The simplest case is where, as in direct-current transmission, no magnetizing power is required. Each machine has its magnetization furnished locally by direct currents. The equality of excitation is indicated in the figure by drawing the exciters of the generator and motor as of the same size.

Above this case is shown the one where magnetization as well as energy is being transmitted from the generator to the motor. This indicates that the motor has insufficient magnetization; it is, therefore, said to be under-excited. The less the direct-current excitation of the motor the greater the magnetizing power absorbed by it. This magnetizing power produces a useful magnetization in the motor just sufficient to supplement the inadequate direct-current magnetization. If the direct-current excitation decreases, the magnetizing power increases, so that finally, if the direct-current magnetization fails entirely, the magnetizing power alone may furnish approximately normal magnetization. A synchronous motor may, therefore, run without direct-current field excitation; in fact, this principle is used in starting synchronous motors and converters. Such an unexcited motor is similar to an induction motor, but is so imperfectly designed for unexcited operation that it takes a much greater proportion of magnetizing power.

An unexcited synchronous motor is, like an induction motor, reversible in regard to flow of energy, and may be used as a generator. However, an unexcited generator or motor must absorb and cannot produce magnetizing power. Therefore an unexcited generator cannot be used to run an unexcited motor unless there is some other source of magnetizing power adequate for both generator and motor.

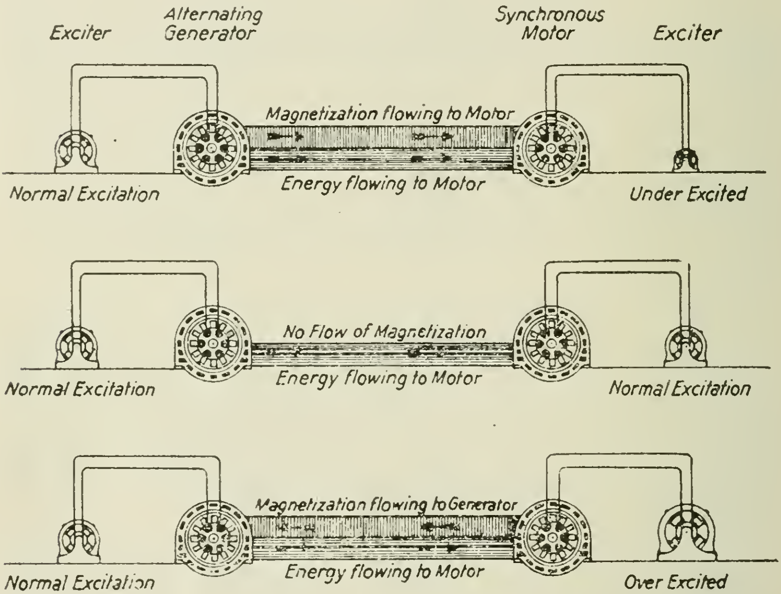

Fig. 6. Flow of Energy and Magnetization at Varying Excitations.

At the bottom of the figure is shown the case where the motor has an excessive amount of magnetization or is over-excited. The magnetizing power now flows from the motor to the generator. The effect of this flow is to demagnetize the motor, the amount of flow being just sufficient to bring the magnetization of the motor down to equality with that of the generator.

The principle is, in fact, general that magnetizing power demagnetizes the machine from which it proceeds and magnetizes the one into which it flows. Magnetizing power may, therefore, be imagined as a current or flow of magnetization from points of surplus to those of deficient magnetization. The surplus magnetization is to be found in those machines strongly excited by direct currents, the deficient magnetization in those weakly excited and more especially in transformers, induction motors and other apparatus having no direct-current excitation at all. Strong and weak excitation are, of course, only relative terms. If the excitation of a generator and a motor are equally strong or equally weak no flow of magnetizing power between them is necessary to preserve a balance. The voltage which a machine tends to have, due to its direct-current excitation alone, furnishes perhaps the simplest measure of the strength of excitation from the present point of view.

Where several alternating-current machines having direct-current excitation are connected together the increase in the excitation of any one machine tends to raise its voltage, but this tendency is counteracted by a magnetizing current which flows away from it to the other machines, demagnetizing it and magnetizing them. A considerable increase in excitation of one machine, therefore, produces a smaller though widespread increase in magnetization of all the machines. Conversely, a decrease in excitation of one machine causes an inflow of magnetizing power and a corresponding reduction in the voltage of the whole system. This condition holds whether the machines are all alternators or all synchronous motors or a mixture of the two. The function of the machine, whether generator or motor, is immaterial; the relative excitation is the essential thing.

The relative excitation of the machines (generators and motors) on a system governs the flow of magnetization, and of that alone. The origin of the excitation is immaterial as regards the flow of energy; the excitation may all come from one machine, any one, or from all the machines in any proportion. As long as some source of adequate magnetization is provided the several machines may be driven as generators or operated as motors at will.

Consequently increasing the excitation of one of two alternators will not shift load to the other, and an alternator may continue to carry its full load even if its excitation is lost.

Raising the voltage at one power house will not shift load to another, and the voltage may be higher at the delivery end than at the generating end of a transmission line.

It is true that such increasing of excitation and raising of voltage does shift the flow of power, but it is the flow of magnetizing power only, not the flow of energy.

In every alternating-current system two kinds of power coexist and flow independently. The two kinds may flow in the same or in opposite directions. Either flow may vary without interfering with the other flow.

We may picture the variations in the two ribbons of power from a generator. The operator can with his right hand increase, decrease, stop or reverse the flow of the ribbon of energy by opening and closing the engine throttle or governor controller, while with the left hand he may similarly and independently control the ribbon of magnetization by raising or lowering the excitation by the field rheostat. The governor controller and the rheostat are the two handles by which to take hold of the two flows.

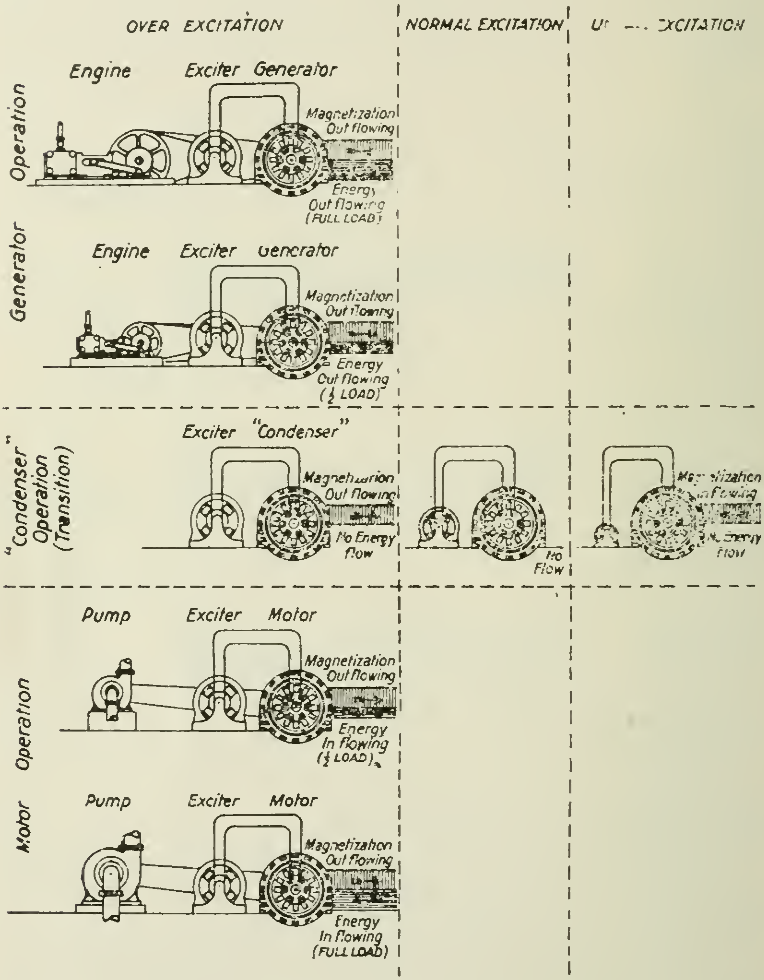

Fig. 7. Synchronous Condenser Operation

machine. As the excitation is supposed to remain unaltered the outflow of magnetizing power is practically unaffected by these changes of load by which a generator has become a motor. The transition stage between motor and generator operation presents the peculiarity that the machine, though neither a motor nor a generator, still produces magnetizing power. This feature is of such

The Synchronous Condenser.

Fig. 7 shows first an alternating-current generator at full load and over-excited. As the load is reduced the energy flow decreases, stops and reverses just as previously shown for a direct-current importance that the machine when so operating has a special name, being called a synchronous condenser.

The synchronous condenser can be used to produce the magnetizing power required for operation of induction motors or induction generators or for the starting of unexcited synchronous motors, or in fact for producing all or any part of the flow of magnetization required for a transmission system.

The amount of magnetization produced is under control, depending on the amount of excitation. The figure shows that with decreased excitation the flow of magnetizing power eventually ceases and that a further decrease reverses the flow. An under-excited synchronous "condenser" may be called a synchronous reactor.

Transformers

Power consists of the product of two components, velocity and pressure. Either may be increased at the expense of the other and the power remains the same.

Mechanically, increase of pressure with decrease of velocity may be accomplished by gearing. In this graphical representation of power where the power as a whole is shown, but not its components the transmission of power through gearing makes no change in the direction of its flow nor in the width of the stream except for the diversion of a small amount corresponding to the losses in the gearing.

Transformers are used for increasing electrical pressures with corresponding decrease in current. A transformer is, therefore, a kind of electrical gearing, and power will pass through it with no change except a slight diminution to cover transformer losses.

Accelerating power can be geared up or down mechanically just as well as energy flow. Similarly magnetizing power can be transformed as readily as energy flow. A transformer is therefore no barrier to the free and independent flow of the two kinds of power.

The electric transformers are a type of gearing corresponding mechanically to a direct-acting pump; the change of pressure being produced by alternating or reciprocating motion. The transformer, therefore, must itself receive a small amount of magnetizing power in order to work at all, but this is an approximately fixed amount, and does not otherwise affect the free flow of magnetizing power through it.

The magnetizing power taken by a transformer is similar in characteristics to that of an induction motor. The principal difference being that the magnetic design of a transformer is much

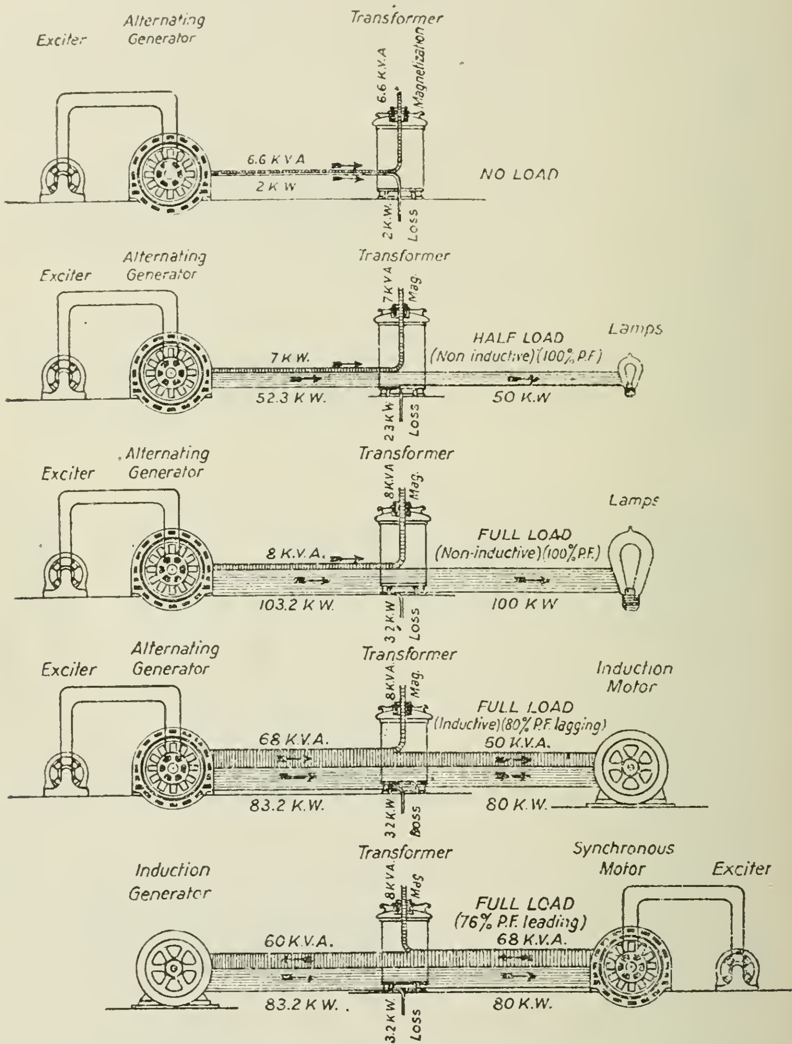

Fig. 8. Flow of Energy and Magnetization Through a Transformer

more perfect than that of an induction motor, so that the proportion of magnetizing power taken is much smaller.

Fig. 8 shows the flow of power through a transformer. The transformer diverts from the energy stream a small branch which is consumed as transformer loss and from the magnetizing stream another small branch which magnetizes the core. Even at no load the transformer must receive these two small streams if it is active. Ordinarily both streams come from the same direction, that is from the generator, but this is not essential, for when an induction generator drives a synchronous motor through the transformer the energy loss stream comes from the generator, the magnetization stream from the motor.

In a broad way generators and motors as well as transformers may be considered as a kind of gearing.

A generator, like a transformer or a gear, transforms the product of one motion and one pressure into an approximately equal product consisting of a different motion and a correspondingly different pressure.

Where both motions and pressures are mechanical the transforming device is called gearing, where one pair is mechanical and the other electrical it is called a motor or generator, and if both are electrical it is called a transformer.

Apparent Power.

While energy flow and magnetizing flow can be considered to exist in the same circuit practically independently, there are not two distinguishable currents of electricity in the same wire. The currents and pressure of energy flow and of magnetizing flow combine into a single current and pressure. Neither the current nor the pressure alone show any trace of the two components of which either may be considered to be built up. However, on comparing the composite current with the composite pressure it is found that the times of reversal are no longer either simultaneous nor in quadrature. The effect on current and pressure of combining energy and magnetizing flow is to shift the relative time of reversal, or as it is ordinarily expressed, the phase is shifted. Conversely, it is found that whatever the difference in phase, the total effect of the current and pressure can be analyzed into two parts, one giving energy flow only and the other magnetizing flow only, and this forms one basis of the conclusion that energy flow and magnetizing flow are two fundamental kinds of power.

The product of current and pressure is power, the kind of power depending upon the phase. Disregarding the phase, which is often unknown, the product is called apparent power. When the phase of the two quantities is the same the apparent power is the same as energy flow, when phases are in quadrature it is the same as magnetizing flow. For intermediate phases apparent power consists of an energy flow component and a magnetizing flow component. It is found that the square of the apparent power is equal to the sum of the squares of the energy flow and the magnetizing flow.

This leads to the conclusion that if the ribbons representing energy flow are laid, say horizontally, and those representing magnetizing flow are turned vertically, then a diagonal ribbon connecting them will represent the apparent power.

Fig. 9 shows how a flow of 80 kilowatts of energy and 60 kilovolt-amperes of magnetization give an apparent flow of 100 kilovolt-amperes.

While apparent power is not itself a fundamental kind of power

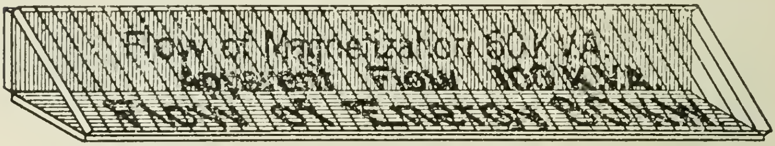

Fig. 9. Apparent Flow Resulting From Flows of Energy and Magnetization.

it is perhaps more readily measured than either energy flow or magnetizing flow, as it is only necessary to measure the current by an ammeter and the pressure by a voltmeter and multiply the result, without regard to the difference in phase.

It is also of importance because furnishing a measure of the size of generators, transformers, motors, etc., which must be used to transmit simultaneously the flow of energy and of magnetization.

Power Factor.

Power factor expresses the relation between energy flow and apparent power. It is the number of kilowatts of power delivered per kilovolt-ampere apparently transmitted.

When the power factor is fixed the relation between the magnetizing and energy flows is also fixed. If the power factor is constant the magnetizing and energy flows can only increase or decrease proportionally.

Fig. 10 shows the relation between the flow of energy and the flow of magnetization at various power factors. The two flows are equal for a power factor of $1/\sqrt{2} = 71$ per cent. With increasing power factors the proportion of magnetizing flow diminishes until it vanishes at unity power factor, while with decreasing power factors the proportion of energy flow diminishes, and it becomes zero at zero power factor.

While the magnetizing power is relatively less at low than at high power factors an increase in power factor does not necessarily mean that the magnetizing power has decreased. Thus, in an induction motor, the power factor is higher at full load than at no-load, nevertheless the magnetizing power is also greater. The increased power factor results from a great increase in energy flow accompanied by a small increase in magnetizing power.

LAGGING AND LEADING CURRENTS.

The terms lagging and leading indicate the relative directions of flow of the two kinds of power. If they flow in the same direction the current is said to be lagging, if in opposite directions, leading. If the current is lagging it may be changed to leading by reversing either, but not both of the flows. If a synchronous motor is under-excited the current is lagging. Increasing the excitation makes the current leading, because it reverses the flow of magnetization, while the flow of energy is not affected. If, however, the

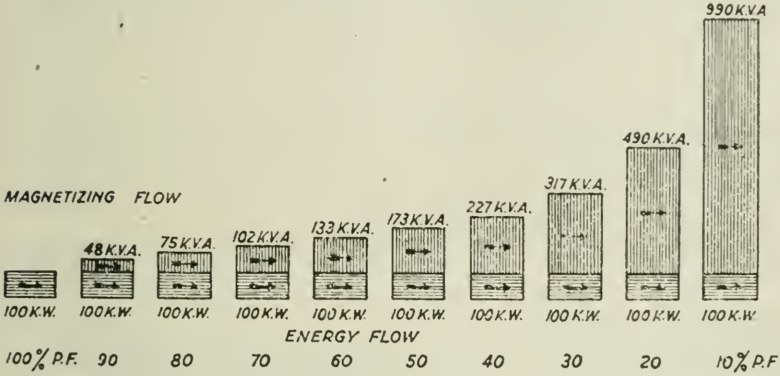

Fig. 10. Ratio of Magnetizing Flow to Energy Flow at Different Power Factors.

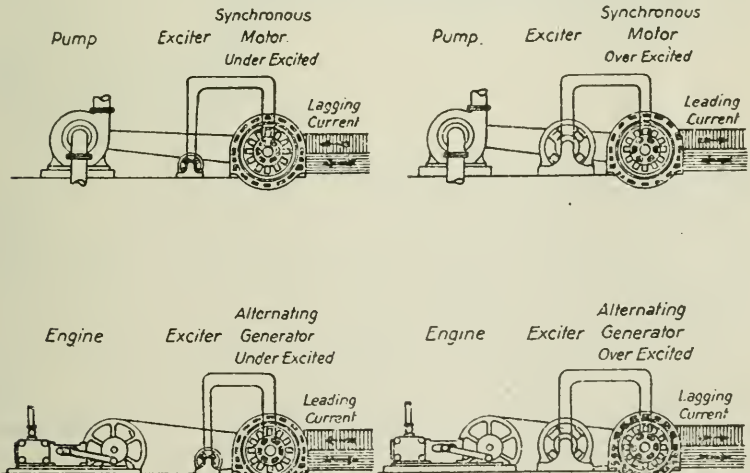

Fig. 11. Directions of Flows With Leading and Lagging Currents.

excitation is not increased, but mechanical power is applied to drive the motor as a generator, the current also becomes leading because the flow of energy has been reversed while the flow of magnetization is not changed. If the excitation is increased and mechanical driving power is also applied, the current remains lagging because both flows have been reversed. These effects are shown in Fig. 11.

Branched Circuits.

Where a circuit branches, say from one generator to two motors operating at different power factors, the determination of the power factor of the generator from that of the motors looks rather complicated. The same problem is extremely simple if viewed as the division of two kinds of currents each into two branches.

For example, a generator supplies an induction motor taking

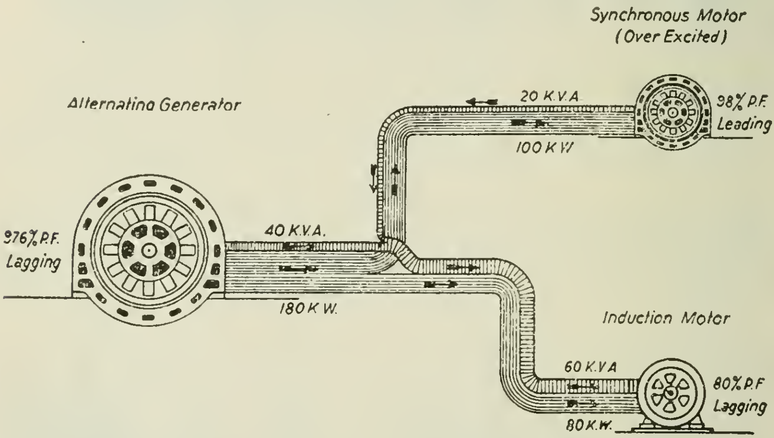

Fig. 12. Power Factors of a Branched Circuit.

80 kilowatts at 80 per cent power factor lagging, and a synchronous motor taking 100 kilowatts at 98 per cent power factor leading. It is evident that the generator supplies the sum of 80 and 100 kilowatts, or 180 kilowatts, but it is not very obvious that its power factor is 97.6 per cent lagging.

Fig. 12 shows that this complicated relation of power factors is merely a roundabout way of saying that the induction motor takes 60 kilovolt-amperes of magnetizing power, while the synchronous motor gives out 20 kilovolt-amperes; therefore the generator must give out the difference, or 40 kilovolt-amperes.

From these elements a picture may be drawn of the flows of energy and magnetization in any transmission and distribution system. The ribbons show graphically the equality between inflowing and outflowing energy and between inflowing and outflowing magnetization. A single flow of energy may have associated with it two or more separate flows of magnetization, as shown in Fig. 13. Here a synchronous condenser forms a local source of magnetization for the induction motors at the end of a transmission line, thus saving the losses of transforming and transmitting this flow as well as performing other useful functions. The generator is shown as furnishing the magnetizing power for motors in its vicinity. Water power transmission systems usually have little load at the generating end, and there are indications that a normal method of operation of such systems is to have the source of magnetization at the receiving end. When the flow of magnetization is

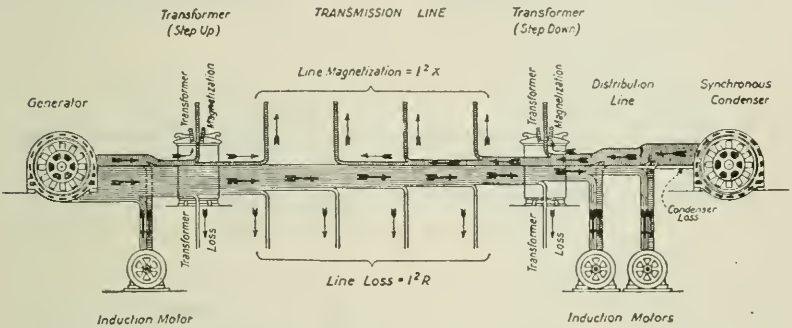

Fig. 13. Flow of Energy and Magnetization Through Transmission Line.

in the opposite direction to the flow of energy at full load the voltage drop due to the load is decreased, and the regulation is improved.

Charging Power.

The electric phenomena previously described are those which result from the storage of energy in an electric circuit due to magnetization. Energy may, however, also be stored in another form due to electric charging. Where the electricity is used in the form of alternating currents the electric charging current, like the magnetizing current, must transport this energy to the part charged and back to the source periodically. Charging power must flow to every part where there is electrostatic capacity. With charging power as with magnetizing power, the current and potential are in quadrature. In fact, charging power is the same as magnetizing power, except that the direction of flow is reversed. That is, a kilovolt-ampere of charging power flowing south is the same as a kilovolt-ampere of magnetizing power flowing north. The single term, magnetizing power, is then sufficient for both. The choice of the term magnetizing power instead of charging power furnishes the basis of the convention which has been used in indicating the direction of flow of this kind of accelerating power.

May, 1915

However, this difference should be noted—an alternating-current electric condenser is always a source of magnetizing power, while an alternating-current magnet is always a sink in which such power disappears.

The alternating-current condenser and the alternating-current magnet are complementary.

The electric condenser, therefore, may be used as a substitute for the direct-current magnets of an alternator in furnishing the magnetization of a transmission system.

An alternator without direct-current field excitation may re-

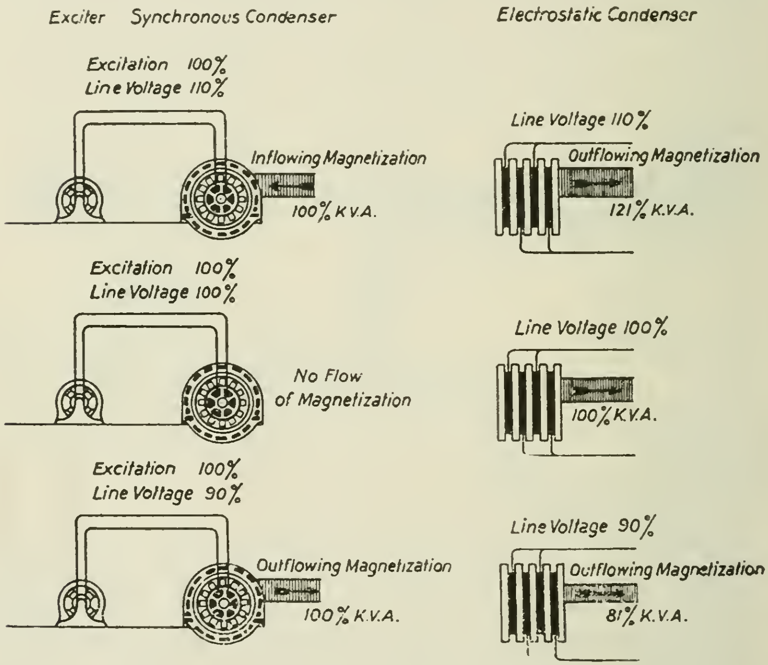

Fig. 14. Flow of Magnetization at Various Line Voltages.

ceive all needed excitation from an electric condenser, and an induction motor may operate as an induction generator, receiving its magnetization from a condenser. These results are obtained in practice, though they are not the normal operating conditions on high-tension transmission systems.

A rotating machine structurally identical with an alternator or synchronous motor, but not performing any mechanical work, may furnish the magnetizing power for a system, in whole or in part, much as an electrostatic condenser would, and hence is called a synchronous condenser.

Fig. 14 shows the essentially different behavior of an electrostatic condenser and a synchronous condenser as the voltage changes. The flow of magnetizing power from an electrostatic condenser increases as the square of the voltage. Magnetizing power flows from a synchronous condenser only when the circuit voltage is below that corresponding to the excitation of the condenser. If these voltages are equal the synchronous condenser is neutral as regards magnetizing power. If the circuit voltage is

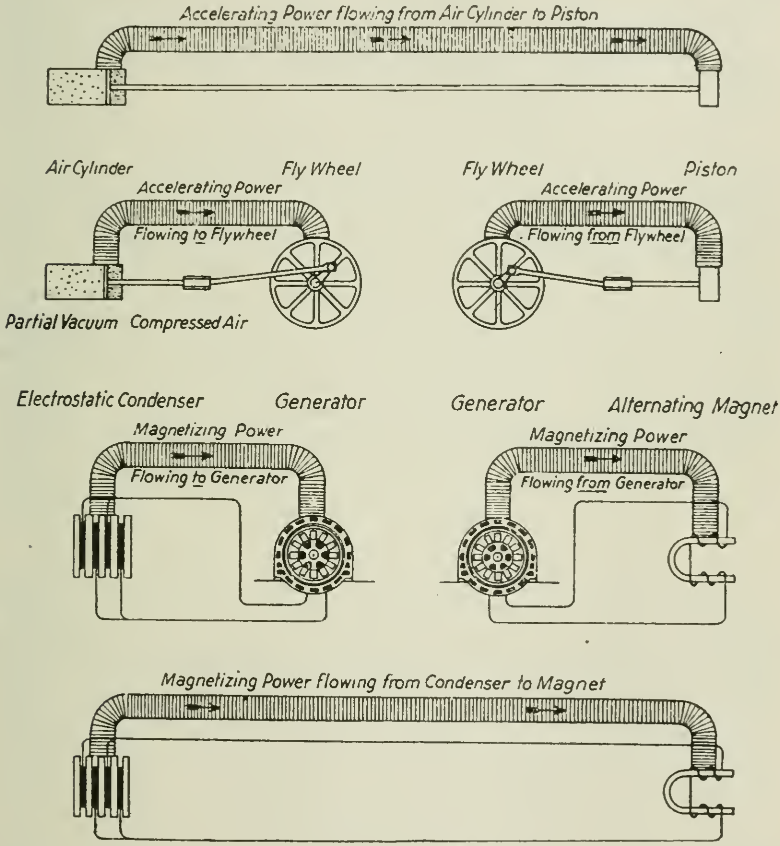

Fig. 15. Flow of Accelerating Power and Magnetizing Power in Oscillating Circuits.

higher, the synchronous condenser absorbs magnetizing power and ceases to be like a condenser, becoming similar to a reactor.

The phenomena due to charging power are not peculiar to electrical transmission. If the steam ports of an engine are permanently closed when the piston is in mid position in the cylinder it cannot be moved in either direction without compressing the air on one side and expanding that on the other side. If the engine shaft is rotated the piston will require a reciprocating force to overcome the air pressure, and this force will be zero at midstroke and maximum at the dead point; that is, it is in quadrature with the motion. For a given direction of motion the direction of this force will be opposite to that which would be required for acceleration. This reversal of one component, but not of both, reverses the direction of the power. Consequently such an air-cushioned piston becomes a source of accelerating power. As it passes the dead point the flywheel now has its minimum instead of its maximum velocity. The effect of connecting the air cylinder to the wheel at this point is to energize it.

Fig. 15 shows that the outflow of accelerating power from an air cylinder is like the outflow of magnetizing power from an electrostatic condenser—one energizes the flywheel, the other magnetizes the generator. Conversely the reciprocating piston and the alternating magnet each take a corresponding inflow and de-energize the flywheel and de-energize the generator, respectively.

If the two flywheels are combined, the energizing and de-energizing processes may cancel. The flywheel then becomes unnecessary to maintain the motion and consequent flow of accelerating power, and the reciprocating motion of the piston may be maintained by connecting it directly to the air cylinder. It is then merely a weight oscillating at the end of an air spring.

The two generators may be similarly combined and eliminated, giving an electrical oscillating circuit of a magnet and a condenser.

DISCUSSION.

Mr. Paul M. Lincoln, President American Institute of Electrical Engineers: I just want to say a word about the desirability of a physical conception. A clear physical conception of the things that go on in an electrical circuit is absolutely essential to the ability to grasp these phenomena. In order to get the full significance we have to go back to the consideration of psychology. It is a fact that the human mind can much more readily grasp concrete ideas than abstract ideas, and that is the reason why we need to have a physical conception before we can grasp the phenomena.

It is a fact that the human mind grasps concrete ideas much more readily than abstract ideas, and it is for that reason that we need to have some concrete ideas before we can grasp all of the phenomena of electricity. When we are dealing with steam engines the mind readily grasps what is going on, but when we are dealing with volts and amperes, and things of that kind, what is going on is not so apparent. We have to imagine what is going on; we cannot picture to ourselves a piston going back and forth; therefore we have to throw it back into some realm where we can. Mr. Philip has taken those power factors and other quantities and put them into the realm where we can grasp them—from the abstract to the concrete—and that is the important thing about the paper.

It has been remarked that the student gets his idea of the phenomena of alternating current by mathematical formulæ. Mathematical formulae tell us a great deal about what is going on, but they do not give a physical conception, and it is the physical conception that is absolutely essential to a complete grasp, and if you cannot get the physical conception you are lost in trying to go further and in trying to analyze just what is going on. We are certainly very thankful to Mr. Philip for giving such a clear idea of the physical conception.

One thing I would like to add: Mr. Philip refers to the fact that the synchronous motor as usually designed will deliver power when unexcited. That has been known for many years, and was taken advantage of by one company—the Westinghouse Company—some years ago in the design of some rotary converters. A number of rotary converters were built some eighteen years ago without any field coils whatever; they were built with an exceedingly small air gap, and magnetization was entirely obtained from the armature. The air gap was made small so the amount of magnetization would be small, and they would be excited entirely by idle current circulating in the armature. Quite a number of machines of that kind were built at that time, the idea being that they would not require any exciters, and the power current, although always lagging, would be uniformly lagging.

W. B. Jackson, President W. S. E.: It is difficult to overestimate the desirability of having a mental picture of the actions going on in a circuit. This paper particularly interests me because of my earlier electrical work which had to do largely with two-phase generators and synchronous motors, and with two-phase induction motors having condensers to supply the magnetizing or wattless current. We always felt somewhat disturbed when it was proposed to install Westinghouse motors on circuits supplied from our generators, since the latter were not then designed to carry heavy induction loads, and thereby provide the magnetizing power for the unusual type of induction motor. In other words, we learned by sad experience that if we permitted a large amount of load on our circuits and did not have plenty of extra exciting power in our synchronous motors and generators we were bound to have trouble in holding the voltage on the lines. Even as far back as 1893 we found that as induction motors without condensers came onto our lines, where we had nothing but synchronous motors, it sometimes became necessary to replace some of our smaller synchronous motors by larger ones, to enable us to maintain the excitation of the system.

In all physical conceptions of electric currents there are some conditions that are difficult to present fully by a picture, notwithstanding that in general the presentation gives a correct picture of the actions involved. I am inclined to think that Mr. Philip would have difficulty in bringing many to the feeling that the single term magnifying power may be suitably used to represent both the magnetizing of a magnet and the charging of a condenser.

H. M. Wheeler, M. W. S. E.: I would like to ask three questions: In the first place, where a machine is started up under no load it takes a certain amount of energy to bring it up to speed, and kinetic energy stored at final speed is, of course, $MV^2 \div 2$. What is the exact relation between this kinetic energy and the *accelerating* energy mentioned in the paper?

Second. We have recently had a paper upon the electrification of the Norfolk & Western Railway, where single phase A. C. system is used upon the line, but changed to three-phase at the motors. Regenerative braking is used down grades. It has been stated that if the current from power station is "off" the motors will run away; i. e., magnetizing current has to be supplied by the power station in all cases. Would it be practicable to install condensers on the line to obviate this difficulty?

Third. A rotary converter, under leading power factor, will furnish excitation to generator. In case of a system operating at 100,000 kilowatt, 99 per cent load factor leading, what does this magnetizing energy amount to?

Mr. Allen: I think Mr. Philip has treated an obscure subject in a very interesting way. What I particularly like about the paper is the emphasis he has placed on the term "magnetizing power" as distinguished from idle or wattless power. In considering the alternating current problems, as we have to sometimes in the actual working out of them, it is not very satisfactory to refer to wattless or idle current, because the next moment we are trying to explain how the carrying capacity of the circuits is reduced and apparatus overheated by their presence. So I think we get a much clearer idea of alternating current phenomena if we consider this component as magnetizing current or power rather than as idle current or power.

CLOSURE.

Mr. Philip: The first question asked was in regard to the application of this method to a case where a phase converter is used to transform from three phase to single phase power.

The single phase current can be considered as the resultant of two polyphase currents rotating in opposite directions. This is equivalent to bringing in the idea of two frequencies, one for forward rotation and the other (equal but of opposite sign) for backward rotation, so that the single phase case is not quite as simple as the polyphase case. We may consider the polyphase case as due to the frequency of forward rotation alone and the single phase case as involving a secondary effect due to a backward rotation of a different frequency. When we have a second frequency, either through backward rotation or from any other cause, the method outlined in the paper for showing the flow of magnetizing power in polyphase systems may be considered as holding for the fundamental frequency. There is then superimposed on the flow shown a fluctuation of power which is not shown due to the secondary frequency.

There is, for example, a demagnetization of the field of a single phase generator due to outflowing magnetizing power, which is the same as the demagnetization produced in a polyphase generator, but on this is superimposed a periodic fluctuation of the field magnetization of the single phase generator which is not found in the polyphase generator due to the second frequency of backward rotation which constitutes the other component of the single phase current.

The same thing holds in the case of mechanical power. For example, take a steam engine having a single piston and a single crank. The mechanical accelerating power corresponds to single phase magnetizing power. In the paper it is pointed out that the mean energy of the flywheel is reduced by the energy drawn from it by the reciprocating parts but that the flywheel of a single crank engine does not move with a uniform speed of rotation. It has a fluctuating speed, which may be considered as consisting of a uniform reduced speed on which is superimposed a periodic motion backward and forward. This fluctuation of speed of the flywheel of a single crank engine corresponds to the fluctuation of magnetism in a single phase alternator and is a part of the phenomena which is not shown in this method of graphical representation.

If, now, you add a second crank and piston of exactly the same weight and stroke and put this crank in quadrature with the first one, then the two reciprocating parts withdraw energy from the flywheel in such a way that the flywheel now runs with a uniformly reduced speed instead of a fluctuating speed. This corresponds to the uniform demagnetization of the field of a polyphase alternator.

Of course, if a polyphase current is unbalanced, it may be resolved into single phase current and a balanced polyphase current.

The phase converter changes a single phase, fluctuating flow of magnetization into an equal polyphase, uniform flow. The magnetization required for the three phase induction motors flows to them from the single phase generator, passing through the phase converter on the way, just as magnetizing power flows through a transformer. As this graphical method takes no note of the periodical fluctuations in single phase magnetizing power which distinguish it from the uniform three phase magnetizing power the magnetizing flow may be pictured as passing through the phase converter, as through a transformer, with no change in magnitude or direction.

A phase converter in its simplest form is a free running induction motor in series with a polyphase working induction motor on a single phase circuit. Such a phase converter must itself absorb additional magnetizing power which must also come from the single phase generator and be in amount about the same as the phase converter would take considered as an ordinary motor.

The phase converter, like other induction motors, may be made self exciting through use of a commutator and may thus itself furnish the magnetizing flow necessary for its own operation or for the main working motors in addition. A phase converter as thus modified has two practically independent functions, one of smoothing out the pulsations in magnetizing power received from an external single phase source, and the other of itself producing magnetizing power.

The second question was whether the case of an electrostatic condenser magnetizing the fields of a generator is properly represented by this method. I consider that it is. I endeavored to point out in the paper that charging power, flowing in one direction is the same as magnetizing power flowing in the other direction. Consider a generator having no direct current excitation connected to a transmission line of sufficient electrostatic capacity to excite it. We can say that charging power is flowing out from the generator to the electrostatic capacity of the line, or, we can say that magnetizing power is flowing from the electrostatic capacity of the line into the generator, the two flows in opposite directions being really one and the same flow.

The next question was regarding the relation of the kinetic energy of uniform motion to accelerating power. Where a flywheel is rotating uniformly, there is a reservoir of energy. No energy is flowing in or flowing out during uniform motion. Take the case of a steam engine with single crank. We have a flywheel moving with fluctuating velocity which can be analyzed into a uniform velocity (which represents the stored energy which is no longer flowing either out or in), and a fluctuating velocity (which represents energy flowing back and forth between the flywheel and the piston).

The next question I understood to be about the same as the one I first answered, in regard to polyphase and single phase power. That is, the case of the phase converter for a railroad. I believe that there was a further point in connection with regenerative braking on a single phase (split phase) railway where the locomotive may run away on a down grade if the excitation of the induction motor is lost, the question being whether the electrostatic capacity of the line, acting as a condenser, could furnish the excitation necessary to prevent the motor running away. Any source of magnetization will keep the motors of the locomotives excited. If magnetized by the electrostatic line capacity they would then absorb magnetizing power from the line but they would not be giving out a flow of energy in addition unless there was some device connected to the line to absorb the energy. For example, some other locomotive on an up grade or a rheostat connected to the line could absorb it. If the line was disconnected from everything but the one locomotive in question the locomotive would run away. The condition then would be that magnetizing power would be flowing from the electrostatic line capacity to the motor but the motor would speed up and the frequency of the circuit would increase. There would be nothing to prevent the frequency increasing, the flow of magnetizing power being entirely separate from the flow of energy and not in itself furnishing any braking power.

The next question was in regard to the rotary converter as a source of leading current. The rotary converter is a synchronous motor, and can furnish leading current, but such current if taken in addition to the ordinary working current, increases the armature heating and demagnetizes the fields, to an extent not contemplated in the design, so that the standard rotary converter, not being designed for operation as a synchronous condenser, is for practical purposes only of small value. Doubtless one could be designed and built which would be suitable for the purpose, but in general rotary converters will give a small amount of leading current, but cannot be depended on to give a great amount.

The next question was in regard to the practical working of the synchronous condensers installed on the Big Creek transmission system. In that system there are two 15,000 K. V. A. synchronous condensers installed at the receiving end of the 240 mile line. These furnish the magnetizing power required at the end of the line, as illustrated in Fig. 13 of the paper. The condensers may be said to have been installed either for furnishing magnetizing power or for controlling the regulation, the two being different points of view of the same thing. I believe these condensers are working satisfactorily and that they are found necessary for the operation of the line. The condensers are an integral part of the design of the line, that is, the use of the condensers to furnish magnetizing power at the receiving end is an essential part of the line design, so it is naturally to be expected they could not be dispensed with in operation. I believe the practical results are quite satisfactory. They give not only a source of magnetization at the end of the line but, by controlling the flow of magnetization to or from them, the received voltage may be held constant at all loads without any change of voltage corresponding to change of load being made at the power house. This method makes the regulation of the delivered voltage independent of accidents to telephone communications to the power house.

THE DESIGN AND ERECTION OF THE PENNSYLVANIA LIFT BRIDGE No. 458 OVER THE SOUTH BRANCH OF THE CHICAGO RIVER

By W. L. Smith and W. W. Priest, Under the Direction of J. C. Bland, Engineer of Bridges.

Read April 12, 1915.

THE DESIGN.

W. L. Smith.

General Description of New Bridge.

The bridge consists of a double track riveted truss lift span, 272 ft. 10 in. c. to c. of end posts, with two trusses of the Pratt type, having inclined top chords and two towers, one at each end, which are from 30 ft. 2 in. to 30 ft. 8 in. wide by 53 ft. 6 in. long and about 185 ft. high. The structure is skewed at an angle of about 47° 20′ to the center line of the stream.

At each end of the bridge there is a sectional counterweight consisting of two structural steel frames covered with about 315 cubic yards of concrete having the following proportions: one part Portland cement, two parts sand and four parts slag.

The approximate weight of each counterweight is:

Structural steel	93,100 lbs.
Concrete	1,489,100 lbs.
Total	1,582,200 lbs.

Careful estimate showed that the cost of the counterweights would be substantially the same whether slag or broken stone was used, with possibly a slight difference in favor of broken stone.

Rivet plugs were also considered, but were not used because they were difficult to obtain in sufficient quantities and were quite expensive.

The machinery house is situated on the top of the lift span at its center. The floor is 4½-in. plank supported by steel beams. The floor area is about 1,150 sq. ft. The walls are of 1½-in. cinder concrete ("float finish" outside) on metal lath supported by a steel frame. The roof is of tin construction laid on steel trusses and purlins. This house is supplied with a 5-ton overhead traveling crane for placing motors, etc.

The operator's house (floor area about 90 sq. ft.) is made of the same material as the machinery house and is suspended therefrom. Steel stairways connect it with the machinery house and with the floor deck of the span.

A walkway extends midway between the top chords the entire length of the truss span, except where it is obstructed by the machinery house. From the ends of this walkway stairways lead to the top and ladders to the bottom of each tower. Walkways are also provided around the edges of each tower at its top.

To render the truss span readily accessible at its extreme height, a ladder has been added to each tower extending from the top of the tower to the top of the lift span when fully raised. These ladders will be extended to provide access to the span at any point of its travel.

Operation.

To permit the passage of vessels, the truss span can be raised to its maximum height from its normal position (a lift of 111 feet) in 45 seconds. The span and its counterweights are suspended by 64, 2¼-in. plow steel ropes over 8, 15-ft. sheaves of structural and cast steel. (16, 2¼-in. ropes are connected to the top chord at each end of each truss, pass over a pair of sheaves and are attached, by means of equalizing devices, to the counterweights.)

The span is operated by two No. 162 Westinghouse railway type interpole 220-volt, 300-H. P. motors which are located in the machinery house. These motors are geared to four cast steel operating drums, each of which carries four 1⅛-in. plow steel operating ropes. These ropes pass over deflection sheaves at the ends of the span—two going up and two going down at each corner—and are fastened to the top and bottom, respectively, of the towers. Either motor alone can operate the driving mechanism. A 50-H. P. gasoline engine will also be installed for emergency service. This engine will lift the span to its maximum height in about ten minutes.

The operator's house contains all operating levers and switches and a mechanical indicator showing position of span.

Limit switches cut off the current when the span has reached its limiting positions, and solenoid brakes are applied automatically. Hand brakes are provided as an additional safeguard. Rail locks at each end of the span are operted by one 3¼-H. P. direct-current No. 2 type K. G. Westinghouse 220-volt motor placed at the foot of each tower.

There is a ball signal on top of the machinery house and there are semaphores at the bottom of each truss and on each end channel pier.

Defects Developed in Operation, Etc.

By far the most serious trouble, and the most expensive as well, has developed in connection with the sheaves. Owing to their size—15 ft. 0 in. pitch diameter—they are of "built-up" construction, i. e., each sheave consists of a center steel casting or sleeve and seven sections of cast steel rim segments, the rim and sleeve castings being connected with a web of built-up riveted steel construction. The detail drawing for the sheaves called for "all contact surfaces between rim segments, between web plates and rim and between web plates and sleeves to be finished to accurate bearing over entire area." As the design of the sheaves was based upon such finish, i. e., the rim segments and center sleeve were not connected to the "built-up" web with sufficient rivets to transmit all the stresses, it was essential that this requirement be met.

The sheaves as manufactured, however, did not meet this requirement. To insure proper action between the rims and webs four splice plates were added to each connection between the web diaphragms and rims, this affording eight additional turned bolts in double shear at each of these points.

To prevent creeping of the built-up portions on the sleeves four alternatives were considered:

(1) To cut out a circular strip from each web and sleeve casting and replace it with a steel ring having a driving fit.

(2) Drill holes for 1-in. pins on line between center castings and hub and drive tight fitting pins into them.

(3 Replace rivets connecting center casting to webs with loose fitting bolts which would permit the webs to move enough to come to a bearing on sleeve casting without shearing the bolts.

(4) To pour opening between webs and sleeves full of sulphur.

It was decided to adopt (1) or (2) and as (2) permitted the work to be done in the field it was adopted. Forty pins 1 in. diameter, 4 in. long, having a computed bearing stress of about 10,000 lbs. per square inch, were added to each sheave as described under (2). After the pins were driven the outside edges of the holes were calked so that they could not work out.

The cost of adding the splice plates was about $390 per sheave or $3,100 for the bridge; the cost of adding the pins was about $3,500 for the bridge.

Operation of the rail locks was difficult at times owing to the failure of the span to seat itself each time in exactly the same position. This was remedied by attaching entering tongues to the end floor beams of the truss span. These entering tongues engage centering guides which are carried by the floor beams at the span ends of the towers.

As originally designed, the operating cables were supported on the center line of the curved top chord by gum wood rollers mounted in steel brackets. These rollers wore rapidly and in some cases failed to turn. The ropes, when slack, abraded each other and the top chords of the trusses.

To overcome this excessive wear on the rollers—a maximum of about ⅝ in.—and to remedy the other conditions above de-

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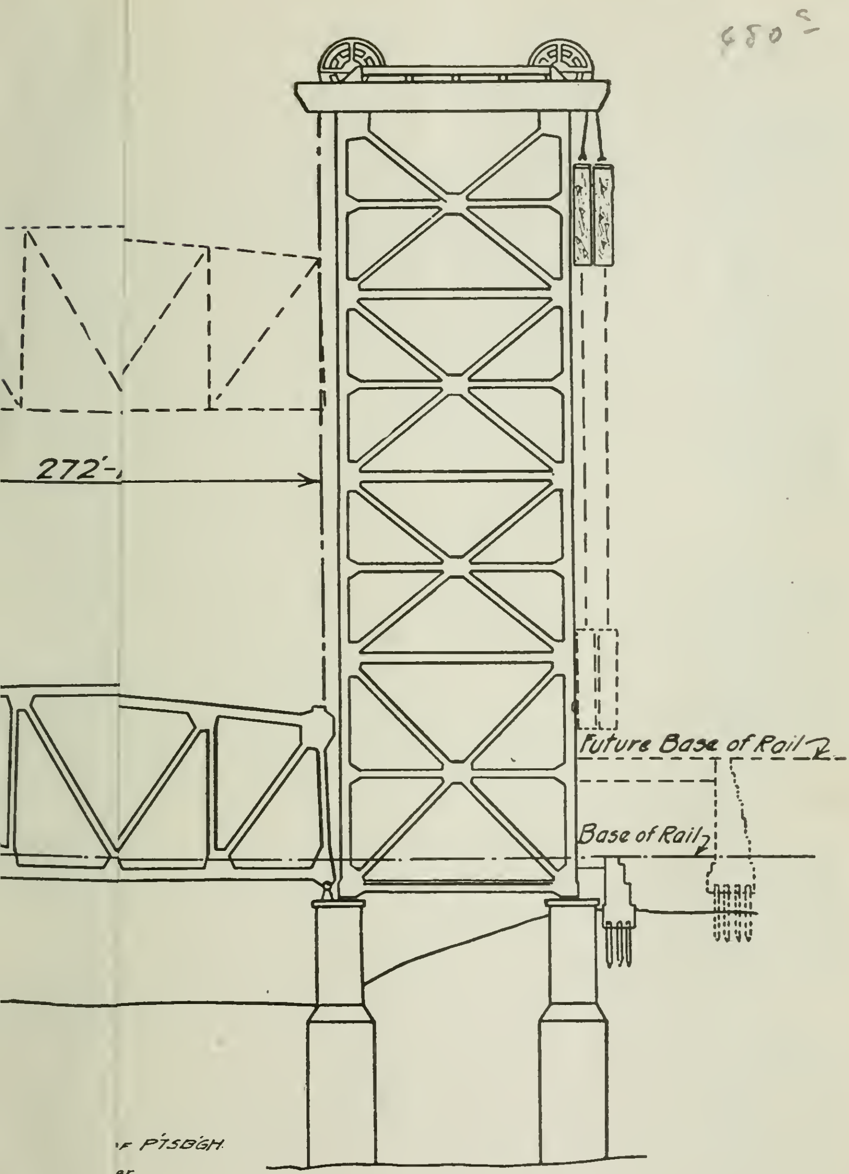

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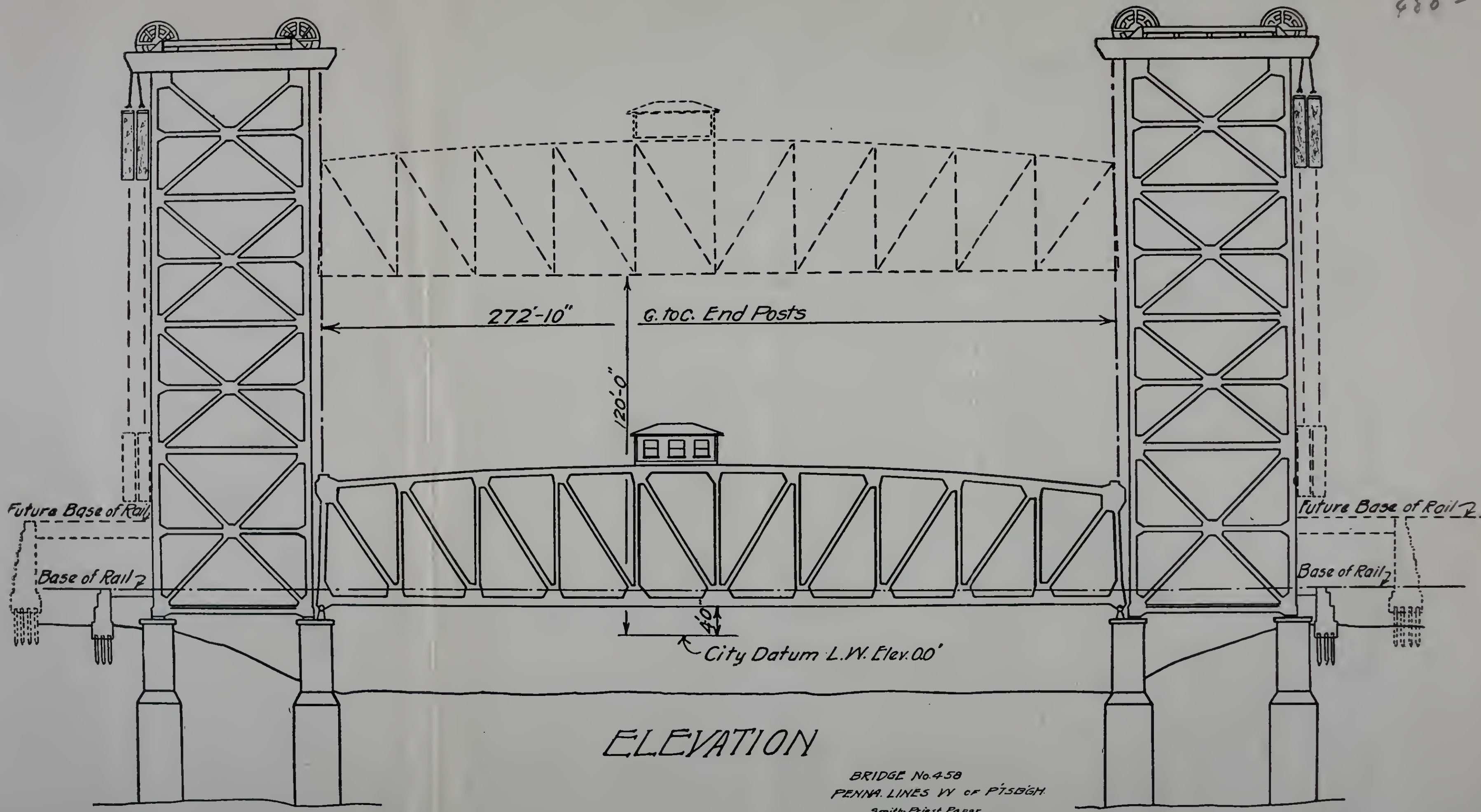


ELEVATION

scribed, deflection sheaves were mounted on the upper chords at each end of each truss.

Adjustment of the downhaul ropes is provided near their connection to the tower columns by means of turnbuckles. When the ropes were slack, these turnbuckles tipped from their normal vertical positions and fouled the ends of the lift span. This condition was remedied by bending a strap around the cables just above the turnbuckles and connecting it to the columns.

The counterweight ropes engage forged steel equalizer bars which are connected, in turn, to the counterweights. The details necessitate considerable spreading of the ropes at these points. As designed, when the counterweights approached the extreme upper limit of their travel the change in angle between the ropes was sufficient to cause excessive wear in the equalizer bars from the turning and grinding of the pins in them. The consulting engineers for this bridge have designed a device which it is thought will, when installed, reduce this objectionable feature to a minimum.

Deficiencies in the Design.

In constructing another bridge of this type we would first of all, in view of our experience with the main sheaves of this bridge and of our Bridge No. 443 (another bridge of the same type of construction), insist that enough rivets be furnished or other positive means be employed to carry all stresses, no reliance being placed upon bearing of the component parts, and also provide a device whereby there would be no "unbalanced load" from counterweight ropes. The lift span as designed is supposed to be perfectly balanced when at mid-height only. At all other points of its travel there is an "unbalanced effect" from these ropes.

This unbalanced condition is plainly a maximum amount when the lift span is at the extreme limits of its travel. When beginning to lift the span from its normal position, therefore, besides overcoming frictional resistances from the weights of the moving span, counterweights, etc., we also have to overcome this maximum unbalanced condition. It should be a comparatively easy matter to overcome this objectionable feature.

Provision should be made for cutting off the power when the operating cables break at either end of the span. As designed, there is nothing to prevent the operator from continuing to hoist the span after the operating ropes break at either end and a condition which is apt to result in wedging the span tight between the tower columns. If the span is not properly counterbalanced, it can be seen that the end of the span where the breakage occurs might, under certain conditions, be pulled down.

Reasons for Adoption of This Type Here.

As stated elsewhere in this paper, it is expected that the tracks will be raised some twenty to twenty-five feet at this point in the future. This type of bridge is particularly well adapted to making such a change. The tower bracing has been so arranged that when this track elevation is attained, the present lower transverse struts can be replaced with the present tower floor beams. All that then remains to be done to the superstructure before putting it in service is to place the supporting columns under the corners of the lift span and raise the tower floor system and the approach girder spans to their new positions and rivet them up.

It will be noted that the entire truss span is raised to bring the track to the new grade—not the floor system alone. This means that not only is the expense and delay incidental to disconnecting the floor system and riveting it up again in its position avoided, but with the raising of the entire lift span the underclearance is increased so as to permit the passage of many small boats which would otherwise require operation of the bridge.

Among other considerations which influenced the selection of this type were:

Its estimated cost was less than that of the three other types of movable bridges under consideration.

As the operating machinery is very simple and direct in its action and as the wire ropes should not, with proper care, require renewal for a long time, the cost of maintenance would seem very low, indeed much lower than that of many other types of movable bridges, some of which have, in the past, shown and developed weaknesses and deterioration at certain particular points.

All stresses in the lift span and towers are fully determinate.

As rigid under traffic as a fixed span.

The adaptability of this type of bridge to a skew crossing, such as the one under consideration, seems to require no more than passing mention.

General Notes.

At both ends of the lift span centering castings on the trusses engage corresponding centering castings on the tower columns. At the fixed end a small clearance is provided; at the other (expansion) end ample clearance is provided for the longitudinal expansion and contraction of the span.

The shoes which bear directly on the masonry are similar at both ends of the span. They consist of massive cellular cast steel blocks with vertical lips (two each) which project above their top surfaces and engage the vertical sides of the truss pedestals. The bearing area on masonry of each shoe is 2 ft. 11 in. $\times$ 5 ft. 4 in. $=$ 2,240 sq. in.

The pedestals bearing upon these shoes are pin connected to the trusses. At the expansion end their bearing surfaces are curved, affording ordinary rocker action for the truss span under expansion and contraction.

An expansion joint is provided in the floor system at the connection of the stringers to the floor beam near the center of the span.

Train thrust frames are provided at about one-quarter span length from each end of the truss span to carry the horizontal loads (from braking trains, etc.) directly into the trusses. The object in using these frames is to prevent lateral bending in the floor beams.

The equalizer bars are of forged steel. Forged steel was considered preferable to rolled steel for this important service inasmuch as it is more thoroughly worked in its manufacture.

Sufficient clearance was provided throughout for the construction of a second bridge of this type at the minimum distance from the present bridge of 35 ft. 6 in. center to center.

Every precaution has been taken to insure safety in the operation of the bridge. One large hood has been provided which covers completely all machinery within the machinery frame. This hood can be readily removed by the overhead hand crane when it is necessary to inspect the machinery, etc. Smaller hoods cover all couplings, revolving set screws, projecting keys, etc., outside the machinery frame. Movable steps have also been provided for passing over the main shafts, which are about three feet above the floor.

The signals indicate "clear" only when the lift span has been raised to its extreme height.

Alternating current is supplied by the Commonwealth Edison Company and is transformed and stored for use in the railroad company's plant. The wire from main feeder line from trolley to the control panel is two 500,000 cir. mil. cables per leg. The size of conduit is 1½ in. The wire from control panel to each motor is two 500,000 cir. mil cables per leg.

The computed torque at the motor shaft is approximately 8,700 ft.-lbs.

Typical Sections.

The top chord members of the lift span are of the usual type of construction consisting of two built-up channels connected with a cover plate. All web and bottom chord members consist of two built-up channels with flanges "turned inside," connected with lacing.

The maximum stress in the top chord is 2,363,000 lbs. The section carrying this stress consists of:

1—Cover plate 38x⅝ in.
2—Web plates 34x¾ in.
4—Web plates 34x½ in.
2—Web plates 24x⅝ in.
2—Web plates 32x$\frac{9}{16}$ in.
2—Top angles 4x4x½ in. (inside).

2—Top angles 4x4x⅝ in. (outside), and
2—Bottom angles 6x6x⅝ in.
Total sectional area = 239.69 sq. in.
Depth = 2 ft. 10¼ in. b. to b. of angles.

The maximum stress in the bottom chord is 2,277,600 lbs. The section carrying this stress consists of:

2—Plates 36x½ in.
2—Plates 36x$\frac{7}{16}$ in.
2—Plates 24x⅝ in.
2—Plates 34x½ in.
2—Plates 34x⅝ in.
2—Plates 24x½ in.
4—Angles 6x6x⅝ in.
Total sectional area = 226.44 sq in.
Depth = 3 ft. 0¼ in. b. to b. of angles.

The tower columns are of "H" section. The lowest section of the most heavily loaded column carries a maximum computed vertical load with span down (present construction) as follows:

Dead load	1,186,300 lbs.
Wind load	809,400 lbs.
Total direct load.......	1,995,700 lbs.

In addition to the above this column resists a bending moment due to wind of 8,640,000 in.-lbs.

The same column carries a maximum computed vertical load with span down (future construction) as follows:

Dead load	1,238,600 lbs.
Live load	232,300 lbs.
Wind load	913,000 lbs.
Total direct load.......	2,383,900 lbs.

In addition to the above this column resists a bending moment due to wind of 5,500,000 in.-lbs.

It, as well as all other lower column sections, is made up as follows:

8—Angles 6x4x⅝ in. (legs of four corner angles "turned inside").
1—Plate 32¾x¾ in.
2—Plate 20x⅝ in.
2—Plate 30x¾ in.
2—Plate 30x$\frac{11}{16}$ in.
2—Plate 30x$\frac{9}{16}$ in.

The sectional area = 216.44 sq. in. The length of these sections is about 80 feet; their weight about 40 tons each.

Assumed Loading.

(a) For truss span.

Dead load = 9,740 lbs. per lineal foot of double track truss span.

Live load, p + Q = 5,500 lbs. uniform + 66,000 lbs. concentrated per track. Concentrated load for floor system connections = 99,000 lbs. per track.

Wind load: For upper laterals, 150 lbs. per lineal foot of span; for bottom laterals, 200 lbs. per lineal foot of span—static, 300 lbs. per lineal foot of span—moving.

(b) For towers.

Dead load—from truss span, etc., and own weight.

Live load—same as for truss span.

Wind load: Span down, 30 lbs. per sq. ft.; span up, 15 lbs. per sq. ft.—reduced in each case by Duchemin's formula.

Tower columns are designed to carry at the same time either—

(1) Dead load + live load + wind load, span down (all as above).

(2) Dead load + live load + wind load, span up (all as above) + impact (= 25% weight of span), or

(3) Dead load + live load (all as above) + impact (= 25% weight of span).

The above cases were considered for both present and future constructions.

Specifications.

For design and manufacture of structural steel work, Specifications for Railway Bridges, Pennsylvania Lines West of Pittsburgh, dated April, 1906, except:

(1) Allowable unit stresses increased 15% for all members carrying loads from two tracks at the same time.

(2) Allowable unit stresses in tower columns increased one-third when loaded under cases (1) and (2) of assumed loading for towers.

(3) Allowable unit stresses in tower and traction bracing: Tension, 12,000 lbs. per. sq. in.; compression, 12,000 — 44 L/r lbs. per sq. in. In truss laterals, 9,000 lbs. per sq. in.

For machinery and electrical equipment special sepcifications were prepared.

The operating ropes were designed in accordance with the following clause:

"The ratio of the total stress (including bending) to the elastic limit shall not exceed 75%; the ratio of ultimate to direct stress shall not be less than 4.5 in. In explanation of what may seem an excessively high ratio (75%) of total stress to elastic limit, it may be added that the consulting engineers considered this ratio a proper one for the following reasons:

Bridge steel is ordinarily stressed to about one-half its elastic limit, impact included. Bridge steel, however, is less thoroughly worked in its manufacture and is less uniformly reliable than the materials entering into the construction of wire ropes.

Approximate Weight of Structural Steel Work and Machinery.

*Lift span	2,623,000 lbs.
Towers (including approach stringers)	3,136,000 lbs.
Counterweights	196,000 lbs.
Grillages (including grillages for one-half the end bearings of future span)	83,000 lbs.
Machinery and castings	749,000 lbs.
Ropes	154,000 lbs.
Total	6,941,000 lbs.

Substructure.

The substructure consists of eight piers supporting the tower columns and two masonry abutments, the backwalls of the latter being "squared up" to the tracks. The four northerly piers were made large enough to carry the adjoining tower columns of the future span, as well as the north columns of the present span.

These four northerly piers were rectangular in section with rounded ends. Their top dimensions were 11 ft. 6 in. wide x 28 ft 0 in. long (both dimensions measured under coping). The length of each pier was maintained constant throughout its height; its width, however, was increased, in its lower portion, to 15 ft. 0 in.

The four southerly piers, which are designed to carry the south columns of the present span only, are rectangular in section with rounded ends in their upper portions. Their lower portions are of circular section. Their top portions are 11 ft. 0 in. wide x 16 ft. 0 in. long (under coping); in the lower portion their diameter is 16 ft. 0 in.

A thoroughly braced steel shell varying from ¼ in. to ½ in. thick, encasing each pier from top to bottom, was manufactured in sections about 4 ft. 0 in. long.

The lowest section of each shell was provided with a cutting edge. Two vertical passageways were provided throughout each shell to provide access to the working chamber (in the bottom sec-

*Machinery and operating houses, walkways, decks, etc., added make weight of lift span = 3,200,000 lbs. (= total weight lifted—ropes excluded).

tion) and for transporting earth, materials, etc., to and from this working chamber.

The sinking of the shells was effected by the weight of the concrete, with which the successive sections were kept filled, and by excavating within the chambers at the feet of the shells. No compressed air was used, the working chambers being practically sealed from the entrance of water.

Simultaneously with the sinking of each shell the successive joints were stuffed with lamp wicking which was well smeared with tallow and fastened together with bolts spaced about 2 in. c. to c.

With but few exceptions the piers (including the shells) were sunk to bedrock (at elevation from 55 to 60 feet below Chicago city datum). In these exceptions the cutting edges of the shells rested some 6 to 9 ft above the rock. In such cases the material between the cutting edges of the shells and the rock was excavated and the excavations were filled with concrete, making the concrete piers continuous and monolithic to the rock.

The concrete mixture throughout was approximately 1:2½:5.

It took from a minimum of about ten days each to sink the smaller piers to a maximum of about one month each to sink the larger piers.

They sank very close to their intended positions, the maximum variation therefrom, for a larger pier, being about 8 inches.

The abutments were constructed to a depth of —2.67 (2.67 ft. below Chicago city datum) and rest on wood piles spaced from about 2 ft. 6 in. to 3 ft. 0 in. center to center. At the east end of the bridge the by-pass under the tower is dredged out to a depth of about 12 feet. To preclude any possibility of sliding of the east abutment (owing to slipping of intervening soil into the by-pass) reinforced concrete piles about 30 feet long were driven tight together, to act as sheet piling, in a straight line between the most easterly pair of piers. Supporting the upper ends of the piles a reinforced concrete beam 3 ft. 0 in. deep and 4 ft. 0 in. wide was extended between the two piers.

The two pairs of piers bounding the main channel are protected by timber fender construction which presents no unusual features.

Miscellaneous.

Messrs. Waddell & Harrington, Kansas City, Mo., were the consulting engineers for this bridge and prepared the stress sheets, general detail drawings and special specifications for the mechanical and electrical equipment under the general direction of Mr. J. C. Bland, Engineer of Bridges, Pennsylvania Lines West of Pittsburgh. It was completed and placed in service on July 30, 1914, at an approximate total cost of $750,000.

May, 1915

The bridge was fabricated and erected by the Pennsylvania Steel Company of Steelton, Pa.

THE ERECTION.

W. W. Priest.

This bridge was built to take the place of a two track swing span of considerable less length, and its location, with reference to the swing span, was such that the latter could not be swung into any position in which it would clear the new bridge with the latter in position for railroad traffic.

In deciding on the method for erecting the new bridge, two important points had to be kept in mind:

1st: That no interference with navigation would be permitted.

2nd: As it was necessary to maintain the railroad traffic on the old swing span up to the time it was transferred to the new bridge, the latter would have to be erected so as to permit the operation of the old span and also so the transfer of the railroad traffic to the new bridge could be made in the shortest possible time, bearing in mind that the old span would have to be removed before the new span could be put in position for traffic.

Two methods to take care of these conditions were considered, one of which entailed the erection of the lift span on falsework parallel with and close to the dock line at some point on the river and afterward floating it into its permanent position on barges.

The other method contemplated erecting the lift span in its permanent position on falsework high enough to clear river navigation.

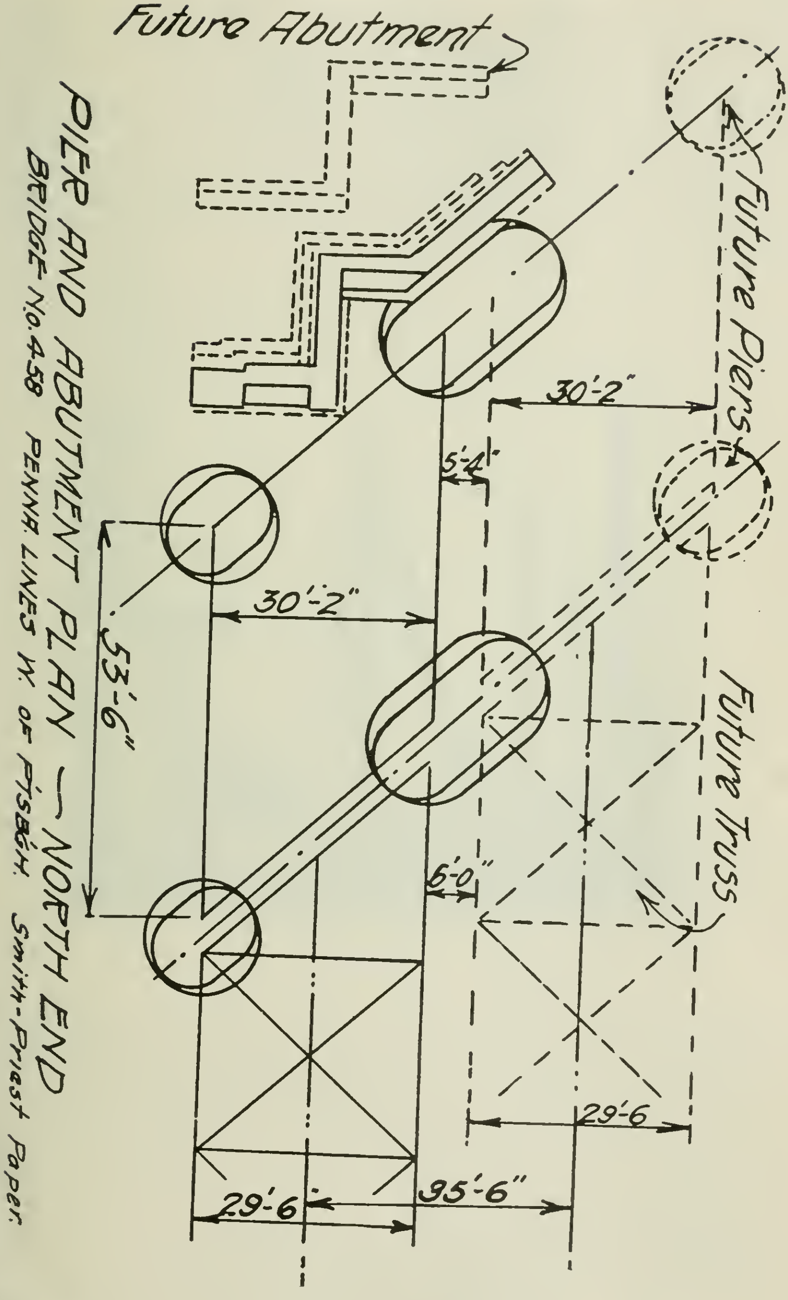
The latter was adopted because it seemed to offer less chance of delay to navigation and a better opportunity to quickly transfer the railroad traffic from the old to the new bridge.

The south end of the old span in its normal position interfered with the erection of the south tower, and clearance for the erection of this tower was obtained by extending the old abutments and changing the line of the old span so it would clear the new superstructure at south end.

The columns in towers were erected in three sections, the bottom section being 80 ft. 11¼ in. long, the middle section 46 ft. 11¼ in. long, and the top section 57 ft. 2⅝ in. long, making a total height of 185 ft. 1⅛ in. from top of masonry to top of columns. The total height of the towers from masonry to center line of sheaves is 195 feet.

On top of these columns, plate girders 75 ft. 2 in. long were placed, upon which the sheaves for counterweight cables were mounted. These girders weigh 40,000 lbs. each and the sheaves 59,760 lbs. each.

The erection of the south tower was commenced on Septem-


Future Abutment
Future Piers
Future Truss
30'-2"
5'-4"
30'-2"
53'-6"
6'-0"
29'-6
29'-6
35'-6"
PIER AND ABUTMENT PLAN — NORTH END
BRIDGE No. 4.58 PENNA. LINES W. OF PITSBGH. Smith-Priest Paper.

ber 4, 1913, the bottom sections of columns, each of which weighs 81,000 lbs., were set in place by a derrick car. (See Fig. 1).

After setting the bottom sections of the columns the tower bracing for these sections was bolted in place and an "A" frame derrick with two booms, especially designed for completing the erection of the tower, was set up on the part of the tower erected.

The erection of the north tower was started in the same way a little later. In order to erect these towers within a reasonable time it was necessary to provide a derrick that would handle a load

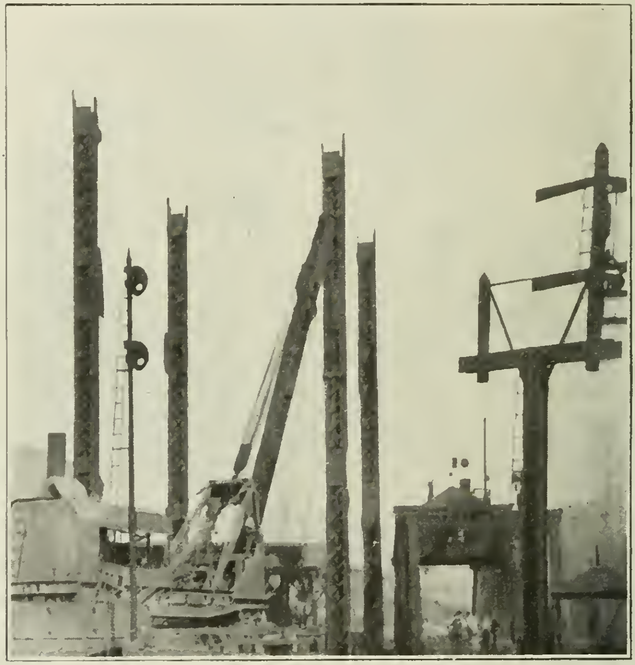
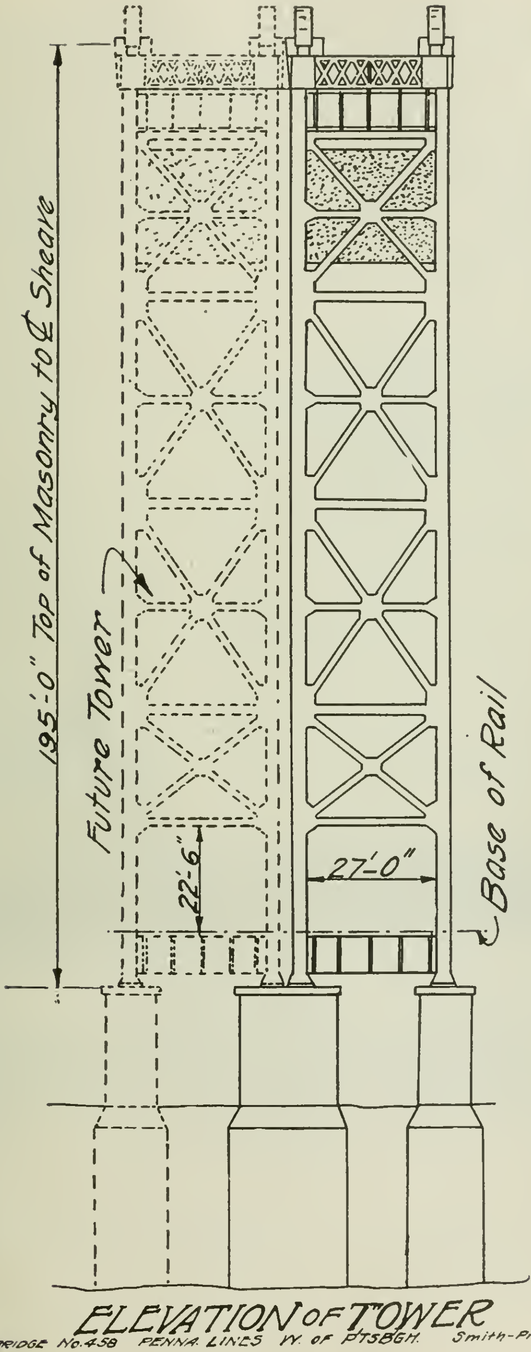


Fig. 1. Three Column Sections Erected—South Tower Facing South Derrick Car Placing Fourth Section.

of about 30 tons at a 44 ft. radius, and it had to be of such design as to permit its being shifted from point to point easily and quickly. The derrick designed for this work consisted of a timber "A" frame and two booms set up on a combination wood and steel beam which was secured to vertical timbers bolted to two sides of the tower, these timbers being extended as the erection of tower progressed. Fig. 2 shows the derrick in first position for proceeding with the erection of the tower.

Each end of the beam supporting the "A" frame was provided with links to which hoisting tackle was hitched to move the derrick up or down as might be required.



ELEVATION OF TOWER

BRIDGE No. 458 PENNA. LINES W. OF PTSBGH. Smith-Priest Paper.

When hoisting material with one boom the other boom was swung as near as possible in line with it and anchored to the material previously erected so as to react against the loaded boom.

This derrick was light, easily and quickly moved, and proved very satisfactory in erecting the towers. After the derrick was erected in first position it had to be raised twice during the erection of the tower. Fig. 3 shows the derrick in its final position in the tower, from which position a portion of the falsework for supporting the lift span was erected and also the end panels of the lift span. (See Figs. 3 and 4.)

In order to clear the river navigation, the falsework for lift span was built in a fan shape and could only extend from the towers to the third panel point from each end of the span, leaving a gap of about 108 ft. under which no falsework could be placed.

The falsework for the lift span consisted of three main legs under each end of each truss, arranged as are the sticks in a fan,

Fig. 2. "A" Frame in First Position in Tower.

the top of the inner one being 31 ft. 8 in. from the center line of inner column in towers, the center one 58 ft. 9 in. and the outer one 85 ft. 11 in. from the same point, the lower end of all the legs being set close together on a concrete foundation built on the masonry at the foot of the inner columns in the towers.

The horizontal thrust developed in the falsework legs by the load they had to carry was taken care of by securing their upper ends to the towers by means of eye bars and plates, and of course they were all thoroughly braced at properly spaced intermediate points.

The inner and center legs of the fan consisted of four 10 in. by

12 in. timbers bolted together, and the outer one of four 10 in. by 12 in. and six 12 in. by 12 in. timbers bolted together, making a sectional area of 1,344 sq. in. in this leg.

The outer leg was 146 ft., 10⅜ in. long on its center line and was built to sustain a load of 360 tons applied at its upper end.

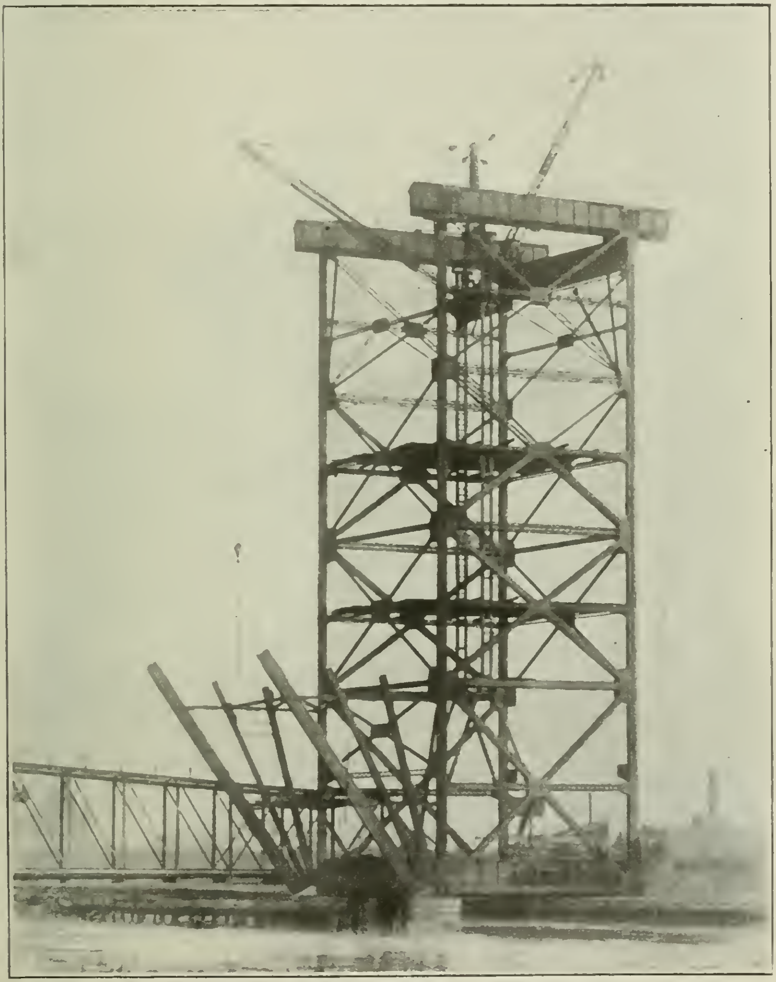


Fig. 3. Showing "A" Frame in Final Position in Tower.

The method of erecting the lift span was as follows:

With the "A" derricks in their final position for erecting the towers, the inner and center legs of the fan falsework were completely erected and properly braced, and the outer leg partially erected. The end panels of one of the trusses was then assembled on the falsework, together with the floor system and the end posts, end sections of bottom chord and end diagonals of the other trusses.

When this was done the "A" derricks were transferred from

Fig. 4. Showing End Panels of Lift Span and Part of Fan False Work Erected.

their position in the towers to a position over the first intermediate post of one truss and the end post of the other truss as shown in Fig. 5.

The fan falsework was then completed and the second panels of one truss and the first panels of the other truss, together with the floor system and lateral bracing, was completely assembled on the falsework, after which the "A" derricks were moved forward one panel and another panel was completely assembled.

The "A" derricks were again moved forward one panel which brought them to their final position for the erection of the span, also to the extreme point of the falsework's support and to the gap under which no falsework could be placed. (See Fig. 6.)

This gap of 108 ft. between the ends of falsework support was cut down to 73½ ft. by the projecting ends of the bottom chord sections already in place, and was closed by connecting the bottom chords with a center section 73 ft. $5\frac{5}{16}$ in. long which was

Fig. 5. Showing "A" Frame in First Position on Lift Span.

swung into position by the two "A" derricks as shown in Fig. 7. This center section of bottom chord weighs about 36 tons.

The erection of the trusses was then completed and the remaining four panels of floor system, lateral and sway system put in place. The span was erected at a clear height of 130 ft. above low water. Fig. 8 shows the trusses completely assembled, except the top chord and diagonal in one panel.

During the erection of the span the counterweight frames were erected and the concrete forming the counterweights poured. These counterweights for each end, when completed, weighed about 800 tons, and were supported by steel brackets attached to foot of columns until the lift span was ready for trial operation. As soon as the erection of the lift span was completed the machinery house was erected, the machinery installed, and the floor deck and tracks put in place. The falsework under the lift span was not removed until the span was loaded with practically all the weight it would carry when completed ready for traffic.

The bridge was completed ready for operation, except some little work on the floor deck, on July 13, 1914, and the span was operated from its maximum height to a point down as far as it

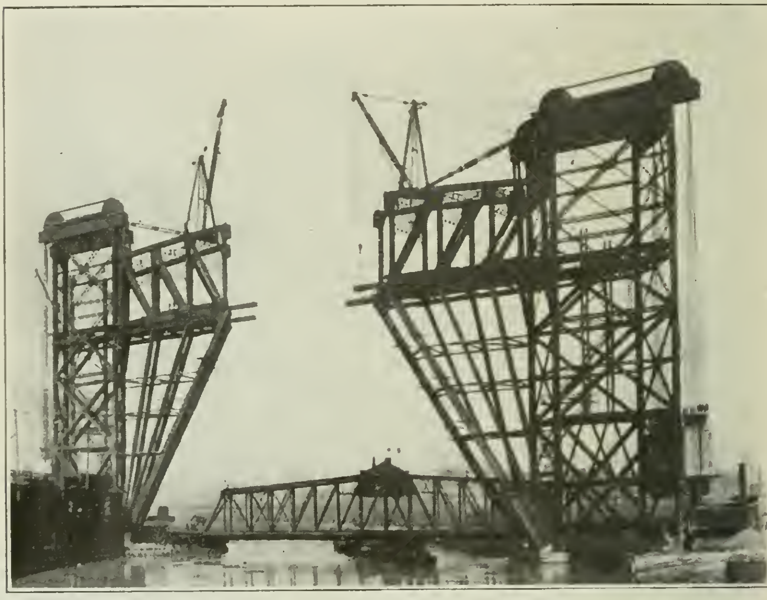


Fig. 6. Showing "A" Frame in Final Position on Lift Span.

weight was provided by filling some of the pockets left in the counterweights for this purpose, and the structure was then ready for traffic as soon as the old swing span could be moved out of the way so that the lift span could be lowered onto its bearings.

There were three different schemes considered for removing the old swing span, as follows:

1st. To swing it around parallel to the river 'channel over barges partly loaded with water, and then lift it clear of the pivot could be lowered without fouling the old swing span. This operation was for the purpose of determining if the span was properly balanced by the counterweights, and it showed that each of them required an additional weight of about 25 tons. This additional pier by pumping the water from the barges, after which it could

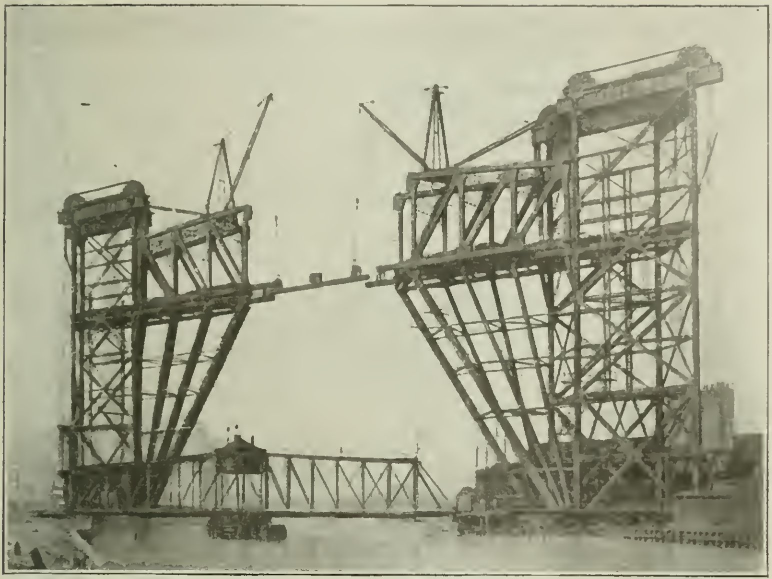


Fig. 7. Center Section of Bottom Chord of Lift Span Being Swung into Position.

Fig. 8. Showing Trusses of Lift Span Completely Assembled, Except Chord and Diagonals in One Panel.

be towed to any point selected and dismantled. This scheme was the best one considered, as it eliminated any interference with navigation and promised the least delay between the time of abandoning traffic on the old span and its resumption on the new, but it was abandoned on account of its cost, the lowest tender for furnishing tugs, barges, etc., for carrying it out being about $8,000.

2nd: A scheme to pivot the span on the south end of west truss, float it around on barges parallel to the south dock line and land it on falsework built close to the south side of the river, where it could be dismantled and loaded on cars, was also abandoned on account of its cost.

3rd: To float two scows partially loaded with water under the

Fig. 9. Showing New and Old Bridges the Day Before Old Bridge Was Removed.

north end of the span, block up on the scows under each panel point of this end of the span, then cut the span in two at a point near the north side of the pivot pier with acetylene flame and float the north end out of the way. When this was done the end of the span resting on the pivot pier was to be jacked east about 4 feet so as to clear the new span and left in this position until dismantled.

The Erection Department of the Pennsylvania Steel Company estimated the time necessary to do the work as outlined under scheme 3 at five hours. This scheme was adopted and preparations were made to carry it out on July 29, 1914. Fig. 10 shows north

Fig. 10. Scows in Position Under North Span of Old Bridge.

Fig. 11. South Span of Old Bridge, North Span Removed.

end of span landed on scows and the scows being lightened to raise it so as to clear for removal.

The various stages of the work of removing the old swing span are shown by the following photographs in the order named:

Fig. 9 shows new and old bridge the day before the old bridge was moved.

Fig. 10 shows scows in position under north span of old bridge.

Fig. 11 shows south span of old bridge, north span removed.

The schedule prepared for doing the work contemplated a delay to river traffic of four hours and to railway traffic of five hours, but owing to inadequate equipment for burning off the north end of span and unforeseen difficulties encountered in jacking the south end of span over on the pivot pier, the river traffic was delayed 6 hours and 20 minutes, and twelve hours elapsed before the old span was in position to clear the new one.

When the new span was finally lowered into position on bridge seats it was found that the line and surface of tracks on span required some adjustment, and also that the operating ropes required adjustment to properly land the span. This work was completed at 2:10 a. m. on the 30th of July, 1914, and the new span was turned over to the Division for regular service.

From the time the railroad traffic on the old swing span was abandoned to the time it was resumed on the new lift span, was 21 hours 10 minutes.

From the time of beginning the erection of the towers to the time the structure was put in service was 10 months and 26 days.

CO-OPERATION AMONG ENGINEERS*

By F. H. Newell.

Presented May 17th, 1915.

The engineering professions are the barometers of future business, being the first to feel the effects of the great business depression that recently occurred. When business begins to pick up and the promoters are considering the development of a mining or other project, the first person they send for is the engineer. At the present time no one is looking for new enterprises and although there is plenty of money in the country there is very little being laid out on construction, there being no new railroads, hydro-electric plants, irrigation projects or drainage works. Nevertheless we must prepare for the work which must come. Many of our associates are keeping their offices open merely for social functions, to see their friends and have a good time, but incidently they are considering the question of getting together and whether or not it would be advisable to inaugurate a cooperative movement in the near future.

We have various engineering societies, the Western Society in Chicago, the National Society in New York, and the local bodies in Washington, St. Louis and other cities, but each of these organizations is devoted to the purely technical side of the work. Engineers are very reticent about entering the commercial world and are far more so in exhibiting the works of their profession. I believe the engineer is the coming man and one who will serve the nation with good sound judgment, but I propose the question,—have we made sufficient effort to inform the public as to the position which the profession should occupy?

The problem which confronts us is how to obtain the cooperation of the non-technical world in developing and making known to the general public the work of the engineering profession. The public is entitled to this information in a way that it can understand. They will not read the technical journals but they will read an attractive story placed in a daily paper in a concise way and I believe it is our duty to adopt some such method of advising the public day by day and year by year of the importance of the engineer in obtaining the best for the community.

As an illustration of this point, the American Society of Civil Engineers is at the present time trying to secure a memorial to Alfred Noble. It is lamentable how few people outside of the engineering profession know the work that was done by this man. When the Panama Canal was undertaken the newspapers attacked the project in a most ferocious manner as they also did the Reclamation Act which was passed at the same time, and it was not until the public was fully educated on the subjects that the benefits to

*Abstracted from stenographic report.

be derived were fully appreciated. The canal work was well advertised day by day by the most skilled publicity experts that could be secured and the world grew to look upon it as the most wonderful effort of the age. The name of Colonel Goethals is now universally known as that of the builder of the canal while the name of Alfred Noble is unfamiliar to those who have not been in intimate contact with his work. This teaches us that if we are not doing all we should to advise the public of our work, it is largely due to the engineering profession itself.

This cooperation could also take up the question of employment. Each year thousands of engineers are leaving the colleges looking for work in addition to those who are already in the field. The question of their employment resolves itself into the problem of putting the square peg in the square hole. Now we could not devise a system that would put square pegs in round holes, so to speak, but we could, by cooperation and judicious advertising, bring the proper job to the man best fitted for it.

This last is but one of the problems that face the profession in organizing this effort, but the right kind of cooperation would undoubtedly meet all such difficulties to the end that they would be worked out to the satisfaction of all concerned.

In closing I would like to bring before the engineering profession another matter,—that of intelligent following up of legislation so as to prevent bad laws and to aid in making good ones. There is but little doubt that we as engineers have not done all we should in this matter.

In the matter of better legislation, in the matter of devising a system of employment for engineers, and in the matter of proper publicity to the public, problems are presented which, to receive a satisfactory solution, necessitate a hearty cooperation among engineers.

BOOK REVIEWS

THE BOOKS REVIEWED ARE IN THE LIBRARY OF THE SOCIETY.

ENGINEERING ECONOMICS. By John Charles Lounsbury Fish, Professor of Railroad Engineering, Leland Stanford Junior University. McGraw-Hill Book Co., New York, 1915. Cloth; 6 by 9 in.; pp. 217. Price, $2.00 net.

This book has been compiled from manuscript used by the author in his class-room for a number of years, and treats only of the first principles of the subject. It is divided into five parts; Part I, "Introduction," which is very short, brings out the great importance of economic selection. Part II treats of the fundamental or primary information, which is so necessary to the student of the subject, such as interest, sinking funds, first cost, salvage value, elements of yearly cost of service, and estimating. Each of the chapters in Part II contains simple examples and formulas showing the methods by which satisfactory results may be obtained. Part III, "Solution of the Problem of Economic Selection," sets forth the principles to be used in a brief, concise manner and can be easily followed. Part IV is a bibliography, and also contains depreciation and life tables which have been compiled by a number of authorities who have given this subject much study and whose conclusions have been used in actual practice. Part V consists of tables and formulas for calculating interest, present worth, sinking funds, depreciation, etc. The book is well indexed, and, with a reasonable amount of study the reader can become familiar with the various formulas and their application and thus greatly reduce the amount of labor so often performed in reaching satisfactory and sound conclusions.

TUNNELING. By Eugene Lauchli, C. E. McGraw-Hill Book Co., New York, 1915. Cloth; 6 by 9 in.; pp. 238. Price, $3.00 net.

Tunnel engineers are indebted to the author for a valuable addition to the literature on tunnels. There are eighteen chapters covering the different subjects in logical sequence.

The first chapter of eight pages covers the importance of geological surveys. The following eight chapters discuss small, medium and large tunnels, and the methods of driving, timbering and lining them. The discussion is thorough and deals with methods and equipment in which tunnel men are always interested. Chapters XI, XII and XIII discuss the temperatures, vitiation and ventilation in long and deep tunnels. These critical matters in long, deep tunnels are carefully covered and numerous examples are given to illustrate. Chapters XIV and XV on tunnels through soft materials and pressures on the same, show methods that have been used for many years. Chapters XVI, XVII and XVIII discuss "Syphon Tunnels," "Tunnels Driven With Compressed Air," and "Miscellaneous Tunnels."

Every railroad engineer contemplating tunnel construction should have this book in his library, as a careful study of some of the chapters might save many lives and a vast amount of capital on a large project. The book has 197 cuts illustrating in a comprehensive manner the discussions. C. C. S.

PROCEEDINGS OF THE SOCIETY

MINUTES OF MEETINGS.

Regular Meeting, May 3rd, 1915

A regular meeting of the Society (No. 901) was called to order at 8 p. m., Monday evening, May 3rd, 1915, by First Vice-President McCullough, and about 100 members and guests in attendance.

There being no business to come before the meeting, Mr. McCullough introduced as the speaker of the evening, Mr. Walter A. Shaw, who informally discussed "The Development and Importance of an Adequate Engineering Department for a Public Service Commission." A very interesting discussion followed in which Messrs. B. J. Arnold, O. P. Chamberlain, R. M. Feustel, S. T. Smetters, W. E. Symons, E. N. Lake, W. H. Finley and Mr. Shaw took part.

At the close of the meeting Mr. R. I. Randolph submitted for consideration a resolution recalling all resolutions sent out by the Society in defense of the members of the Society who were criticized by the newspapers in connection with a Water Power Report of the Sanitary District. It was moved and carried that the resolutions be referred to the Board of Direction for action.

After a few announcements and a reel of moving pictures, the meeting adjourned at 10:30 for refreshments.

Extra Meeting, May 10, 1915

An extra meeting (No. 902) in the interest of the Bridge and Structural Section was held Monday evening, May 10, 1915. Mr. H. C. Lothholz, chairman of the Section, called the meeting to order at 8 p. m. with 100 members and guests in attendance. After announcing future examinations for positions with the Illinois Public Utilities Commission, Mr. Lothholz introduced Mr. C. M. Spofford, who read a paper on "The Apportionment of Cost of Bridges Between Street Railways and Cities." Mr. Spofford's paper was illustrated with lantern slides and brought forth discussion from the following: C. F. Loweth, F. H. Cenfield, E. H. Lee, I. F. Stern, Ernest McCullough, J. N. Hatch and H. S. Baker. After a closure from Mr. Spofford and two reels of industrial motion pictures, the meeting adjourned at 9:30 for refreshments.

Extra Meeting, May 17, 1915

An extra meeting of the Society (No. 903), and the regular May meeting of the Hydraulic, Sanitary and Municipal Section, was held Monday evening, May 17, 1915.

The meeting was called to order at 8:10 p. m. by Mr. G. O. D. Lenth, the chairman, with about 175 in attendance, including a number of ladies. There was no business before the section. Mr. Lenth then introduced Prof. F. H. Newell, formerly of the Reclamation Service, now Professor of Civil Engineering at the University of Illinois, Urbana, Illinois.

Mr. Newell addressed the meeting on "Co-operation Among Engineers," individually and between the several local societies. The speaker then proceeded to show some of the features of the Reclamation Service with many beautiful lantern slides.

At the conclusion Dean Goss proposed a vote of thanks to Professor Newell for his interesting address, which was carried by a rising vote, and the meeting then adjourned at 9:45 p. m., when refreshments were served.

Extra Meeting, May 24, 1915

An extra meeting of the Society (No. 904), a meeting of the Electrical Section, Western Society of Engineers, held jointly with the Chicago Section of American Institute of Electrical Engineers, was held Monday evening, May 24, 1915. The meeting was called to order by E. W. Allen, chairman, at 8 p. m., with about 130 members and guests in attendance.

The Secretary reported from the Board of Direction that at their meeting held that afternoon, the following had been elected into the Society:

Albert M. Wayne, Chicago	Associate Member
Gardner S. Williams, Ann Arbor, Mich	Member
Chas. U. Freund, Chicago	Associate Member
Adrian K. Webster, Dawson Springs, Ky	Junior Member
Leigh G. Curtis, Chicago	Member
Clifford H. Westcott, Chicago	Junior Member
LeRoy B. Fugitt, Cushing, Okla	Associate Member
Webster D. Corlett, Oak Park, Ill	Junior Member
W. F. Hebard, Chicago	Affiliated Member

Also that the following had applied for admission:

John Wesley Lowell, Chicago.
Verne S. Lawrence, Logan, Iowa.
John W. Wilson, St. Charles, Ill.
Robert Smyth Adams, Chicago.
Eugene E. Aetman, Chicago.
John W. Baring, Chicago.
Charles Lawrence Bolte, Chicago.
Joseph C. Dolan, Chicago.
Ellis Skopbell Schlin, Chicago.
David Morse Goe, Chicago.
James Francis Hillock, Chicago.
John Jucker, Jr., Chicago.
John Reames Le Vally, Chicago.
Emmet Raymer Marx, Chicago.
Victor Emanuel Marx, Chicago.
Lawrence John McHugh, Chicago.
Franklin Leslie Pond, Chicago.
Herman N. Simpson, Chicago.
Geo. J. Trinkous, Chicago.
Walter Lee Juttemeyer, Chicago.
Samuel E. Sosna, Chicago.
George Bernard Perlstein, Chicago.
C. Arnold Grasse, Chicago.
Henry Wilkins, Chicago.
Herbert Paterson Sherwood, Chicago.
Guy Foote Wetzel, Chicago.
Peter J. Vollmann, Chicago.
Charles Woodward Morgan, Chicago.
Robert F. Havlik, Aurora, Ills.
Edwin George Birren, Chicago.
Henry Charles Wendorf, Chicago.
Thure Wm. Ingemanson, Chicago.
Ralph G. Culbertson, Ridgeville, Ind.
Harry Edward Connors, Chicago.

President Jackson then presented a paper prepared by Mr. E. B. Ellicott, M. W. S. E., on "Ten Years of Evolution in Hydro-Electric Units." Some discussion followed from Mr. R. F. Schuchardt, P. B. Woodworth, L. L. Holaday, H. M. Wheeler, S. Montgomery and P. Junkersfeld with replies and explanations from the chairman, E. W. Allen, E. R. Ellicott and Wm. B. Jackson.

Meeting adjourned about 9:15 when refreshments were served.

LIBRARY NOTES

The library committee desires to return thanks for donations to the library. Since the last publication of the list of such gifts, the following publications have been received:

MISCELLANEOUS GIFTS.

C. L. Strobel, M. W. S. E.:
  Architectural Iron and Steel, Birkmire. Cloth.
Lewis E. Moore, M. W. S. E.:
  Specifications for Bridges Carrying Electric Railways, Boston Public Service Commission, 1915. Pam.
John Crerar Library:
  20th Annual Report for 1914. Pam.

EXCHANGES.

American Society of Agricultural Engineers:
  Transactions, 1914. Pam.
Columbus, Ohio, Division of Water:
  Annual Report, 1914. Pam.
New York Board of Estimate and Apportionment:
  Development and Present Status of City Planning in New York City. Pam.
Canada Department of Mines:
  Preliminary Report on the Bituminous Sands of Northern Alberta. Paper.
  Summary Report of the Mines Branch of Department of Mines for 1913.
  Clay and Shale Deposits in the Western Provinces. Pam.
  Moose Mountain District, Southern Alberta. Pam.
  Geology of North American Cordillera at the 49th Parallel. Paper.
  Annual Report of the Mineral Production of Canada, 1913. Paper.
  Investigation of the Peat Bogs and Peat Industry of Canada, 1911-12. Paper.
  Notes on Clay Deposits near McMurray, Alberta. Pam.
Ontario Hydro-Electric Power Commission:
  Sixth and Seventh Annual Reports, 1913 and 1914. 2 paper.
Institution of Water Engineers, London:
  Transactions, 1914. Cloth.
Carnegie Institution of Washington:
  Year Books, 1911, 1912, 1913, 1914. 4 paper.
Pennsylvania Commissioner of Health:
  Annual Reports, 1910, 1911. Cloth.
American Railway Bridge and Building Association:
  Proceedings, 24th Annual Convention, 1914. Cloth.
American Mining Congress:
  Proceedings 17th Annual Session, December, 1914. Paper.
Wisconsin Geological and Natural History Survey:
  Polyporaceae of Wisconsin. Cloth.
  Mine Valuation and Assessment. Cloth.
Georgia Geological Survey:
  Preliminary Report on the Feldspar and Mica Deposits of Georgia. Cloth.
Boston Transit Commission:
  Twentieth Annual Report, June 30, 1914. Cloth.
Liverpool Engineering Society:
  Transactions 40th Session, 1914. Paper.
North-East Coast Institution of Engineers and Shipbuilders:
  Transactions, 1913-14. Cloth.
Michigan State Board of Health:
  Annual Report, 1913. Cloth.

RULES FOR ESTABLISHMENT OF BRANCH ASSOCIATIONS OF THE WESTERN SOCIETY OF ENGINEERS.

(1) Branch Associations of the Western Society of Engineers may be established by the adoption of a Constitution, which shall be approved by the Board of Directors, and by organization of the proposed Branch Association thereunder.

(2) Said Constitution shall provide:

(a) That all members of the Branch Association shall be members, in good standing, of the parent body.

(b) That all fees and dues assessed by the Branch Association against its members shall be in addition to regular fees and dues required by and paid to the parent body.

(3) A copy of the minutes and proceedings of each meeting of the Branch Association shall be filed with the Secretary of the Western Society of Engineers within ten days after the meeting.

(4) The Western Society of Engineers may publish in the Journal such proceedings of the Branch Association as shall be approved by the Publication Committee.

Journal of the
Western Society of Engineers

Vol. XX JUNE, 1915 No. 6

SOCIETY ACTIVITIES

MEMBERSHIP.

Since the last report the following additions to membership have been made. The applications for the year now number ninety-five.

ADDITIONS.

Adams, Robert S., Chicago	Student Member
Altman, Eugene E., Chicago	Student Member
Baring, John W., Chicago	Student Member
Bates, Stanley E., Chicago	Associate Member
Birren, Edwin G., Chicago	Student Member
Bolte, Charles L., Chicago	Student Member
Dolan, Joseph C., Chicago	Student Member
Echlin, Ellis S., Chicago	Student Member
Goe, David M., Chicago	Student Member
Grasse, C. Arnold, Chicago	Student Member
Havlik, Robert F., Aurora, Ill.	Associate Member
Hillock, James F., Chicago	Student Member
Ingemanson, Thure W., Chicago	Student Member
Jucker, John, Jr., Chicago	Student Member
Lawrence, Verne S., Logan, Iowa	Junior Member
LeVally, John R., Chicago	Student Member
Lowell, John W., Jr., Chicago	Associate Member
McHugh, Lawrence J., Chicago	Student Member
Marx, Emmet R., Chicago	Student Member
Marx, Victor E., Chicago	Student Member
Perlstein, George B., Chicago	Student Member
Pond, Franklin L., Chicago	Student Member
Sherwood, Herbert P., Chicago	Student Member
Simpson, Herman N., Chicago	Student Member
Sosna, Samuel E., Chicago	Student Member
Trinkous, George J., Chicago	Student Member
Wendorf, Henry C., Chicago	Associate Member
Wetzel, Guy F., Chicago	Student Member
Wilkins, Henry, Chicago	Student Member

NEW APPLICATIONS.

John A. Dailey, Chicago.
Samuel G. Artingstall, Jr., Chicago.

William A. Goss, Madison, Wis.
Homer W. Deakman, Chicago.
Roy A. Nelson, Chicago.
William M. Kinney, Chicago.
Frederick H. Newell, Urbana, Ill.
Clyde C. Younglove, Sioux City, Iowa.
William E. Wilson, Mason City, Iowa.
William F. Harvey, Chicago.
Fred Kellam, Valparaiso, Ind.
Arthur W. Nelson, Valparaiso, Ind.
Maurice D. Blumberg, Chicago.
Theodore H. Schlader, Chicago.

Transfers.

James A. Cook, Chicago.
Albert L. Wallace, Chicago.
J. Frank Ward, Evanston, Ill.
Glenn P. Beach, St. Paul, Minn.
Arrigo M. Young, Seattle, Wash.

SMOKER, JUNE 28, 1915.

In planning the program of meetings this Spring it seemed best that the last meeting before the summer vacation should be free from the weighty matters presented for our consideration during the winter; and that nothing heavier than a travel talk would do. The Entertainment Committee decided on a smoker, and a Sub-Committee, consisting of C. C. Saner, J. H. Libberton, R. H. Rice, J. E. Cahill and N. M. Stineman was appointed to carry it out, with no instructions other than to "stage the liveliest party the Western Society had ever had." All present—two hundred and ten members and guests—will testify that the committee followed both the letter and the spirit of their instructions.

The smoker was to be on the last Monday in June, with all outdoors luring our members away from the meetings, but Libberton provided a notice that was a powerful magnet. It will be one of the classics of the Western Society. It was enough to wake the dead, and its drawing power demonstrated the value of "Truth in Advertising."

The meeting started with a moving picture—"His Only Pants" —whose absurdities brought down the house. Then the "Western Society Glee Club," 200 strong (a few couldn't lay down their pipes even that long), led by Hogan, rendered assorted melody, from "Tipperary" to "Chinatown." This was followed by a travel talk on "The Philippines," in which Jay Rossiter related his experiences in that far-away part of Uncle Sam's possessions, illustrating them with many beautiful colored lantern slides.

Another movie was scheduled here, but the audience wanted to participate in the entertainment themselves, and when order was finally restored, Hogan again led the chorus of "We're Here Because We're Here," and other old favorites.

When voices were exhausted, the surprise of the evening was sprung. N. M. Stineman, perpetrator of the paper on "Reactions in a Three-Legged, Stiff Frame, with Hinged Column Bases," presented last Fall, appeared; several cartoons on the activities of the society, the engineering profession, and prominent members, were thrown on the screen, and Stineman verbally added some of the laugh-producing stingers that he hadn't dared to put on paper. The slide of a cartoon on a Past-President had miraculously disappeared, but the photographer was roused from bed and brought the negative down in a taxicab, whereupon the Past-President left suddenly, claiming there was only ten minutes to train time.

The lights were turned on, and everyone rushed to the library, where sandwiches, radishes and sixteen gallons of lemonade—not a construction camp menu—rapidly disappeared. This concluded the last meeting of the most successful season the Western Society has ever had. Since January 1st, 4,800 people have attended the meetings, an average of almost 200 at each, an increase of 60 per cent over last year and 160 per cent over 1913. The program contemplated for next Fall is splendid, and this year's attendance should reach 8,000.

THE BINGHAM AND GARFIELD RAILWAY—A SHORT ROAD IN UTAH WITH SOME UNUSUAL FEATURES

By H. C. Goodrich, Assoc. M. W. S. E., Chief Engineer.

Utah has made rapid strides in the past few years in the development of her rich mineral resources. The state is a land of mountains, valleys and plateaus. The Wasatch Range extends throughout the greater part of its length, dividing it into two distinct geographical areas; the succession of fertile valleys lying along the western base of the range, with the mountain and desert regions of the westernmost part of the State; and the high plateaus to the eastward bounded by the Wasatch on the west, and the long, high ridge of the Uintah Range on the north. The term desert is properly applicable only to the region immediately west of the Great Salt Lake.

A short time after the founding of the commonwealth as the Territory of Utah in 1850, the people through their Legislative Assembly petitioned Congress for a railroad, that they might be brought in touch with the eastern states as well as the Pacific Ocean. In 1862, the overland telegraph was completed to Salt Lake City and the railroad was completed in 1869.

Bingham Canyon is in Salt Lake County, Utah, in the Oquirrh Range of mountains, and is entirely within the area embraced in the West Mountain Mining District.

The Bingham & Camp Floyd, a narrow gauge railroad, constructed with a maximum grade of 4%, was built into Bingham Canyon in 1875, the terminus of this road being at the lower end of the mining district at an elevation of about 5,850 feet above sea level. This road was laid to standard gauge about 1888, and is now called the Bingham Branch of the Denver & Rio Grande Railroad. This line was located, however, farther up into the mining district to an old Spanish mine, at an elevation of about 8,000 feet, and during the early period of mining operations, a tramway was constructed and the ore was brought down in small steel ore cars, drawn up to the workings by horses and run down loaded by gravity. In the winter of 1900 and 1901 the small tramway was reconstructed by the Copper Belt R. R. Co., to a standard gauge railroad, using 7% grades with 40 degree maximum curvature. This line is shown in Fig. 1, and is marked "Copper Belt R. R." The motive power used is the Shay engine, which is a twelve-wheeled geared locomotive.

At that time it was known that there was a large body of low grade ore on what is now the Utah Copper Company's estate, but it was supposed to be of too low a grade to pay and was not taken up for active development until the organization of the original Utah Copper Company in 1903. Previous to that time, any work

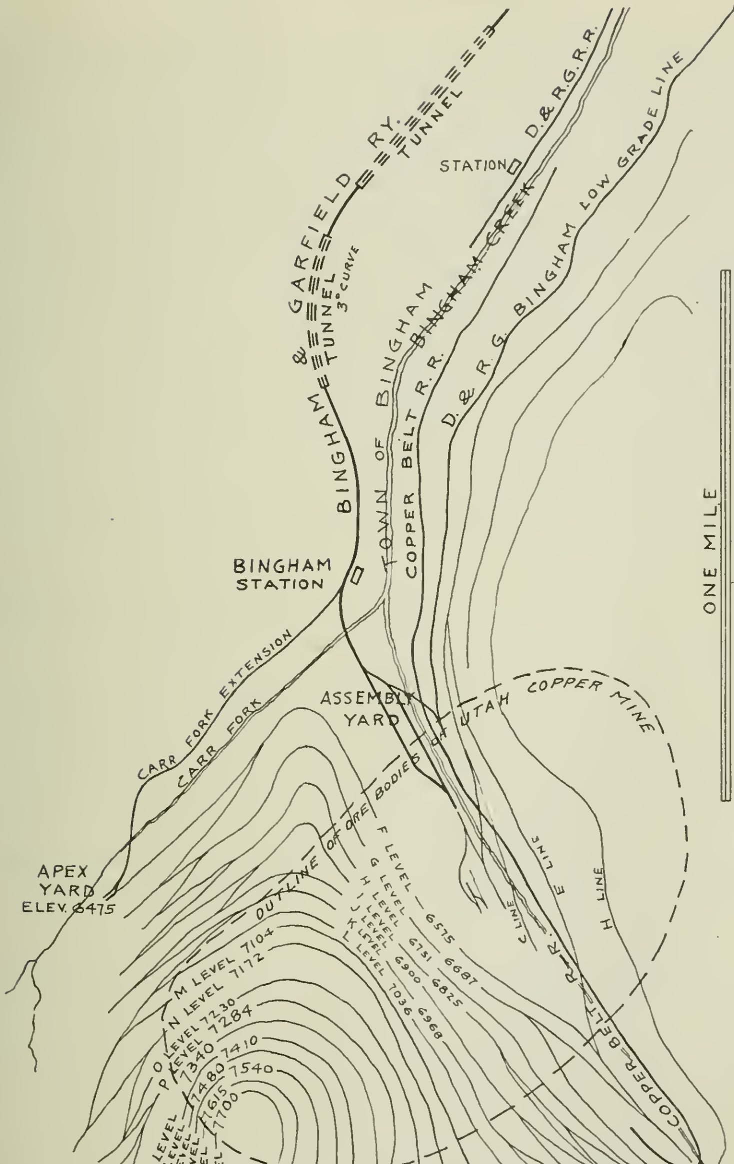


Fig. 1. Bingham Canyon, and Terminus of Bingham & Garfield Ry.

done was in hunting for the rich copper ore that is found here and there in the seams of the rock and in the fissures and fault planes.

The ore bodies of the Utah Copper Mine, which are indicated in outline on the map, Fig. 1, consist of an altered silicious porphyry, containing small grains of copper minerals, very uniformly disseminated throughout the mass, both in fracture seams and in the body of the rock, and averaging about 1.50% copper, 0.15 of an ounce silver and 0.015 of an ounce gold. The ore body, as at present developed, has a maximum length of a little over one mile, and a maximum width of more than one-half mile. The entire area has not yet been developed, but existing developments in this area show now an average thickness of about 445 feet or a total of about 361,220,000 tons. This ore after being mined is sent to the mills for cencentration, and the concentrates are sent to the smelter, where the blister copper is obtained, to be sent East for refining.

In 1903, the Utah Copper Company had constructed a mill at Copperton, about one and one-half miles below the D. & R. G. station at Bingham. The mine is located about a mile and one-half above the terminus.

At that time, the Utah Copper ore was all mined underground, loaded into railroad cars and taken down the steep 7% grade with the Shay engines, to the upper terminus of the Denver & Rio Grande Railroad, where it was transferred and taken down the Bingham Branch with standard locomotives, to the mills. These facilities were not capable of handling the tonnage that the mine could produce, and surveys were made to ascertain if a railroad could be located on lighter grades and with lighter curvature. Such a location was secured, but before actual construction work started, the Utah Copper Company had decided on radical changes in their mining and milling operations, which would increase the milling capacity from 600 tons per day to 6,000 tons per day; these changes necessitating greater transportation, milling and smelting facilities.

The mills were located about thirteen miles from and almost due north of the mine, near the shores of Great Salt Lake, at points shown on the map, Fig. 2, as Magna Mill and Arthur Mill. A new smelter was constructed at a point shown as Garfield Smelter. The Magna plant was designed to treat 6,000 tons of ore daily and the Arthur plant 3,000 tons, and it was imperative, therefore, that better railroad facilities be provided.

Consideration was given to the proposition of double-tracking the main Bingham Branch of the Denver & Rio Grande Railroad with 4% grades and double-tracking and electrifying the Copper Belt extension into the mining district, with 7% grades, but this plan was abandoned and a line called the Bingham Low Grade Line with 2.5% grades and 16 degree curves, built on the easterly side of the Main Bingham Canyon from the Utah Copper Mine to a point on the main Bingham Branch, called Welby, where the grades meet.

From this latter point the line goes in a northwesterly direction to the mills.

By referring to the map, Fig. 2, it will be noted that the elevation of the tracks at the Magna station is 4,457 and at the Bingham yard 6,331, or a difference in elevation of 1,874 feet. It will also be noted that the Denver & Rio Grande Bingham Low Grade Line, about three miles northeast of the mine, turns abruptly to the south and directly away from the mills. This was made necessary on account of the location being on the easterly side of Main Bingham Canyon; the supporting ground turning that way and the additional distance developed being required to establish an economical crossing of the Main Canyon, which was made at Artwell, as shown. This line continues in a generally easterly direction for about six miles to Welby, where the grade meets and from there it turns in a northwesterly direction to the mills and smelter at Garfield, as stated above. This line makes the distance for hauling the ore from the Utah Copper Mine to the mills 27½ miles. The road was completed and put into operation in the spring of 1907. The capacity of the mills and mines was increased, however, to an average daily capacity of 10,000 tons by the end of 1909, and the experiments in progress warranted the expectation that this tonnage would be doubled by the end of 1911.

During the summer of 1908, surveys were made by the Bingham & Garfield Railway Company between the mines and the mills to determine the feasibility and practicability of constructing a railroad in a more direct line and using the westerly side of Main Bingham Canyon in leaving the mine. The results of these surveys proved that a location could be secured with no insurmountable problems. In the spring of 1910, it was decided to build on this plan. Surveys were immediately started on the westerly side of Bingham Canyon, complete topography was taken and lines were projected on grades ranging from 2% to 2.5%, and with 12 degree maximum curvature.

In the meantime, the locomotive and car problems had been taken up with the manufacturers, and advice was received from them that Mallet articulated compound locomotives could be furnished that would haul forty empty ore cars up a 2.5% grade at an average speed of twelve miles per hour. The car manufacturers advised that a car 31 feet long over all could be constructed with a capacity of sixty-six tons of ore. This information was used as a basis for determining the gradient to use. The road was to be primarily a mining road, and when in operation, its traffic would be heavy. The greatest number of loads would be from the mine to the mills, and all down grade; practically only empty cars would be going up from the mills to the mines. If the locomotives used could take up the same number of empties as they brought down loads, it would not matter materially whether our maximum grade was 2% or 2.5%. The capacity of the line for all practical pur-

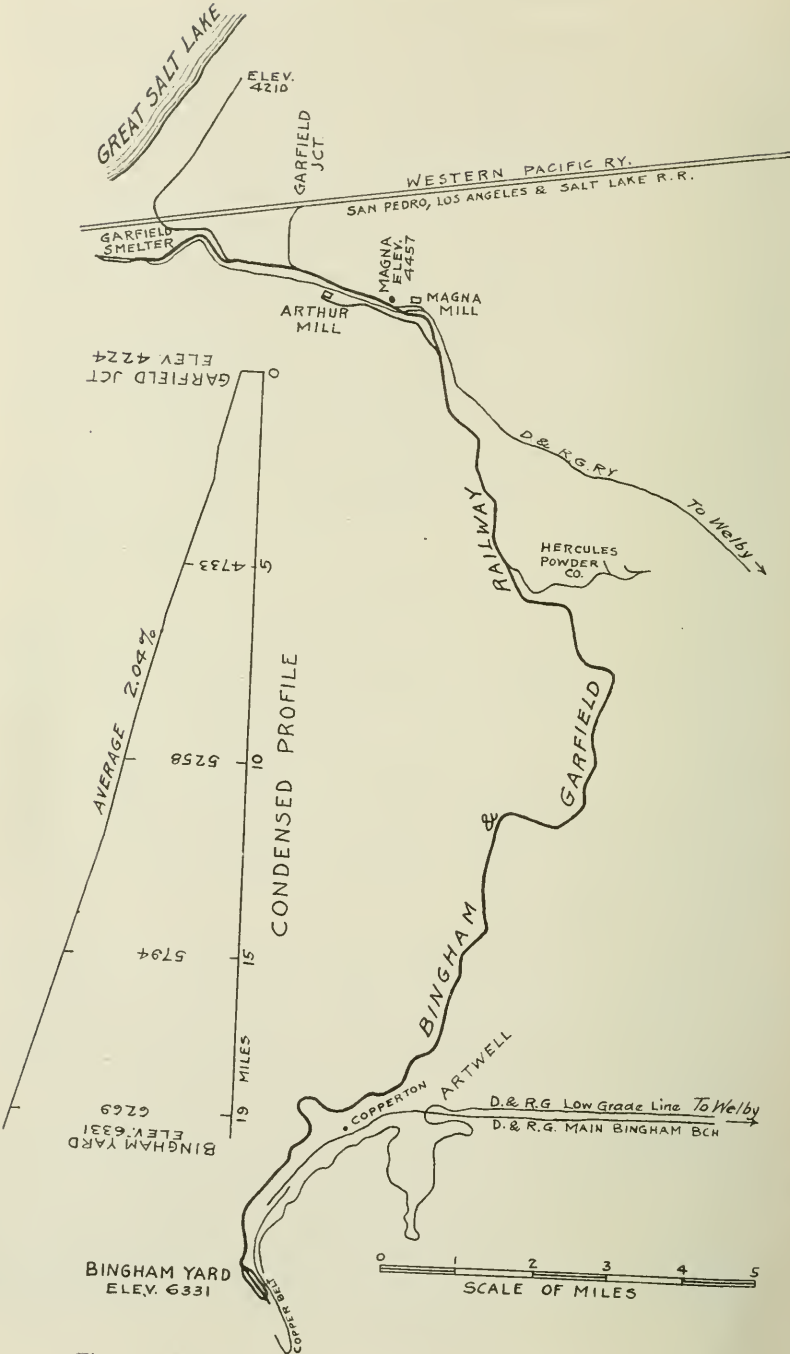
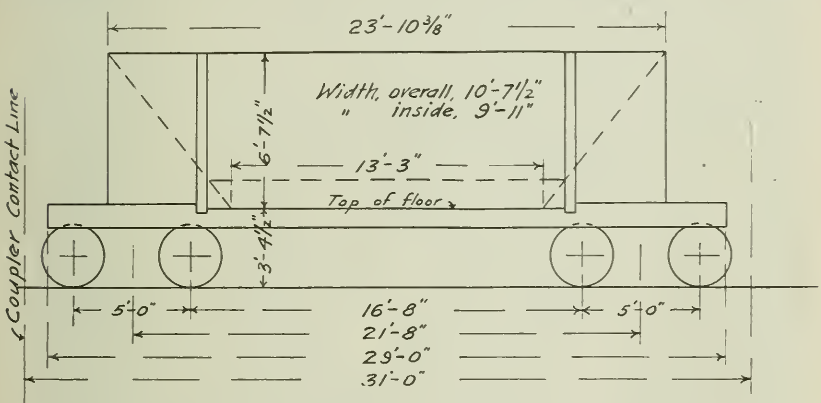


Fig. 2. Map and Profile of Bingham & Garfield Railway.

poses would be the same. Inasmuch as the number of loads in the trains going down grade would be fixed by other considerations than the number which could be handled, such as time, convenience of loading, capacity of assembly tracks at the mine, brake capacity of engines and the amount of rolling stock in use, these items would all help to determine the economical size of trains.

A desirable location for the Assembly Yard at Bingham was situated between two deep canyons, which is shown in the foreground and on the right in Fig. 4, where tracks could be constructed at a reasonable cost to accommodate trains of forty cars each, and inasmuch as the capacity of our terminal tracks was therefore fixed at forty cars, and the hauling capacity of the locomotive up a 2.5% grade fixed at forty cars, it was decided that a maximum 2.5% grade



BINGHAM & GARFIELD R.R. ORE CARS
Cubic Capacity, 1221 cu.ft.
Marked Capacity, 120,000 lbs
Weight of Empty Car, 42,900 lbs.
Total Weight of Car, with
Maximum Load, 174,900 lbs.

Fig. 3.

would be proper and that all the essential requirements would have been met. By the rules, generally speaking, for estimating the negative values of distance and curvature, it might be shown that the 2% line would be the proper one to select; but because of the peculiar conditions which would prevail on this road with loads all moving in one direction, these rules were considered of doubtful application.

On account of the Town of Bingham being located at the bottom of the canyon, with residences, school houses, churches, etc., constructed immediately at the base of the mountain, it was thought unwise to attempt to construct the railroad through this portion of

Fig. 4. General View of Bingham Gulch, Showing Utah Copper Mine and Terminus of Bingham & Garfield Railway.

the canyon on the mountain side. The curvature would also have been excessive, and the operations after construction would not have been as safe; therefore the line was drawn into the mountain and constructed with tunnels. The balance of the location presented no unusual engineering difficulties, as the maximum grade and curvature had been adopted. For a distance of about ten miles below Bingham the railway, of necessity, passes through very rough and broken country. It was necessary to expend a large sum of money in the construction of this ten miles, so that the work has probably cost as much per mile as any other equal length of line in the West. The first three miles below Bingham were rendered unusually costly on account of the deep canyons that had to be bridged and the tunnels that were constructed. These three miles cost about $1,170,000, the construction of the first mile costing $592,250, being the most expensive piece of work on the line on account of including the Carr Fork and Markham Gulch bridges, as well as the yards at Bingham and one tunnel 1,280 feet long. The total length of tunneling on the line is 4,795 feet, divided into four tunnels of the following lengths:

Tunnel No. 1, 6 degree curve....	682 feet
Tunnel No. 2, tangent...........	754 feet
Tunnel No. 3, tangent...........	2,079 feet
Tunnel No. 4, 3 degree curve....	1,280 feet

These are single track tunnels, 18 ft. wide and 22 ft. above top of rail. Where the sections had to be supported they were timbered, by use of the three segmental arch, with a plate timber along the tops of posts to allow for economical work. The timbered sections are fireproofed with redwood strips along the arch timbers, one inch boards on the two side segments and two inch boards for the top segment. In driving the tunnels, in order to economize on labor and make more rapid progress, a "Jumbo" was devised so that the tunnel could be handled in three benches. This jumbo was a frame structure riding on rails and was built two stories high. The top story would take the top bench out by running outriggers from the jumbo to the bench so that the material could be wheeled out and deposited in a bin or directly in the cars; in the same way the second bench was handled through the second story of the jumbo, the lower bench being shoveled directly into the cars. The average progress of the work was five feet in each heading per twenty-four hours.

All tunnels were driven by air from both ends to expedite the work and were finished on time without fatal accidents. After the completion of the tunnel work, in order to determine the exact volume of rock moved, and have a record of the sectional outline, a tunnel sectioner was devised.

Taking care of the drainage along the mountainous part of this road was quite a serious problem. The standard for the open-

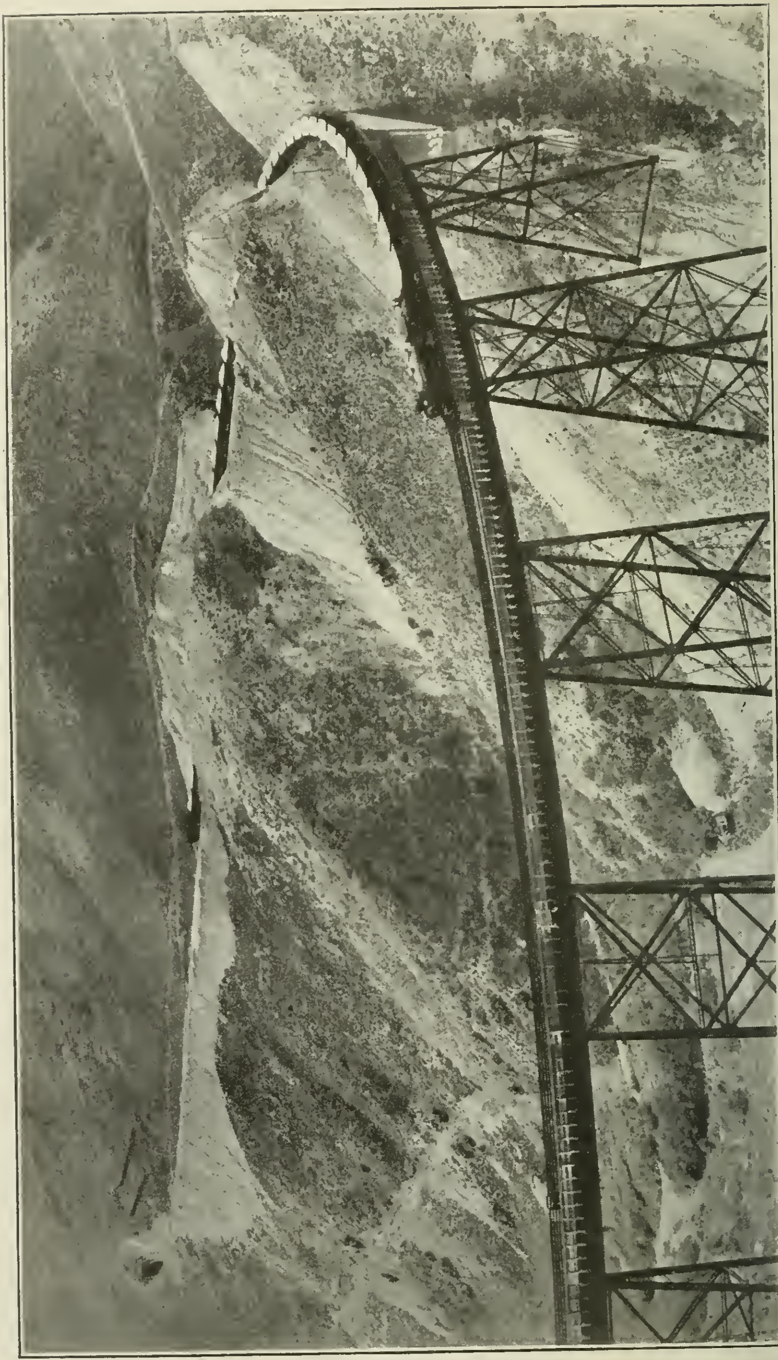


Fig. 5. Dry Fork Viaduct on 10 Degree and 10 Minute Curve.

ings adopted was concrete arches of varying sizes from three feet span up to ten feet span. It was difficult at some points to locate these arches in such a way that their foundations could be economically excavated and the length of the arch made as short as possible. The heaviest part of the work was in this locality. It was important to start the graders at as early a date as possible and for them

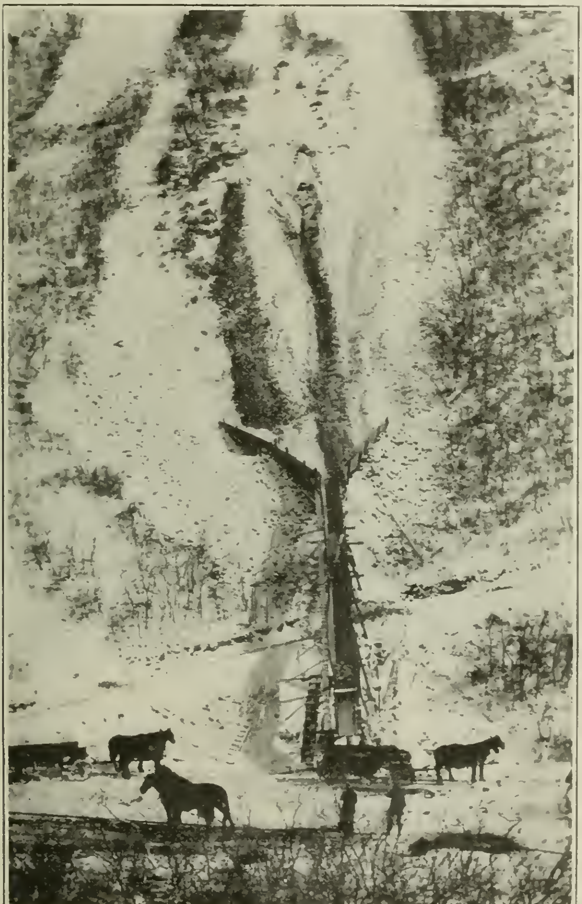


Fig. 6. Method of Securing Aggregate for Concrete.

to continue their work uninterrupted so that the line would be completed on time. In studying this problem and to avoid any delay in the construction work, it was found that small tunnels could be driven through the original ground in such a way that the placing of the embankment in the gulches could proceed, at the same time the work of driving the drain tunnels was done without interfering with each other. The services of experienced miners were secured to do the work, and it has proven successful in every way.

There are three steel viaducts. The one across Carr Fork on a 5-degree curve is shown in the center of the photograph, Fig. 4. The one across Dry Fork, on a 10-degree and 10-minute curve is shown in Fig. 5, with a forty-car ore train on its way from the mine to the mills. The Utah copper mine is directly behind the high point in the foreground of the picture. The flood water ditch above the cuts and the snow fences above the portal of the tunnel can be seen. This country is subject to violent rain storms during the summer and heavy snow storms during the winter. The wagon trail on the lower left of the photograph was built by the contractors to facilitate grading and tunnel work. These three viaducts rest on concrete piers carried to bedrock. The piers are five feet square at the top and have a batter of one and one-half inches per foot, to a size of nine feet square, this size being maintained to bedrock at depths varying from 12 feet to 96 feet.

A novel way of securing aggregate for the concrete is shown in Fig. 6. The sides of the mountains in this vicinity in places have quantities of so-called slide rock, ranging in size from sand to rocks of 8 or 10 cubic feet. As this photograph shows, a chute was built from the base of one of these slide rock deposits with several screens in the bottom to clean and size the rock. An anchor post was bedded at the top where a block was fastened, an ordinary slip scraper was fastened to a rope, the rope passed through the block and all operated by the team at the bottom, the aggregate being loaded directly into dump wagons and hauled to the bins at the mixer.

The plate girders were fabricated by the Pennsylvania Steel Company, the towers by the Minneapolis Steel and Machinery Company, the erection work being performed by the Garrick & Garrick Construction Company. There was no difficulty found in the erection, all members fitting nicely and the work being completed without mishap.

The photographs show the steep side hill character of the country. There were six steam shovels and over 1,000 men used continuously on this work; two shovels in that territory shown in Fig. 4, two as shown on Fig. 7, and two in the vicinity of the Magna Mill. Fig. 7 shows the cross-country character in that locality. The flood-water ditch is shown at tops of cuts, the line to the left being a pipe line for delivering water to the different construction camps, the length of which was slightly over five miles.

A rather ingenious plan was adopted for excavating the short, deep cuts, called the "Swede Trap," the plan being to drive a small tunnel just below grade, large enough to accommodate small dump cars. After the tunnel was well under, a raise was started and chutes built with gates. The material above was blasted, falling into the chutes and drawn by gravity into the dump cars, through the gates. In some of the cuts over 95% of the material was handled this way without extra handling and without the use of shovels. These small tunnels were extended as required and additional chutes constructed at short intervals.

The contract for the grading of this line was let to the Utah Construction Company on March 30, 1910, and they had the major portion of the work covered with men, teams and equipment by May. The first work was started on April 17, 1910, and completed by April, 1911. During that period this company handled the following work:

Fig. 7. Typical Country After Leaving Bingham Canyon.

746,970	Cu. yds. solid rock excavation
618,222	Cu. yds. loose rock excavation
315,079	Cu. yds. earth excavation
4,795	Lin. feet tunnel excavation
818	Lin. feet drain tunnel excavation
1,494,416	Ft. B. M. tunnel timber
11,698	Cu. yds. concrete.

This was considered a remarkable performance in railroad construction over such a short piece of line. The contract for the steel viaducts was let to the Minneapolis Steel and Machinery Company, covering approximately 3,000 tons of structural steel.

The heavy service tracks are laid with 90 lb. open hearth A. R. A. Section, Series "A" rail, the remainder of the track being laid with 65 lb. open hearth, A. S. C. E. section. The ties are

Oregon Fir. untreated, 7 in. by 8 in. by 8 ft., spaced eighteen to a 33 ft. rail and fully tie-plated, the 90 lb. rail having tie plates 8 in. by 8½ in. and the 65 lb. rail 8 in. by 8 in. Some difficulty has been experienced in maintaining the 90 lb. rail in position, and recently they have been testing tie plates 7 in. by 10 in. On the heavy service tracks these ties are to be renewed with treated ties 7 in. by 9 in. by 8 ft. The 90 lb. rails are all connected with the continuous angle bar, weighing 83.6 lbs. per pair. The rails are anchored on all grades with at least eight P. & M. rail anchors to each length of rail, and on all curves of 3 degrees and over, the rails are braced with the Ajax Rail Brace, two on every third tie. This railway has one foot of rock ballast under the ties of all their heavy service tracks. By referring to Fig. 8, showing method of securing solid roadbed, it will be noted that the grade line shown conforms to the

Fig. 8. Method of Securing Solid Roadbed at Ends of Cuts.

elevation as left after construction. Since that time 12 inches of rock ballast has been placed in the tracks.

Open hearth frogs were provided, but on account of the heavy service, their life was not satisfactory. There had been under observation for over two years in the tracks at the mine, two No. 7 solid manganese frogs to fit 65 lb. rail, with more than 40,000 tons passing over them daily. These frogs gave such excellent service that this type is being installed in all of the permanent heavy traffic lines. There has also been in the switching tracks at Magna for the past year, the Conley type of frog, made of manganese steel. These frogs have proven satisfactory at the points located.

At the end of the year 1913, the total mileage consisted of the following:

Main line	25.93 miles
Yards and sidings	35.07 miles
Tracks at Bingham	41.08 miles
Total	102.08 miles

The equipment consists of the following:

4 Mallet articulated compound locomotives.
8 Heavy service switching engines.
1 Consolidation type switching locomotive.
375 Ore cars.
50 General service cars.
75 Concentrate cars.
8 Flat cars.
4 Steel underframe box cars.
1 120-ton wrecking crane with necessary outfit cars.
2 Passenger cars.
1 Business car.

During the year 1913, the road handled a total of 6,044,959 tons of freight, being an average of 16,561 tons per day, and throughout the year a twice-daily passenger service was operated between Salt Lake City and Bingham; the total number of passengers handled being 134,151. The greatest tonnage of Utah copper ore handled in any one day was 26,730, and in addition to this there was some commercial freight.

On account of the operations necessitating the handling of the larger part of the tonnage on a down grade, it was found objectionable to handle the 40-car ore train with standard brake equipment, and arrangements were made to have applied to the ore cars the empty and load brakes as manufactured by the Westinghouse Air Brake Company. The heavy type of locomotive has solved the problem of grade operation in so far as the ascent of the grade is concerned, and consequently it is possible to haul heavy trains up long grades at a satisfactory speed; however, in order to safely handle the same train down the grade it frequently becomes necessary to provide a higher braking power on trains as a whole. In the past this has been accomplished by adding a sufficient number of empty cars, dividing up the train and taking it down the grade in sections, or using hand brakes in connection with air brakes.

This empty and load brake operates to materially increase the total braking power controlling train units on grades, which gives a practical uniform braking power on car units, whether empty or loaded, in any service. It is entirely interchangeable with the standard freight brake, including the well-known type K quick service, retarded release and uniform recharge freight triple. On tests made on this line under actual load conditions it was found necessary to load the cars not to exceed 56 tons capacity, and trains not to exceed forty cars per train with the standard brake equipment, and with a small factor of safety in reserve. In actual road tests of the empty and load equipment, it was found that the cars could be loaded to 75 tons per car, the train consisting of 50 cars, and a very high factor of safety be maintained with a consumption of less than half of the air required for the standard equipment.

This equipment has been entirely satisfactory, holding the heavy trains down the 2.5% grade at a uniform speed.

It will be interesting to note the following comparative distribution of braking power on two forty-car trains on this line; one having standard equipment, the other having empty and load equipment:

Braking power on empty car 60% of empty car based on 50 lbs. brake cylinder pressure.

Braking power on loaded car 40% of weight of loaded car based on 50 lbs. brake cylinder pressure.

	Standard Equipment Full Serv. Reduct.	Empty and Load Equip. Full Serv. Reduct
Number of cars in train	40 cars	40 cars
Light weight of car....	40,000 lbs.	40,000 lbs.
Capacity of car........	120,000 lbs.	120.000 lbs.
Loaded weight of car..	160.000 lbs.	160,000 lbs.
Total weight of train..	6,400,000 lbs.	6,400,000 lbs.
Total braking power...	960,000 lbs.—15%	2,560,000 lbs.—40%

It is generally believed that this equipment helps to reduce the flange and rail wear.

On the ore cars they use over 5,000 brake shoes per month, can handle from 100 to 150 tons per shoe, and the shoes will average from 400 to 450 miles each.

In the main line where the heavy ore service is handled, there are about 6,000 open hearth rails of 90 lb. section. Operations in ore service began September 14th, 1911, and since that date there have been removed 193 rails on account of failure, or slightly over 3%. It was observed that on the 6 degree curves and over, the metal in the outside rail would cut, and the metal in the inside rail would push down. In order to overcome this difficulty, they have laid four of the curves with the "Frictionless Rail," but this has not been in the track long enough to determine its ultimate merit. It can be said, however, that it has been no detriment to the tracks or service.

The problems at the mine were numerous and difficult to solve both from an engineering as well as a financial standpoint. These involved the removing of approximately 50,000,000 cubic yards of capping rock overlying the ore-body, which had a developed thickness varying from thirty feet to two hundred feet, approximately, and moving it to dumping ground that had to be secured, as well as moving the ore when available to the railroad yards, in regular and uninterrupted quantities to meet the mill requirements.

The characteristic topography of Bingham Canyon and its connecting canyons and gulches is steep, prominent ridges and mountain sides with intervening low flat gulches. The main canyon had been built up as a town and was too valuable to be considered as a place to dump the capping; the available ground, therefore, for this capping was the low, flat gulches lying off of and away from the ore body. That portion of the Utah Copper property that was to be operated first is shown in Fig. 4 in the background of the picture. The elevation of the railroad yard is 6,340 feet; the elevation of the top of the mountain, 7,900 feet, or a vertical distance of 1,560 feet. There were twenty-one levels established for steam shovel operation, varying in height from 60 feet to 75 feet each. These steam shovels had to be provided with supplies and provision made for hauling the ore away. Various plans were suggested, discussed and rejected for the handling of this property, and it was finally agreed that railroad tracks should connect each one of the steam shovel levels with the railroad yards. On account of the character of the country it was necessary in order to reach the various elevations to construct these railroads on a switchback system, and it will be noted in the photograph that in places these tracks are one above the other as close as the slopes of the material will allow.

The equipment of the Utah Copper Mine consists of twenty-two steam shovels and fifty-one locomotives. The locomotives are four-wheel connected, saddle-tank, with a total weight on drivers of fifty tons. These locomotives were to be used in hauling the ore cars from the railroad yards up the switchbacks to attend the different steam shovels, as well as to haul the capping out to the waste dumps in side-dump cars. It had been proven that the most economical way to handle the capping was on level lines; that is, provision should be made for the necessary room for the capping from each level, so that it could be hauled out on level lines. It had also been proven that any grade over 4%, equated .04 per degrees for curvature would not be economical to operate the dinky locomotives hauling the empty ore cars up grade, and that the maximum curve should not exceed 16 degrees. This plan was adopted and construction work was started during 1910 on the switchbacks in Carr Fork. These tracks leave the Bingham Yard, going up Carr Fork on the right-hand side, and are not shown in the photograph on account of their lying back of the ridge; they, however, are shown on the mountain-side opposite.

In order to facilitate and make more flexible the operations at the mine, it was thought necessary to establish other connections of this character at the south end of the property. These connections start from the south end of the auxiliary yard and are located on the easterly side of Main Bingham Canyon. The lower portions of these switchbacks are not shown in the photograph, but they can be observed up as far as the "J" Level on the left-hand side.

It will be well to call attention to one rock fill shown in Fig. 4. This fill has a slope of 1.2 to 1, and a height of 175 feet. It is constructed in terraces, the rock having been placed by hand. It has stood for over three years, and so far does not show any signs of failing.

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The switchback system in Carr Fork and the one at the south end of the property are all connected across each steam shovel level, and with the main tracks at the bottom. It is impossible to conceive of any accident or unforeseen occasion arising that would materially interrupt the output of the mine. These tracks are handling approximately 65,000 tons per day, and of necessity it is a busy place with its steam shovels and numerous dinky locomotives moving backwards and forwards at regular intervals. These movements are all controlled by dispatchers, assisted by various flagmen, located at advantageous places, who indicate whether trains are to proceed or wait for a meet.

In addition to handling the business of the Utah Copper Company, these tracks are accessible to every mine located in Bingham Canyon; this camp having better railroad facilities than any other in the west.

The locomotives at the mine are capable of hauling six of the empty ore cars up the 4% grade, to be loaded by the steam shovels, and on account of the empty and load brake equipment, they can be handled down the grade with safety.

At the location shown at "7" in photograph, Fig. 4, a good many million yards of room for capping from the mine was found and made available. The same is true of that locality in the vicinity of "8" in the photograph, but as these two places were at a higher elevation, it was necessary to provide dumping ground for the capping below the "I" Level. This was secured on the easterly side of Main Bingham Canyon, as shown at "9" on the photograph, and to the north of that point.

The mileage of the different cars in the Utah Copper ore service varies from day to day on account of the distances from the assembly yards to the different shovels, the cars to be loaded being taken by the dinky engines as they come to Bingham, to the shovel requiring them first. The distance from the yards at Magna to the yards at Bingham is approximately seventeen miles. When these cars arrive at Bingham, if they are to be taken to the shovel working on the "A" Level, Elev. 6,340, they will have to be handled about one-half mile to the shovel and back, making an additional haul of one mile. The "F" Level, Elev. 6,600, four miles additional; the "K" Level, Elev. 6,968, nine miles additional; the "O" Level, Elev. 7,230, twelve miles additional. The ore from the "P" Level, Elev. 7,284 and above, is being dumped into raises from the old underground workings and hauled out to bins at the main level, to be loaded into the cars direct. From the "A" Level to the "F" Level, a vertical distance of 260 feet, the loading is from one face, the intermediate levels having been abandoned. It is intended to continue this plan on the higher levels as soon as the capping rock is entirely removed from the ore faces.

The terminal facilities at Bingham consist of station, machine shop, engine house, 100-foot turn-table, coaling platform, air compressor and line for charging and testing air on trains, and section and bunk houses. As will be noted in Fig. 4, the station shown at "15" is above the town of Bingham, and an electrically operated inclined passenger and express elevator working in balance, is used for delivering passengers and light express to and from the town. This inclined tram is constructed on a 40% grade, with a difference in elevation of 200 feet from the lower end of the tram to the upper end.

The terminal facilities at Magna consist of station, engine shop, engine house, car repair shed and tracks, coaling station, water supply and bunk houses, as well as cottages to accommodate the employees.

Since the beginning of operations of the Bingham & Garfield Ry., the tonnage of Utah Copper ore has increased to 23,000 tons daily, and direct facilities have been provided for three of the other big mines at Bingham; the remaining properties using aerial tramways to deliver the ore to loading bins below.

A powder plant has been established along the main line to make both dynamite and black powder, and connections have been made with both the San Pedro, Los Angeles and Salt Lake Railroad and the Western Pacific Railway.

STRUCTURAL ENGINEERS' LICENSE LAW OF THE STATE OF ILLINOIS

The Act providing for the licensing of structural engineers, which is intended to relieve the disability which the Illinois law for licensing architects imposed upon structural engineers, was passed by the Forty-ninth General Assembly on June 19th, after a vigorous campaign by the Legislative Committee of the Western Society of Engineers, and was signed by the Governor of the State on July 5th. It is expected that the Governor will appoint the Examining Board within a short time.

It should be noted particularly that the reason for this activity of the Western Society of Engineers in this matter, was the hardship under which structural engineers labored because of the operation of the architects' license law, rather than upon a fixed policy as to the general question of licensing engineers, which is quite another matter. There has been a peculiar situation affecting those engaged in the practice of structural engineering in the State of Illinois, which has placed them under a heavy handicap, the extent of which is perhaps not fully comprehended by those not engaged in that particular line of work.

In modern office buildings, and similar large buildings, for instance, the safe design of the supporting structure requires the skill of the engineer and is equally important with the function of the architect in providing a pleasing appearance and a convenient general arrangement. The law, however, did not permit an architect and an engineer to form a partnership, and it was necessary for the engineer to work as a subordinate of the architect.

Buildings of a distinctively engineering character, in which the architectural features were of minor importance or non-existent, were required to have an architect as their sponsor.

The bill as originally introduced in the legislature was strongly opposed by the architects, but several amendments were agreed upon and the opposition to the bill was officially withdrawn by the joint committee of the Illinois Chapter of the American Institute of Architects and the Illinois Society of Architects, although individual architects continued to oppose it.

The Act as passed, is as follows:

Section 1. Be it enacted by the People of the State of Illinois, represented in the General Assembly: That within thirty days after the taking effect of this Act the Governor of the State shall appoint a State Board of Examiners of Structural Engineers, to be composed of five members, one of whom shall be a professor in the Civil Engineering Department of the University of Illinois, and the others shall be structural engineers of recognized standing, who have had not less than ten years practical experience, then practicing as structural engineers in the State of Illinois, to hold, regulate, supervise and control examinations of applicants for license to practice structural engineering in this State. Two of the members shall be designated to hold office until January 31, 1917, and the other three shall hold office until January 31, 1919; and thereafter upon the expiration of the term of office of the persons so appointed, the Governor of the State shall appoint a successor to each person whose term of office shall expire, to hold office for four years, and said person so appointed shall have the above specified qualifications. In case appointment of a successor is not made before the expiration of the term of any member, such member shall hold office until his successor is appointed and duly qualified. Any vacancy occurring in the membership of the Board shall be filled by the Governor of the State for the unexpired term of such membership.

2. The members of the State Board of Examiners of Structural Engineers shall, before entering upon the discharge of their duties, make and file with the Secretary of State the constitutional oath of office. They shall, as soon as organized, and biennially thereafter in the month of February elect from their number a President and a Secretary who shall also be the Treasurer. The Treasurer, before entering upon his duties, shall file a bond with the Secretary of State, for such a sum as shall be required of him by the Secretary of State, and in such form and with such sureties as may be approved by the Governor of the State. The Board shall adopt rules and regulations not inconsistent with this Act to govern its proceedings; shall adopt a seal; and shall cause the prosecution of all persons violating any of the provisions of this Act, and may incur necessary expense in that behalf. The Secretary shall have the care and custody of the seal; and shall keep a record of all the proceedings of the Board which shall be open at all times to the public.

The Secretary of the Board shall receive a salary to be fixed by the Board, and which shall not exceed the sum of Fifteen Hundred ($1500.00) Dollars per annum; he shall also receive his traveling and other expenses incurred in the performance of his official duties, and each of the other members of the Board shall receive the sum of Ten ($10.00) Dollars for each day actually engaged in the performance of his duties, and all legitimate and necessary expenses incurred in attending the meetings of the Board and in conducting examinations, which together with all other lawful expenses shall be paid from funds appropriated therefor, as provided by law.

3. Three members of the Board shall constitute a quorum. Meetings of the Board shall be called by the Secretary upon the written request of the President or any two members, by giving at least seven days written notice of such meetings to each member, counting from the day on which the notices are post-marked, telegraphed or personally delivered.

The Board shall adopt rules and regulations for the examination of applicants for license to practice structural engineering, in accordance with the provisions of this Act, and may amend, modify, and repeal such rules and regulations from time to time. The Board shall immediately upon the election of each officer thereof, and upon the adoption, repeal or modification of its rules of government or its rules and regulations of examinations of applicants for licenses, file with the Secretary of State and publish at least twice in at least one engineering journal of general circulation in the State of Illinois and in one daily newspaper published in the State of Illinois, the name and address of each officer, and a copy of such rules and regulations, or the amendments, repeal or modification thereof.

4. Provision shall be made by the Board hereby constituted for holding examinations at such place or places as shall be appointed by the Board, and at least two in each year, of applicants for license to practice structural engineering. Notice of the time and place of the holding of such examinations shall be published in the same manner as is hereinbefore provided for the publication of the rules and regulations pertaining to such examinations adopted by the Board: provided that the last day of such publication shall be at least twenty (20) days prior to the date of holding such examinations. Each applicant shall pay to the Secretary of the Board, in advance, a fee of Twenty ($20) Dollars, and shall present his affidavit that he is of the age of twenty-one years, or above. Such examinations shall be held by the examiners as a body, a majority of whom shall constitute a quorum, or by a committee of two or more members selected and appointed by the Board. Examinations

shall be conducted by written or printed interrogatories, in whole or in part.

Each applicant examined shall sustain a satisfactory examination in the design and construction of buildings and structures according to scientific principles and with special reference to strength and safety; the strength and properties of the various building materials; the principles of theoretical and applied mechanics; the ability of the applicant to apply his knowledge to the ordinary requirements of structural engineering; and in such other matters and subjects as the Board of Examiners may require as suitable to fairly and thoroughly test the competency of the applicant to practice structural engineering in this State.

Every applicant for a license, except those who apply by virtue of the provisions of Sections Five (5) and Six (6) of this Act, shall present to the Board of Examiners satisfactory proof, by affidavit, or otherwise, as the Board may direct:

(a) That at the time of the taking effect of this Act, he was actually engaged in the practice of structural engineering in this State, and did not apply for a license under Section Five (5) of this Act, and in such case the applicant shall be entitled to an examination without regard to the number of years he has practiced. Or,

(b) That within ten years next prior to his application, he has practiced structural engineering in some state or territory of the United States, or in some foreign country, for not less than six years, during at least two full years of which period he shall have been in responsible charge of work, as principal or assistant. Or,

(c) That within ten years next prior to his application, he has pursued a course of study and training in the theory and practice of structural engineering covering at least the subjects above specifically enumerated, for the period of not less than six years, in the employ or under the supervision, direction and tuition of one or more practicing structural engineers, during at least two full years of which period, every such applicant shall show that he has been in charge of work in designing or construction in the employ or under the direction of such engineer or engineers. Such applicants who have graduated from a college or school of engineering considered by the Board to be in good standing and requiring a course of study of not less than four years, during at least thirty weeks in each year, shall be credited two years upon the six-year period required above, the remaining four years to be pursued as hereinabove in this paragraph provided. The Board in its discretion may adopt rules providing for credit not exceeding two years on said six-year period to applicants who have pursued a course of instruction in schools or colleges of engineering approved by the Board, but who have not graduated.

If the result of the examination of any applicant shall be satisfactory to a majority of the Board, under its rules, the Secretary, upon an order of the Board, and upon payment by said applicant of the further sum of Thirty ($30) Dollars, shall issue to said applicant a license to practice structural engineering in this State, in accordance with the provision of this Act, which license shall contain the full name, birthplace, and age of the licensee, and shall be signed by the President and Secretary and sealed with the seal of the Board.

All papers received by the Secretary in relation to applications for license, shall be kept on file in his office, and proper index and record thereof shall be kept by him.

Any fraudulent act or representation by any applicant in connection with his application for examination, or for a license without examination, under this Act, or during the conduct of his examination, shall be sufficient cause for the withholding of the license by the Board of Examiners or for its revocation after it has been issued.

5. Any person who shall by affidavit or other proof as the Board may direct, show to the satisfaction of the State Board of Examiners of Structural Engineers that he was a resident of and engaged in the practice of structural engineering in this State, on the date of the taking effect of this Act, shall be entitled to a license without examination, provided such application shall be made within six months after the taking effect of this Act. Such license, when granted, shall set forth the fact that the person to whom the same was issued was practicing structural engineering in this State at the time of the taking effect of this Act and is therefore entitled to the license to practice the profession of structural engineering without an examination by the Board of Examiners, and the Secretary of the Board shall upon the payment to him by the applicant of a fee of Fifty ($50) Dollars issue to the person named in said affidavit a license to practice structural engineering in this State in accordance with the provisions of this Act.

6. The State Board of Examiners may in its discretion, issue a license, without examination, upon payment of a fee of Fifty ($50) Dollars, to a structural engineer licensed under the laws of any other state or territory of the United States, or any foreign country, provided it appear to the Board that in the state or territory or country in which such license was issued, the requirements for a license to practice structural engineering were equal to those prescribed in this State, and that such state, territory or country accord a like privilege to structural engineers who hold licenses issued under the provisions of this Act.

7. Every person holding a license to practice structural engineering in this State shall have it recorded in the office of the Secretary of State and the date of recording shall be endorsed thereon, and upon such recording said license shall be of force and effect throughout the State. The Secretary of State shall be entitled to receive a fee of $1.00 for the recording of each license filed for record. Until such license is recorded as herein provided, the holder thereof shall not exercise any of the rights or privileges conferred therein and thereby.

8. Every licensed structural engineer shall have a seal, the impression of which must contain the name of the structural engineer, his place of business, and the words, "Licensed Structural Engineer," "State of Illinois," with which he shall stamp all plans, drawings and specifications issued by him for use in this State.

9. Persons licensed to practice structural engineering in this State under this Act shall be exempt from the provisions of "An Act to provide for the licensing of architects and regulating the practice of architecture as a profession," approved June 3, 1897, and in force July 1, 1897, and all amendments thereto.

10. No corporation shall be licensed to practice structural engineering, but it shall be lawful for it to prepare drawings, plans and specifications for buildings and structures as defined in this Act, which are constructed, erected, built or their construction supervised by such corporation, provided that the chief executive officer or managing agent of such corporation in the State of Illinois shall be a structural engineer licensed under this Act.

11. It shall be lawful for one or more licensed structural engineers to enter into copartnership with one or more architects licensed under the laws of this State, for the practice of their professions.

12. Any person who shall be engaged in the designing or su-

pervising of the construction, enlargement or alteration of any structures, other than buildings, as hereinafter defined, or any part thereof, for others, and to be constructed by persons other than himself shall be regarded as practicing structural engineering within the meaning of this Act, and shall be held to comply with the same. Structures within the meaning of this Act shall be construed to mean all structures other than buildings, having as essential features, foundations, columns, girders, trusses, arches and beams, with or without other parts, and in which safe design and construction requires that loads and stresses must be computed and the size and strength of parts must be determined by mathematical calculations based upon scientific principles and engineering data, and any person who shall be engaged as a principal, in the designing and supervision of the construction of structures or the structural parts of structures designed solely for the generation of electricity, or for the hoisting, cleaning, sizing or storing of coal, cement, sand, grain, gravel or similar materials, elevators, manufacturing plants, docks, bridges, blast furnaces, rolling mills, gas producers and reservoirs, smelters, dams, reservoirs, waterworks, sanitary works as applied to the purification of water or plants for waste and sewage disposal, or roundhouses for locomotives, railroad shops, pumping or power stations for drainage districts, or power houses, shall be considered as structural engineers within the meaning of this Act, and shall be entitled to the benefits of these provisions, even though such structures may come under the definition of "buildings" as defined in "An Act to provide for the licensing of architects and regulating the practice of architecture as a profession," approved June 3, 1897, in force July 1, 1897, and all amendments thereto; provided, however, that nothing contained in this Act shall be construed to limit or abridge the rights, privileges and duties of architects licensed to practice under the provisions of said Act, nor to modify, limit or repeal any of the provisions of said Act; and provided, further, that nothing contained in this Act shall prevent draftsmen, students, clerks of work, superintendents and other employees of those legally practicing as structural engineers under licenses as herein provided, from acting under the instructions, control or supervision of their employers or shall prevent the employment of superintendents of construction paid by the owner from acting if under the control and direction of a licensed structural engineer who has prepared the drawings and specifications for the structure; and provided, further, that nothing contained in this Act shall be construed to prevent any person, mechanic or builder from making plans or specifications, or supervising the construction, enlargement or alteration of any structure or building which is to be constructed by himself or his employees, and for his own use.

13. After six months from the taking effect of this Act, it shall be unlawful for any person to practice structural engineering without a license in this State, or to advertise, or to display a sign or card, or other device which indicates or represents that he is entitled to practice as a structural engineer in this State, and any person guilty of the violation of any of the provisions of this Act shall be punished by a fine of not less than Ten ($10) Dollars nor more than Two Hundred ($200) Dollars, for each and every offense.

14. It shall be lawful and be the duty of the State Building Commissioner appointed and acting under any State Building Code which is now or which may hereafter be in force and effect in this State, or of any Building Commissioner of any city, town or village organized under any general or special law of this State, which has adopted a building code or other ordinance or laws relative to the construction, alteration, repair, maintenance and safety of buildings and structures, and providing for the issuing of building permits by a Building Commissioner or other officer designated for that purpose, to issue permits for the construction, enlargement or alteration of such buildings, as defined in Section 12 of this Act, or structures to any owner, or his agent, upon the filing with the State Building Commissioner or with the Building Commissioner of such city, town or village, of a true copy of the plans, drawings and specifications for the construction, enlargement or alteration of such buildings or structures, and a certificate signed by the structural engineer who executed them certifying under his seal that said plans, drawings and specifications are in accordance with the State Building Code, or the Building Code of such city, town or village, as the case may be, provided, such structural engineer shall be licensed under this act, and provided, such owner or his agent has complied with all other requirements of law requisite to obtain such building permit, and provided, further, that such plans, drawings and specifications are in accordance with the State Building Code, or the Building Code of such city, town or village, as the case may be.

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15. Every licensed structural engineer in this State, who desires to continue the practice of his profession, shall annually, during the time he shall continue in such practice, pay to the Secretary of the Board during the month of July, a fee of Ten ($10) Dollars, and the Secretary shall thereupon issue to such licensed structural engineer a certificate of renewal of his license for the term of one year. Failure by any licensed structural engineer in actual practice to cause his license to be renewed during the month of July in each and every year, shall constitute valid grounds for the revocation of his license. The failure to renew such license in apt time shall not deprive such structural engineer of the right of renewal thereafter; but the fee to be paid upon the renewal of a license after the month of July shall be Fifteen ($15) Dollars.

It shall be the duty of the Secretary of the Board to file with the Secretary of State on the 15th days of February and August in each year certified lists of all licenses then in force, upon the filing of each of which said lists, the Secretary of State shall be entitled to receive a fee of $1.00.

16. Licenses issued in accordance with the provisions of this Act shall remain in full force unless revoked for cause, as hereinafter provided. Any license so granted may be revoked by a four-fifths vote of the State Board of Examiners for gross incompetency; or recklessness in the construction of buildings or other structures; or for fraudulently affixing his seal to plans, drawings or specifications; or for any dishonest practice or practices on the part of the holder thereof; or for fraud in obtaining his license; or practicing without payment of the annual license renewal fee provided in Section Fifteen (15) of this Act; but before any license shall be revoked such holder shall be entitled to at least twenty days' notice of the charge against him, and of the time and place of the meeting of the Board for the hearing and determining of such charge.

For the purpose of carrying out the provisions of this Act relating to the revocation of licenses, the Board, and each member thereof, shall have the power to administer oaths, and said Board shall have the power to secure by its subpoena both the attendance and the testimony of witnesses, and the production of books and papers, relevant to any investigation by the Board for the purpose of carrying out the provisions of this Act, relating to the revocation of licenses. Witnesses shall be entitled to the same fees and mileage as witnesses in a Court of Record, to be paid in like manner. The accused shall be entitled to the subpoena of the Board for his witnesses, and to be heard in person or by counsel in open public trial. Any Circuit Court of this State or any judge thereof, either in term time or vacation, upon application of such Board, may in its discretion by order duly entered by such court or judge thereof, require the attendance of witnesses, the production of books and papers, and giving of testimony before such Board, and upon refusal or neglect to so appear and testify and produce such books and papers as commanded by such order of the court or judge thereof, may compel, by attachment or otherwise, as provided by law, the attendance of such witnesses, the production of such books, and papers and the giving of testimony before such Board, in the same manner as production of evidence may be compelled before said court. Every person who, having taken an oath or made affirmation before said Board, shall wilfully swear or affirm falsely, shall be guilty of perjury and upon conviction shall be punished accordingly. It shall be the duty of the Secretary of the Board to promptly give notice of all revocations of licenses to the Secretary of State who shall make an entry thereof in his records.

17. The State Board of Examiners shall have power to entertain and grant for good cause shown, petitions to vacate its orders revoking licenses and reinstate such petitioner to practice in this State, and to adopt rules and regulations governing the requirements and hearing of such petitions, provided that at least one year shall intervene between the date of the entry of the order revoking a license and the filing of such petition in cases involving gross incompetency, recklessness, dishonest practices, or fraud. The Board in its discretion may require petitioners whose licenses have been revoked for gross incompetency or recklessness to submit to an examination by the Board touching their professional qualifications and competency to practice, which shall at least cover the subjects required of applicants for a license by examination. Such petitions shall briefly state the date and cause of revocation, the grounds upon which petitioner seeks reinstatement, and such other facts as the Board by its rules may prescribe, and shall be verified by the petitioner. The Board in the hearing of such petitions shall, as near as

may be, follow the practice required by this Act in relation to citations to revoke licenses. Any person interested may appear and contest such petitions. A majority vote of the Board shall be sufficient to reinstate such petitioners to practice.

Every petitioner shall pay to the Secretary of the Board, in advance, upon the filing of his petition, a fee of Ten ($10) Dollars.

It shall be the duty of the Secretary of the Board to promptly notify the Secretary of State of the reinstatement of any such applicant, and the Secretary of State shall note the same on his records accordingly.

18. It shall be the duty of the Secretary of the Examining Board to file at the close of each fiscal year with the Auditor of Public Accounts of the State of Illinois, a full annual report of the proceedings of the Board, including a statement of all funds received and disbursed, and he shall also pay over to the State Treasurer of the State of Illinois, quarterly, all license fees and renewal and other fees collected by him during the preceding quarter and take his receipt therefor. Said report shall be attested by the affidavits of the President and Secretary.

PRESSURES ON PILES SUPPORTING MASONRY

By R. P. V. Marquardsen, assoc. m. w. s. e.

Books on design of retaining walls, piers, abutments, etc., usually contain formulas for finding the intensity of pressure on the foundation supporting the structure under consideration, but none (at least of those that have come to the writer's notice) show how to ascertain the pressure per pile if the masonry is resting on piles.

As the latter case is perhaps of more frequent occurrence than the former, it might not be out of place to discuss briefly the systematic procedure for finding the pressure on a given pile in instances where the wall, pier, or abutment is lodged on piles.

In the necessary derivation of formulas in connection herewith it will be assumed,

(1) that all loads are carried by the piles,

(2) that all piles are alike and sustain the same load under like conditions,

(3) that the pressure on each pile is concentrated at the center of the pile,

(4) that all piles are driven vertical,

(5) that the tops of the piles are at the same elevation, and

(6) that the masonry at the horizontal plane of the tops of the piles is rigid (which is equivalent to neglecting the slight continuous-beam action that actually takes place in that region).

The following notation will be used:

Aa, Ab, Ac = perpendicular distance between line A-A and piles "a," "b," and "c," respectively. See Fig. 1.

Ba, Bb, Bc = perpendicular distance between line B-B and piles "a," "b" and "c," respectively. See Fig. 1.

G_1, G_2, G_3, ... Gn = perpendicular distance between line G-G and rows 1, 2, 3, ... n, respectively. See Fig. 2.

Gv = distance between the point where V must be applied in order to produce equal pressures on all piles and the actual point of application of V. See Fig. 2.

N_1, N_2, N_3, ... Nn = number of piles in rows 1, 2, 3, ... n, respectively. See Fig. 2.

Nt = total number of piles supporting the wall, pier or abutment under consideration.

Pa, Pb, Pc = total vertical pressure on piles "a," "b" and "c," respectively. See Fig. 1.

P'_1, P'_2, P'_3, ... P'n = vertical pressure per pile on piles in rows 1, 2, 3, ... n, respectively, due to force V'. See Fig. 2.

P''_1, P''_2, P''_3, ... P"n = vertical pressure per pile on piles in rows 1, 2, 3, ... n, respectively, due to couple V"—V. See Fig. 2.

P_1, P_2, P_3, ... Pn = total vertical pressure per pile on

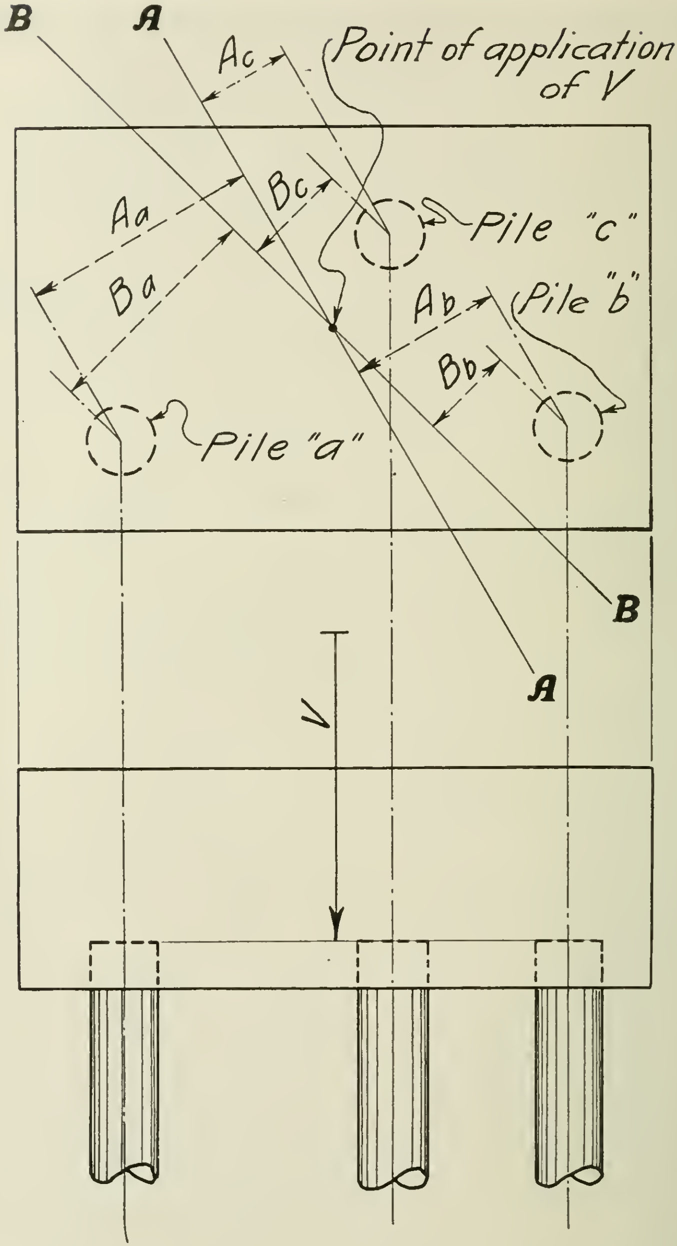
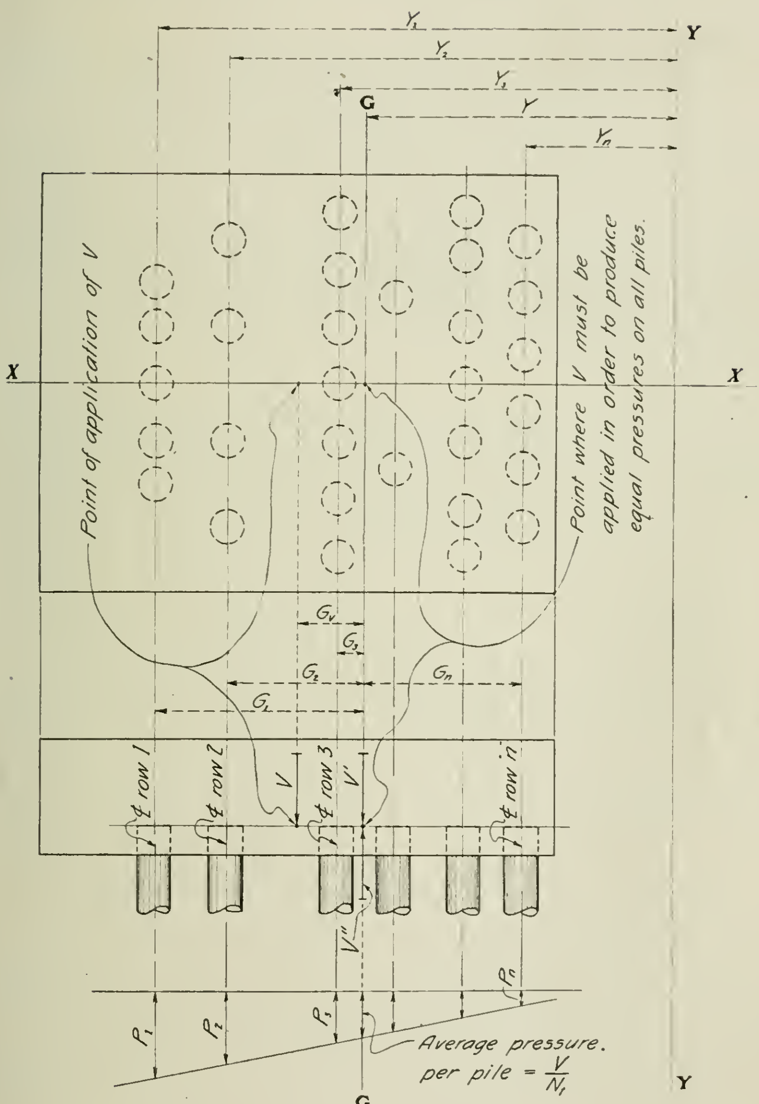

B
A
Ac
Point of application of V
Aa
Bc
Pile "c"
Ba
Ab
Pile "b"
Bb
Pile "a"
B
A
V

Fig. 1.



Y1
Y
Y2
Y3
G
Y
Yn
X
X
Point of application of V
Point where V must be applied in order to produce equal pressures on all piles.
Gv
G3
G2
Gn
G1
℄ row 1
℄ row 2
V
℄ row 3
V'
℄ row n
V''
P1
P2
P3
Pn
Average pressure. per pile = V/N1
G
Y

Fig. 2.

piles in rows 1, 2, 3. . . . . n, respectively. See Fig. 2.

V = vertical component of resultant of loads supported by the piles.

V′ and V″ will be referred to later.

Y_1, Y_2, Y_3, ... Yn = perpendicular distance between Y—Y line and rows 1, 2, 3. . . . . . n, respectively. See Fig. 2.

Y = perpendicular distance between Y—Y line and point where V must be applied in order to produce equal pressures on all piles. See Fig. 2.

To comprehend the amount of work involved in analyzing a perfectly general case consider a problem as indicated in Fig. 1, where the magnitude of V and its point of application with respect to the piles, as well as the location of each pile, is known.

By assumption (1) all loads are carried by the piles, and we may therefore write that

$$V = Pa + Pb + Pc \quad \text{.......... (a)}$$

The forces acting being in equilibrium, the sum of the moments of the piles on one side of any line passing through the point of application of V, about the line, must equal the sum of the moments of the piles on the other side of the line, about the line, or

$$Pa\ Aa = Pb\ Ab + Pc\ Ac \quad \text{.......... (b)}$$

$$Pa\ Ba = Pb\ Bb + Pc\ Bc \quad \text{.......... (c)}$$

From (b)

$$Pa = Pb\left(\frac{Ab}{Aa}\right) + Pc\left(\frac{Ac}{Aa}\right) \quad \text{.......... (d)}$$

and from (c)

$$Pa = Pb\left(\frac{Bb}{Ba}\right) + Pc\left(\frac{Bc}{Ba}\right) \quad \text{.......... (e)}$$

Equating (d) and (e) and solving for Pb there results

$$Pb = Pc\left\{\frac{\left(\frac{Bc}{Ba}\right) - \left(\frac{Ac}{Aa}\right)}{\left(\frac{Ab}{Aa}\right) - \left(\frac{Bb}{Ba}\right)}\right\} \quad \text{.......... (f)}$$

Substituting in (d)

$$Pa = Pc\left[\left\{\frac{\left(\frac{Bc}{Ba}\right) - \left(\frac{Ac}{Aa}\right)}{\left(\frac{Ab}{Aa}\right) - \left(\frac{Bb}{Ba}\right)}\right\}\left(\frac{Ab}{Aa}\right) + \left(\frac{Ac}{Aa}\right)\right] \quad \text{.......... (g)}$$

Using the values given by (f) and (g) in (a) and solving for Pc we get

$$Pc = \frac{V}{1 + \frac{Ac}{Aa} + \left(1 + \frac{Ab}{Aa}\right)\left\{\frac{\left(\frac{Bc}{Ba}\right) - \left(\frac{Ac}{Aa}\right)}{\left(\frac{Ab}{Aa}\right) - \left(\frac{Bb}{Ba}\right)}\right\}} \quad \ldots\ldots\ldots (h)$$

That this method may be extended to solve problems comprising any number of piles is evident; but that it becomes impracticable if there are too many piles is equally obvious.

In practice, however, the piles generally are, or may be assumed to be, placed symmetrically about a given line, and the point of application of V usually falls, or may be regarded as falling, on this line.

For the purpose of deriving practical formulas, it may, therefore, in addition to the assumptions already made, be further assumed,

(7) that the piles are arranged symmetrically about a line passing through the point of application of V.

To analyze a general case under these conditions, contemplate a problem as indicated in Fig. 2.

As before, the magnitude of V and its point of application with regard to the position of the piles are known.

To find the point where V must be applied in order to produce equal pressures on all piles, draw, conveniently distant from the last row of the piles, a line Y—Y, perpendicular to the X—X line about which the piles are grouped symmetrically. The point in question is, of course, located on line X—X, and its distance Y from the Y—Y line may, as little consideration should make clear, be found by the following formula:

$$Y = \frac{Y_1X_1 + Y_2X_2 + Y_3X_3 + \ldots\ldots\ldots + Yn\,Xn}{Xt} \quad \ldots\ldots\ldots (1)$$

Having located accurately to scale this point, draw through it and parallel to line Y—Y the line G—G, and obtain by scaling the distances G_1, G_2, G_3, ... Gn, and Gv.

At the point under consideration, we may, without changing the equilibrium, conceive applied two forces, V′ and V″, of the same magnitude but of opposite direction, and each equal and parallel to V. (See Fig. 2.)

The single force V has now been replaced by a direct force V′ which will produce equal compressive stresses in all piles, and by a couple V″—V causing compression in the piles located on the same side of the G—G line as the point of application of V and tension in the remainder of the piles.

The pressure per pile on piles in any row, as row 1, due to the direct force V′, may be found by dividing V′ (=V) by the total number of piles, or

$$\frac{V'}{Nt} = \frac{V}{Nt} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

The stress per pile in piles located in any row, as row 1, due to the couple V″—V, bears a certain relation to the stress per pile in piles located in any other row, as row 2, the stress in any pile being directly proportional to the perpendicular distance between the pile and the G—G line; that is,

$$\frac{P''_1}{G_1} = \frac{P''_2}{G_2} = \frac{P''_3}{G_3} = \ldots\ldots\ldots\ldots\ldots = \frac{P''n}{Gn} \ldots\ldots\ldots\ldots (3)$$

from which

$$\left.\begin{array}{l} P''_2 = P''_1 \dfrac{G_2}{G_1} \\ P''_3 = P''_1 \dfrac{G_3}{G_1} \\ \ldots\ldots\ldots\ldots \\ P''n = P''_1 \dfrac{Gn}{G_1} \end{array}\right\} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

The moment of the couple V″—V (= VG_v) is resisted by the sum of the moments of the stresses in the piles about the G—G line, or

$$VGv = P''_1G_1N_1 + P''_2G_2N_2 + P_3''G_3N_3 + \ldots + P''nGnNn \ldots (5)$$

Substituting in formula (5) equivalent values as given by formula (4), and solving for P''_1, we have

$$P''_1 = VGv\frac{G_1}{G_1^2N_1 + G_2^2N_2 + G_3^2N_3 + \ldots\ldots + Gn^2Nn} \ldots\ldots (6)$$

The total pressure per pile on piles in any row, as row 1, is equal to $P'_1 + P''_1$; or by combining formulas (2) and (6)

$$P_1 = V\left(\frac{1}{Nt} \pm \frac{Gv\,G_1}{G_1^2N_1 + G_2^2N_2 + G_3^2N_3 + \ldots\ldots + Gn^2Nn}\right) (7)$$

the plus sign to be used if row 1 is located on the same side of the G—G line as the point of application of V, and the minus sign if on the other side.

The pressure per pile on piles in any row, as row 1, being known, the pressure per pile on piles in any other row can be found graphically by laying off to any convenient scale through the point where V must be applied in order to produce equal pressures on all piles the average pressure per pile as given by formula (2), and in its proper position the known pressure per pile, and drawing a straight line through the extremities of these two values. A study of Fig. 2 will best elucidate the details of the procedure.

If it is found by investigation that some of the piles are in tension, that is, if a pull is being exerted on them, and if it is thought that this pull is too great, the problem should be gone over again, the piles on which the pull is beyond the allowable limit being ignored, as a decrease in the number of piles acting will sometimes materially increase the pressure on the piles farthest away from those in tension.

IN MEMORIAM

JAMES T. BRANSFIELD, M. W. S. E.

Born Jan. 1st, 1860. *Died Jan. 21st, 1915.*

Mr. Bransfield was a good example of the self-made engineer. Born at Sparta, Wisconsin, in 1860, he acquired his early education in the village school and at the age of 18 entered the service of the C. & N. W. Ry. as rodman, and continuing in the service for eight years, arose to the position of Assistant to the Division Engineer. In 1886 we find him in Alaska on a mining proposition. From 1887 until 1893 he was engaged with varying success in the contracting business. From 1893 until 1900 he was employed by the Sanitary District of Chicago as instrument man and in charge of construction. From 1900 to the date of his death he was engaged in contracting in the vicinity of Chicago, being associated most of the time with the W. J. Newman Company and attaining considerable success.

Mr. Bransfield was a man sincere in his friendships and loyal to his associates in business. His many friends will regret the early termination of his career.

He was elected a member of the Western Society of Engineers on April 15th, 1899. He was also a member of the Maccabees and of the Modern Woodmen of America.

LINDON W. BATES, JR., M. W. S. E.

Memorial services for Lindon Wallace Bates, Jr., who met his death by the sinking of the "Lusitania" on May 7th, were held at the Fifth Avenue Presbyterian Church in New York City, Thursday evening, June 10th, and were attended by representatives of the Western Society of Engineers.

Mr. Bates, who was born in Portland, Oregon, July 17th, 1883, and who consequently had not reached the age of thirty-two, had had a very remarkable career.

In his youth he attended the North Side High School in Chicago and subsequently the Harrow School in England and from the latter went to Yale University, where he was graduated in 1902. Immediately after graduation he went into engineering work with his father and was engaged in the Galveston grade-raising and on the New York Barge Canal. He later became the consulting engineer of the Western Engineering Corporation and of the Denver Mining Investment Company and was the American

Memoir Prepared by Isham Randolph and W. T. Keating, Committee.

manager of the Laguintos Oil Company, Maikop Areas, and Trinidad Cedros Oil Company.

In 1896 he traveled in Russia and in 1900 he went on an exploring and hunting trip to the islands north of Hudson Bay. In 1904 he visited Panama and in 1908 he made a midwinter sledge journey through Siberia and Mongolia. In 1911 he went to Venezuela and made a trip up the Orinoco.

The same year he was elected a member of the New York Assembly and was the author of condemnation and civil service reform measures, direct nomination and employers' liability bills.

He was a member of the New York County Committee from 1908 to 1911.

Mr. Bates was appointed by Mayor McClellan one of four engineers to report on the Catskill Aqueduct Tunnel; by Governor Hughes, a member of the National Conservation Congress. He was a member of the Western Society of Engineers, a Junior Member of the American Society of Civil Engineers, a member of the Societe Belge des Ingenieurs et des Industriels, and the Harrow

Association. He was a member of the City, Lawyers, Republican and Yale Clubs.

As an author he won high repute by his writings. "The Political Horoscope" (with Charles A. Moore, Jr.) in 1904; "The Loss of Water in New York's Distribution System," 1909; "The Russian Road to China," 1910; and "The Path of the Conquistadores," 1912, were all able works. Besides these he was an extensive contributor on technical and economic subjects.

At the creation in London of "The Commission for Relief in Belgium," he was put upon its executive board without any consultation with him. The execution of the work to be done called for the highest order of organizing and executive efficiency and disinterestedness in service which would sacrifice personal interests, and it was a remarkable tribute to a man of thirty-one that he was named on the first executive committee.

He remained in the United States for a time organizing the office staff, the accounting and purchasing systems, the interrelations of the women's section and of the state committees, the personnel, the interior assembling depots, special express and postal arrangements, and all the machinery for conducting successfully a stupendous task.

His organization has remained and has proved its adequacy. It is said that when there were delicate negotiations to be carried on he was usually the ambassador of the commission and usually successful. He was traveling on the business of the commission when he met his death.

One of his friends has written, "Perhaps the most beautiful quality in his nature was his companionableness to all men. The numbers who have followed his personal destinies, who have clung to him in his ups and downs, in good and bad political fortunes, are known. His father had spent many years abroad, but for every need the son knew some individual, tried and not found wanting."

His last moments are recorded in a report made by the chairman of the Belgian Relief Commission in London, which said, "After the torpedo struck the Lusitania Mr. Bates was on deck with Major and Mrs. Pearl, of New York City, whom he had known before sailing.

Some of the Pearl children were below, and Mr. Bates went down to search for and bring them up. He groped his way down the stairs and into the dark, but the waters had risen to where he could go no farther, so he returned to the deck. By that time the ship was sinking rapidly by the bow; the confusion and anguish were dreadful among the passengers. He called to all within hearing to come to the stern, where the last chance lay.

He helped the women and children along the slippery, precipitous deck, and just before the end stripped off his own life-belt and gave it to a woman.

When the end came the calm group stood by the side of the ship. They were Mr. Bates, Herbert Stone, Madam De Page and Dr. Houghton. All three of the men had taken off their life-belts and gave them to the women. Lindon Bates, Jr., took off his overcoat, and as the ship made her final plunge all four members of the little group dived. Neither Lindon Bates, Jr., nor Herbert Stone was seen again.

June, 1915

BOOK REVIEWS

THE BOOKS REVIEWED ARE IN THE LIBRARY OF THE SOCIETY.

THE ECONOMICS OF CONTRACTING, Vol. II. A Treatise for Contractors, Engineers, Manufacturers, Superintendents and Foremen Engaged in Engineering-Contracting Work. By Daniel J. Hauer, Editor of The Contractor. E. H. Baumgartner, Chicago, Ill., 1915. Cloth; 6 by 9 in.; pp. 334; 27 ill. Price $2.00.

Mr. Hauer is a consulting engineer specializing in general contracting work. He is also editor of *The Contractor*, and has been known for many years to readers of such papers as *The Dirt Mover*, *The Contractor* and *Engineering and Contracting,* his writing being of a nature to appeal to men on the job. The present volume is the second having the same title. The books contain, with some additions, articles of a practical nature on the many problems confronting contractors, which have appeared in the pages of *The Contractor*.

The attempt of the author is to expedite the gaining of experience in a line of work which hitherto had no text books and no professors. It is well worth the reading of all men engaged in contracting work and should be of considerable value to young engineers contemplating taking up general contracting. The following table of contents merely hints at the valuable information given by the author: Chapter I, Estimating and Bidding upon contracts. Chap. II, Making contracts and obtaining bonds. Chap. III, The financial end of contracting. Chap. IV, Preventing lawsuits and legal aspects of contracting. Chap. V, Planning construction jobs. Chap. VI, Handling and training men. Chap. VII, Office filing systems. Chap. VIII, Organization of a construction company. Chap. IX, Lines of contracting and specialization. Chap. X, The standing of contractors. Appendix A, By-Laws for a construction company.

McC.

ENGINEERING OFFICE SYSTEMS AND METHODS. By John P. Davies, M. E. McGraw-Hill Book Co., New York, 1915. Cloth; 6 by 9 in.; 544 pp.; 243 ill. in text. Price $5.00.

The author had many years experience as an office engineer in engineering companies doing work all over the world. He made a collection of "reminders" which grew until the necessity for a convenient arrangement of a permanent nature suggested the preparation of a book. It contains a veritable mine of information on all the phases of office work in the offices of engineers and construction companies. It deals with the collection and arrangement of preliminary information; preparation of specifications; testing materials; domestic and export shipping; consular papers, etc. He deals well with office drafting and filing systems and the collecting and indexing of information; proper organization and arrangement of offices. On the whole, the author has done his work well and the book can be commended to those who must often in a very short time decide matters which otherwise should be decided by more experienced men. It deserves a place in the reference library of every engineer.

McC.

PROCEEDINGS OF THE SOCIETY

MINUTES OF MEETINGS.

Regular Meeting, June 7, 1915.

A regular meeting (No. 905) was held Monday evening, June 7, 1915, in the Society rooms, convening at 8 p. m.

The meeting was called to order by Vice-President McCullough, with about 85 members and guests in attendance.

The Secretary reported from the Board of Direction that at their meeting, held that afternoon, the following applications for admission into the Society had been presented:

John A. Dailey, Chicago.
Samuel G. Artingstall, Jr., Chicago.
William A. Goss, Madison, Wis.
James A. Cook, Chicago (Transfer).
Homer Ward Deakman, Champaign, Ill.
Albert L. Wallace, Chicago (Transfer).
Roy Arthur Nelson, Chicago.

Also that the following had been elected into the Society:

Stanley Edward Bates, Chicago....Associate Member
John W. Lowell, Jr., Chicago....Associate Member
Verne S. Lawrence, Logan, Iowa....Junior Member
Robert Smyth Adams, Chicago....Student Member
Eugene E. Altman, Chicago....Student Member
John W. Baring, Chicago....Student Member
Charles L. Bolte, Chicago....Student Member
Joseph C. Dolan, Chicago....Student Member
Ellis S. Echlin, Chicago....Student Member
David M. Goe, Chicago....Student Member
James F. Hillock, Chicago....Student Member
John Jucker, Jr., Chicago....Student Member
John R. Le Vally, Chicago....Student Member
Emmet R. Marx, Chicago....Student Member
Victor E. Marx, Chicago....Student Member
Lawrence J. McHugh, Chicago....Student Member
Franklin L. Pond, Chicago....Student Member
Herman N. Simpson, Chicago....Student Member
George J. Trinkous, Chicago....Student Member
Samuel E. Sosna, Chicago....Student Member
George B. Perlstein, Chicago....Student Member
C. Arnold Grasse, Chicago....Student Member
Henry Wilkens, Chicago....Student Member
Herbert P. Sherwood, Chicago....Student Member
Guy F. Wetzel, Chicago....Student Member
Robert F. Havlik, Aurora, Ill....Associate Member
Edwin G. Birren, Chicago....Student Member
Henry C. Wendorf, Chicago....Associate Member
Thure W. Ingemanson, Chicago....Student Member

The Secretary reported that Lindon Bates, Jr., of New York, a member of this Society, had been lost by the sinking of the Lusitania, and that it was in order to have a memoir of him prepared for publication in our Journal. The Chairman said a Committee for such work would be appointed. Also that a notice had been received that memorial services would be held in the Fifth Avenue Presbyterian Church, New York City, the evening of June 10. The Secretary was authorized to write to some of the members of the Society in New York, informing them of these memorial services, and asking them if they could do so to attend as representing the Society.

Mr. C. M. Wirick of the Crane Technical High School was introduced, who said he desired to get some information from engineers relative to the study of chemistry and its use to them in their professional work. Some discussion followed, showing in general that engineers appreciate the advantage which follows even a brief study of chemistry.

The Chairman then introduced Mr. Walter D. Moody, Director of the Chicago Plan Commission, who addressed the meeting on "The Present Status of the Chicago Plan." Many beautiful stereopticon views were shown in illustration. Meeting adjourned about 10 p. m., when refreshments were served.

Extra Meeting, June 21, 1915.

An extra meeting (No. 906), a joint meeting of the Electrical Section, Western Society of Engineers and the Chicago Section, American Institute of Electrical Engineers, was held Monday evening, June 21, 1914, convening about 8 p. m., with Mr. E. W. Allen presiding and about 65 members and guests in attendance. Mr. Allen announced for the A. I. E. E. that the election of three members of the Executive Committee by postal card ballot had been held and the results showed that William J. Norton was elected Chairman, T. Milton, Secretary, and E. W. Allen as a member of the Executive Committee to serve three years. Mr. H. B. Gear was then introduced, who addressed the meeting on "The Application of the Diversity Factor." Discussion followed from Messrs. E. N. Lake, P. Junkersfeld, J. R. Cravath, W. J. Norton, T. Milton and W. B. Jackson, with a closure from Mr. Gear. Mr. Allen stated that the annual meeting of the A. I. E. E. would be held next week (June 29-July 2, 1915) at Deer Park, Maryland. The meeting adjourned at 9:20 p. m., when refreshments were served.

Extra Meeting, June 24, 1915.

An extra meeting of the Society (No. 907), in the interests of the Bridge and Structural Section, was held Thursday evening, June 24, 1915. This was the adjourned meeting from June 14th, when the street car troubles prevented the holding of the usual meeting.

The meeting was called to order by Mr. H. C. Lothholz, Chairman of the Section, at 8 p. m., with about forty members and guests in attendance. The Chairman introduced Charles N. Bainbridge, Assoc. M. W. S. E., who presented his paper, "A Study of Grade Crossing Elimination in Cities." A written discussion of the subject prepared by Mr. E. N. Layfield was read by Mr. N. M. Stineman in the absence of the author. Discussion followed from Messrs. E. T. Howson, Ernest McCullough and Walter S. Lacher. Meeting adjourned at 9:40 p. m.

Extra Meeting, June 28, 1915.

The last meeting of the season (No. 908) of the Western Society of Engineers, a Smoker, was held on June 28th, 1915, at 8 p. m. The program had been placed in charge of the Entertainment Committee, no schedule being given beforehand, and each number elicited merited applause. The meeting was conducted by the Chairman of the Entertainment Committee, Mr. E. H. Lee, Past-President, with the assistance of the other members of the committee. There were 210 members and guests in attendance.

Mr. J. A. Rossiter entertained the meeting with a talk on the Philippine Islands, illustrated by about 125 colored lantern slides.

Two reels of comic pictures were shown, and between the numbers of the program songs were sung by the audience and the meeting was entertained with stories by a professional entertainer.

Mr. Norman M. Stineman displayed some lantern slide views of original cartoons of familiar items of Society news, the cartoons illustrating the work of the Entertainment Committee being especially popular.

The meeting was opened by the members indulging in an opening smoke from accessible supplies of clay pipes and tobacco.

The meeting adjourned at 10:15 p. m., after which refreshments were served.

J. H. WARDER, Secretary.

LIBRARY NOTES

The library committee desires to return thanks for donations to the library. Since the last publication of the list of such gifts, the following publications have been received:

NEW BOOKS.

John Wiley & Sons:

Materials of Construction, A. P. Mills. Cloth.

E. H. Baumgartner:

Economics of Contracting, Vol. II, D. J. Hauer. Cloth.

McGraw-Hill Book Co.:

Purchasing, C. S. Rindsfoos. Cloth.

Technical Publishing Co., London:

Engineering Problems, W. M. Wallace. Cloth.

MISCELLANEOUS GIFTS.

Universal Portland Cement Co.:

Annual Reports, Ohio State Highway Commission, 1908, 1910-11-12.
Report of State Road Commission, Maryland, 1908-09-10-11.

E. C. Carter, M. W. S. E.:

Kentucky Geological Survey, Series IV, Vol. I, Parts I and II.

Philadelphia Bureau of Surveys:

Report on the Collection and Treatment of the Sewage of Philadelphia, 1914. Cloth.

Chicago Railway Terminal Commission:

Preliminary Report, March 29, 1914. Pam.

C. M. Spofford:

Report of Special Committee on Study of the Local Real Estate Assessment Situation, Cambridge, Mass., March 25, 1915. Pam.

EXCHANGES.

Canada Department of Mines, Geological Survey:

The Basin of Nelson and Churchill Rivers. Pam.
Geology of Franklin Mining Camp. Paper.
Museum Bulletins Nos. 11, 12, 13. 3 pams.
Coal Fields and Coal Resources of Canada. Paper.
Coal Fields of Manitoba, Saskatchewan, Alberta and Eastern British Columbia. Paper.
Preliminary Report on the Clay and Shale Deposits of the Province of Quebec. Paper.

Canada Department of Mines, Mines Branch:

Petroleum and Natural Gas Resources of Canada, Vol. I. Paper.

Canada Commission of Conservation:

The National Domain in Canada and Its Proper Conservation. Pam.

Canada Department of the Interior:

Treated Wood-Block Paving. Pam.
Wood Using Industries of the Prairie Provinces. Pam.

Association of Ontario Land Surveyors:

Annual Report and Proceedings for 1915. Paper.

June, 1915

Institution of Engineers and Shipbuilders in Scotland:
Transactions, 57th Session, 1913-14. Cloth.

Victorian Institute of Engineers:
Proceedings, Vol. XIII, 1914. Cloth.

West Virginia Geological Survey:
County Reports, 1915, Boone County. Cloth and Box of Maps.

Wisconsin Geological and Natural History Survey:
Limestone Road Materials of Wisconsin. Cloth.

Ohio State Geological Survey:
Building Stones of Ohio. Cloth.

University of Illinois Engineering Experiment Station:
Bulletin No. 78, A Study of Boiler Losses, A. P. Kratz. Pam.

New York Public Service Commission, Second District:
Seventh Annual Report, 1913, Vols. I, II, III. Cloth.

Iowa Engineering Society:
Proceedings, 26th Annual Meeting, 1915. Paper.

National Association of Cotton Manufacturers:
Transactions, 1914. Boards.

Maine Society of Civil Engineers:
Proceedings, 1914. Paper.

Board of Supervising Engineers, Chicago Traction:
Sixth Annual Report for Year ending January 31, 1913. Cloth.

Illinois Society of Engineers and Surveyors:
Proceedings, 30th Annual Meeting, 1915. Paper.

Journal of the

Western Society of Engineers

VOL. XX SEPTEMBER, 1915 No. 7

On April 19th, 1914, Alfred Noble, Past President of the Western Society of Engineers, Past President of the American Society of Civil Engineers, Past President of the American Institute of Consulting Engineers, Honorary Member of the Institution of Civil Engineers of Great Britain and the worthy recipient of many other honors both at home and abroad, died at his home in New York.

A joint committee of the Western Society of Engineers, The American Society of Civil Engineers, The American Society of Mechanical Engineers, The Franklin Institute and the American Institute of Consulting Engineers, was appointed to prepare a memoir of Mr. Noble, and this joint committee in turn appointed three of its members as a sub-committee to prepare the memoir. This sub-committee was composed of Mr. Ralph Modjeski, chairman, Mr. Onward Bates and Mr. Isham Randolph, and the memoir prepared by them is published in this issue of the JOURNAL.

Another joint committee is arranging for the placing of a bronze statue in one of the public squares in the City of Washington.

The Western Society of Engineers is proud of the history of its membership and its officers, which include many of the most distinguished and honored engineers of the nation, and is proud to point to Alfred Noble as a conspicuous member of its honored group of Past Presidents.

While the achievements of Alfred Noble were international and the results of his work belong to the world, the Western Society of Engineers feels that in a peculiar sense he belongs to them. He was born and educated in the West, and his early engineering triumphs were in the West. He was elected Second Vice-President of the Western Society of Engineers in 1896, First Vice-President in 1897 and President in 1898. During these three years the Society was in a distinctly formative period of its history, and the influence of Alfred Noble was deeply impressed upon the Society. The publication of the JOURNAL was begun and the finances of the Society established on a firm basis.

ALFRED NOBLE

ALFRED NOBLE, PAST-PRESIDENT, W. S. E.*

Died April 19th, 1914.

Our America, America of the Twentieth Century, enlightened, progressive, prosperous beyond any other country of the world, would not be what it is to-day if it had not brought forth an army of engineers, an army small in numbers but mighty in accomplishment, always in the van of progress, making plain the highways of development in which the multitude marches on to attainments ever higher and higher.

The work of this little army has never had just recognition, and these who have wrought the victories of peace tread the quiet paths of life and pass out of it, leaving behind works of enduring usefulness without having recorded upon such works in time-defying bronze or graven stone even their names. Not so with the army, which with trumpets blaring and flaunting banners marches into the "imminent deadly breach" and reaps a harvest of death and a halo of glory. There is scarcely a city or town in these United States which has not reared a monument to some military hero or some group of the rank and file whose support lifted the hero to the plane of public admiration.

The great and good men of our profession are living their useful lives without a thirst for fame, doing the duty at hand faithfully and well, and passing resolutely on to the next which presents itself.

This was the history of Alfred Noble, who, on April 19th, 1914, peacefully ended a useful life. A life so honorable, so kindly, so full of achievement that we delight to honor his memory, and would in some enduring way chronicle the deeds which have so eminently earned for him the love and admiration of his fellow-engineers. We, who thus delight to do him honor, are members jointly and severally of the Western Society of Engineers, the American Society of Civil Engineers, The Franklin Institute, The American Society of Mechanical Engineers, and the Institute of Consulting Engineers. Ours is a common loss, a community of feeling, and unitedly we record our appreciation of the man, the engineer, and the faithful friend. His were the simple homely virtues of truth, honesty, industry, and human kindness. Upon the solid foundation of sterling character he reared the superstructure of a splendid manhood, the story of which we would perpetuate, not only to do him honor, but to hold up to the men who come after us a worthy example of a professional career to be emulated.

*Memoir prepared by a Sub-Committee (composed of Ralph Modjeski, Onward Bates, and Isham Randolph, Members W. S. E.) of a Joint Committee appointed by the Western Society of Engineers, the American Society of Civil Engineers, The American Society of Mechanical Engineers, The Franklin Institute, and the American Institute of Consulting Engineers.

September, 1915

In an old family Bible it is recorded that on August 7th, 1844, a son was born to Charles Noble and Lovina Drew, his wife, at Livonia, Wayne County, Michigan. This son received the Christian name of Alfred. The child grew and waxed strong in body and in mind, and in those early and impressionable years no doubt the teachings of his mother helped to mould the character which commanded the respect and admiration of all those with whom he came in contact. She is described as being a "Woman of remarkable qualities, self-reliant, precise, austere, pious—New England type." Many of Alfred Noble's best traits were due to her training.

Our land can never pay its debt to the Christian mothers, who have gone to their rest, and its hope must still hang upon Christian mothers living and yet to come.

The concise chronicle before us goes on to say of his "early life and education":

"Spent on his father's farm until the age of eighteen. Helped his father and brothers in the arduous work of clearing, draining, and cultivating land in the new Michigan Country. Meanwhile, obtained education at the district school, beginning attendance when four years old. His three brothers all died young. When old enough to ride a horse he attended the Union School, at Plymouth, Mich., where most of his early education was gained. Of studious disposition, learning rapidly and thoroughly, according to his old Teacher, Dr. Frisbie."

This is all we have from the family record, to which tradition contributes nothing, and the only side light we have is from the pen of Judge Edgar O. Durfee, of Wayne County, Michigan. He writes (May 27th, 1914):

"I have known Alfred Noble as long as I have known anybody. His farm home was about a mile from the farm on which I was brought up, and I saw him very often. Some of the time we attended the same district school, and the winter of 1861 attended the graded school in Plymouth, where we were in the same class in higher algebra. From his earliest school days he always excelled in all of his studies. He was very studious, and as a boy was the same as a man, always truthful and always lived up not only to the letter but to the spirit of his promises."

Scant as is this record of the first eighteen years of his life, it is sufficient to show "the boy as the father of the man."

We have now reached the war period, and the record says:

"On August 9th, 1862, two days after his eighteenth birthday, he enlisted in Company C, 24th Michigan Volunteers. Before doing so, however, obtained the consent of his mother, who opposed his going, but who withdrew her opposition on his declaration that he felt it his duty to enlist."

Here let us interpolate from Judge Durfee's letter:

"One little thing illustrates his character in that regard [loyalty to truth]. He was eighteen years old on the seventh day of August, 1862, on which day he enlisted in Company C, Twenty-fourth Michigan Infantry. His mother was thoroughly imbued with the idea that card playing was the greatest vice in the army—although we of the rank and file learned that the games played there were only euchre and old sledge. She asked him not to play cards, and he promised her he would not play cards while in the army. He lived up to this promise strictly, although he watched the boys play and learned more of cards than most of them, and as much as any of them."

The Judge gives his estimate of Mr. Noble thus:

"I think he was the best boy and man I ever knew, taking him all in all. He was very quiet, not given to boasting, was a warm friend, and had as fine a sense of humor as any person I ever knew. I am sure that everybody who came in contact with him as a boy and man was his friend."

Once more we quote from the scant outlines afforded by the record:

"The regiment (24th Michigan Infantry) was raised principally in Wayne County, following Lincoln's call in June for 300,000 volunteers. It was one of the first regiments composing the 'Iron Brigade', so called by General Hooker for its behavior at the battle of South Mountain. The regiment, being drilled for a time, did not participate in that battle (South Mountain), but arrived at the front in time to get into action at Fredericksburg in December. From that time until February, 1865, Alfred Noble took part in all of the principal engagements of the Army of the Potomac. At Gettysburg his brigade bore the brunt of the first day's fighting, and in particular his regiment lost 80 per cent of its number. Although compelled to retire because of greatly superior numbers, the resistance of the 'Iron Brigade' on that occasion is generally credited with saving the Union position and making possible the final victory on the third day, on which the result of the entire war hinged. Alfred Noble was never wounded during the war, but at one time was very ill in the hospital, and considered that he owed his recovery to the ministrations of the Sisters of Charity. He was mustered out of service with his regiment in June, 1865, with the rank of sergeant, having acted as orderly at corps headquarters for a period of five months.

"He kept a diary during the war and throughout the rest of his life. Thus is told, in a statement of about 225 words, the story of his young soldier's life during nearly three years of marching, fighting, and enduring, a fraction of one word of each of these 1,000 days of stress, hardships, and danger. We long for a glimpse of the diary that he kept during the period when our country was fused in the 'melting pot' of war."

James H. Brace, M. W. S. E., in his personal reminiscences of Mr. Noble, says:

"In the long twilight after supper, Mr. Noble could sometimes be induced to talk of his war experiences. He was very reluctant at all times to discuss this subject. He seemed to believe that it was every good citizen's duty to serve, then when the war was over, go about his regular business as though nothing had happened; that the country owed him nothing for his services, and that there was no good in keeping up the old spirit."

Eugene W. Stern, says:

"As you know, Mr. Noble was very loath to speak of his war experiences, and it was during the course of the last three years of rather close acquaintanceship with him that from time to time I was able to glean a few incidents. It appeared to me that he wanted to forget the Civil War. The humorous side he was more inclined to dwell upon. He never wore a Grand Army button, to my knowledge. He told me the following incidents:

"Some years ago, when he was Resident Engineer on the Memphis Bridge, a man wearing a Grand Army button, claiming to have been a Colonel or Brigadier General during the war, came to see Mr. Noble about some matter or other in connection with some material he was selling. 'He told me,' said Mr. Noble, 'that he had been at Chancellorsville, and mentioned a certain incident which I knew did not agree with the facts, which I told him. He seemed rather astonished at my information on this point, and asked me how I knew, and I told him that I was there. He asked me to what Army Corps I belonged, and what rank I held. 'I am the last surviving member of it,' I said. He seemed curious to know, and I replied, 'The great Corps of Privates.'"

Mr. Stern says, further:

"On another occasion, in talking with him about the requisite qualities of a good soldier, he said, 'Ability to withstand hunger, fatigue, and hard marching, were very essential qualities, but to be a good runner was also often a very useful attribute.'"

We know that, youth though he was, he served his country as a fighting man for three long years, and emerged from the ordeal of war uncontaminated by its demoralizing influences and conscious in his modest estimate of himself, that he was capable of service to his country and his kind in the more congenial paths of peace.

As we know, he chose for himself a career which he had to enter through the door of educational preparation. How he went about it is briefly told in the skeleton record of facts to which we must frequently refer.

"From July, 1865, to September, 1867, he held a clerical position in the War Department at Washington (Adjutant General's Office). During this time he saved his earnings and prepared himself, with the help of private tutors, to enter college, with such industry that in the fall of 1867 he entered the University of Michigan as Sophomore in the class of '70. Among his classmates were Justice William R. Day and Judge Rufus H. Thayer, of Washington, D. C. He was a member of the Alpha Delta Phi fraternity, and became vice-president of his class in his Junior year. While an undergraduate, he was absent a year and a half in Government employ, acting as recorder with the United States Lake Survey, and kept up his studies at the same time, taking his degree of C. E. in 1870."

Of this period Mr. Justice Day, writing under date of November 3d, 1914, says:

"It was my privilege to be a classmate of his in the University of Michigan, where we graduated together in the class of 1870. I have met him from time to time since, and have known of the great career which he has had in his profession, and am glad to know that it is the opinion of his associates that he was among the first engineers of this country.

"I well remember when Alfred Noble came to the University of Michigan, where he entered the Sophomore class in 1867. He was somewhat older than the rest of us, and, in my opinion, far more able than any of us. He had had three years' experience in the army, and those who knew him there said that he had been a faithful and valiant soldier. I do not think any of his classmates ever heard him speak of his army career. He probably regarded it as merely a part of his duty, and not a thing to be talked about."

We shall quote again from this letter in another connection.

As we leave this brief mention of his college career, we have no thought of derogating from the honor of any other graduate of that great seat of learning when we say that the proudest name upon its roster is that of Alfred Noble; and Ann Arbor can set before its students no higher professional inspiration than the story of Alfred Noble's life and work.

We have now reached the period when that life's work began in earnest, and the years that follow are full of action and achievement.

We turn again to the record, which reads:

"From June to September, 1870, he was engaged on harbor surveys on the eastern shore of Lake Michigan and the western shore of Lake Huron. In October, 1870, he was put in charge of the work at Sault Ste. Marie, Mich. In 1873 it was found necessary to build a new canal lock at the Sault and to dredge and straighten the channel of St. Marys River, and Alfred Noble was placed in charge of the work as U. S. Assistant Engineer under General Godfrey Weitzel, of the U. S. Engineer Corps. In this work, which occupied nine years, he practically designed and supervised the construction until completion of one of the present locks, known as the Weitzel Lock. This lock embodied new features that attracted the attention of engineers both at home and abroad. Most previous locks had been filled by admitting water through slides in the upper gates, and the water was released in the same way through slides in the lower gates."

It is appropriate here to quote from Mr. Joseph Ripley's letter under date of June 5th, 1914:

"The lock Mr. Noble built at the 'Soo' was named for Godfrey Weitzel. He always gave Mr. Noble full credit for his part in the work at the 'Soo.' (See Johnson's Encyclopedia, article on St. Marys Falls Canal, which was written by General Weitzel.) When the first boat, *The City of Cleveland*, was locked through to the Lake Superior level, the occasion was made quite an event, and about twenty engineer officers were present. Mr. Noble did not ride with the officers on the steamer, but stayed on the wall, watching locking operations. I heard Major (later General) Roberts, author of 'Roberts' Parliamentary Rules,' congratulate General Weitzel on the completion of the greatest lock in the world, a work which would be a great personal honor and give renown to General Weitzel personally and, through him, be credited to the Engineer Corps and add much prestige to it. General Weitzel replied that 'Alfred Noble deserved all of the credit for designing and building the lock.' * * *

"When General Sherman made a tour of the Western forts, Mr. Noble was directed by General Weitzel to meet the party on arrival at the 'Soo' and to show them about the lock work. Mr. Noble delegated his assistant, Mr. Davock, to meet General Sherman while he (Mr. Noble) went up to the head of the canal and stayed there all day, so as not to put himself at all forward in the presence of so notable a man."

These are two instances of the modesty which clothed the man like a distinctive garb; but the last one raises the question, is modesty a justification for disobedience of orders? General Weitzel ordered Mr. Noble to meet General Sherman; that order was disobeyed. This, however, is the only instance of insubordination of this man who respected rightful authority and honored the law.

On May 31st, 1871, he married Miss Georgia Speechly, of Ann Arbor, Mich. One son survives this union, and truly Frederick C. Noble has a proud heritage in his father's name and fame. Of his married life we, who compile this memoir, have no record, nor is it essential or even appropriate that we should have; but we know that Alfred Noble maintained in the seclusion of his family life the same true and admirable character that is known to us in his career.

From now on we will not follow step by step the upward strides which he made, until he reached the highest distinction which could come to any man in the engineering profession, any further than to note the date and the character of each attainment in usefulness and honor; but we will make a part of our presentation letters from distinguished men whose association with him peculiarly fitted them to record their appreciation of his work.

Enters Railroad Work in West.—In August, 1882, the canal being practically finished, he resigned from the Government service to become Resident Engineer on the construction of a railroad bridge across the Red River at Shreveport, La., the late L. G. F. Bouscaren, Chief Engineer. In March, 1883, he resigned this position to accept a similar one on the Northern Pacific Railroad, then nearly completed as to track laying, on the construction of a bridge across Snake River, at Ainsworth, Washington Territory, the late General Adna Anderson, Chief Engineer. In September he was put in charge also of the replacement of a timber bridge over Clark's Fork of the Columbia, near Belknap, Mont. Both bridges were completed about the middle of the following year. In September he was put in charge of the construction of foundations of a high trestle across Marent Gulch near Missoula, Mont.; and in October of the foundations of a bridge across St. Louis Bay at Duluth, Minn. The Marent Gulch Viaduct was completed in June, 1885, including superstructure and new foundations. The St. Louis Bay Bridge was completed in May, 1885, according to original plans, and the construction of an additional draw-span was started in July. From August to October of this year was spent at Trenton, N. J., inspecting the ironwork for the draw at the shops, and from October to the following January, 1886, he was supervising its erection. In February, 1886, he was in New York City, in the office of George S. Morison. During March and April, he was inspecting bridge manufacture at Buffalo, and in May was inspecting iron at Pottsville, Pa. He then returned to New York in June. He visited Omaha Bridge in July, and then went to St. Paul for temporary duty with the Northern Pacific Railroad as Acting Principal Assistant Engineer. In September he went to Pittsburgh to inspect ironwork.

Washington Bridge.—In October, 1886, he resigned to accept an appointment as Resident Engineer of the bridge across the Harlem River at 181st Street, New York City, since known as the Washington Bridge. Mr. Hutton was Chief Engineer.

Cairo Bridge.—In July, 1887, he resigned to accept an appointment as Resident Engineer of the Illinois Central Railroad bridge over the Ohio River at Cairo, Ill., George S. Morison and Elmer L. Corthell, Chief Engineers. This bridge was opened for traffic on October 29th, 1889.

Memphis Bridge.—In November, 1889, he assumed charge, as Resident Engineer, of the railroad bridge over the Mississippi River at Memphis, Tenn, George S. Morison, Chief Engineer. This bridge was opened for traffic in May, 1892.

Partnership with Mr. Morison.—On the completion of the Memphis Bridge he entered a limited partnership with Mr. Morison in Chicago, which lasted until April 30th, 1894. During this term he was Assistant Chief Engineer of the bridge across the Mississippi at Alton, Ill., and of the bridges across the Missouri at Bellefontaine, Miss., and Leavenworth, Kans.

Enters Private Practice.—On the expiration of the partnership, in April, 1894, he established an office in Chicago and entered general practice as Consulting Engineer. During the first two years of his practice he was connected with various constructions, including the regulating works of the Chicago Main Drainage Channel, a power canal at Sault Ste. Marie, the foundations of a bridge across the Harlem River, New York City, foundations of office buildings in the lower part of Manhattan Island, and a wharf at Tampico, Mexico.

In April, 1895, he was appointed by President Cleveland as a member of the Nicaragua Canal Board. The board visited Central America, examined both the Nicaragua and Panama Canal routes, returned to the United States, and completed its work in November, 1895.

In July, 1897, he was appointed by President McKinley a member of the United States Deep Waterway Commission, to make surveys and estimates of cost for a ship canal from the Great Lakes to deep water in the Hudson river.*

In June, 1899, he was appointed by President McKinley as a member of the Isthmian Canal Commission, which was charged with the determination of the best canal route across the Isthmus. The Commission visited Europe, examined the data relating to the Panama Canal collected in the office of the French Company, in Paris, and visited the Kiel, Amsterdam, and Manchester Ship canals.

In the spring of 1898 he was appointed by William R. Day, then Assistant Secretary of State, as arbitrator in a dispute between a citizen of this country and the Government of San Domingo. He visited that Republic, returning to New York a few days before the declaration of war with Spain.

In the fall of 1900 he was appointed a member of an engineer board to advise the State Engineer of New York concerning the plans and estimates for a barge canal across that State.

In November, 1901, the city authorities of Galveston, Texas, appointed him as a member of a board of engineers to devise a plan for protecting the city and suburbs from future inundations. This board reported a plan involving the building of a solid concrete wall more than 3 miles in length and 17 ft. in height above mean low water, the raising of the city grade, and the making of an embankment adjacent to the wall, the whole to cost about three and a half millions of dollars.

In November, 1901, Mr. Noble formed a partnership with Ralph Modjeski, Past-President, W. S. E., for the purpose of engi-

*Engineering Record, April 25th, 1914, p. 466.

neering the Thebes Bridge over the Mississippi River at Thebes, Ill.; and the corporation representing the several interests, for which that bridge was to be built, engaged these gentlemen, thus associated jointly, to design and build that bridge. From that time until January, 1905, Mr. Noble, without neglecting any of the other great engineering works with which he was identified, devoted a great deal of time to this bridge, one of the most massive and imposing of the many now spanning the Father of Waters.*

From 1902 to 1909 Mr. Noble was Chief Engineer of the East River Division of the New Division of the New York extension of the Pennsylvania Railroad, and was in entire charge of this most difficult piece of work, involving as it did a very accurate survey across Manhattan and the constructon of the foundations of the Pennsylvania Station of the land tunnels and of the East River Tunnels.

In 1905 he was appointed by President Roosevelt a member of the International Board of Consulting Engineers for the Panama Canal. This board was commissioned to advise the President and the Congress of the United States concerning the type of the canal. Its work has passed into history, and the lock canal across the Isthmus is to-day a monument to the wise counsels of five Americans who, through a minority report, convinced the President and the Congress that a sea-level canal should not be considered. Of the membership of that board all but Alfred Noble survive, and each of the twelve survivors is ready to bear testimony to the splendid work which he contributed to the labors of the board and to recognize the potency of his influence in bringing about the results, of which, as a people, we are proud to-day.

Nor did his work in connection with the Panama Canal end with the life of that Board of Consulting Engineers, for his advice was later requisitioned in connection with vital problems in its construction, such as Gatun Dam and the lock foundations.

During the four years, from January, 1910, until the time of his death in April, 1914, Mr. Noble's work in private practice covered a broad field. He was called on for advice twice by the United States Government and twice by the Canadian Government, he was twice employed by the City of New York as consulting engineer, and acted as consulting engineer for various corporations, reporting on ten different water-power projects. All of the foregoing involved careful studies in what is commonly referred to as the theoretical side of engineering. An evidence of the breadth of his experience is the fact that during the same time he was employed on nine different occasions by contractors on large construction works to advise them in regard to the so-called purely practical questions involved in carrying out their works.

In addition to all of the above, he found time during this period to undertake, in a public-spirited desire to benefit the profession, a

*For fuller details see appendix.

large number of gratuitous tasks, such as serving on various committees. The amount of time and labor which he gave to this work was very great, amounting to about one-third of his total time. This will be appreciated only by those who were associated with him.

In behalf of the United States Government, he went to Honolulu to examine and report upon the Pearl Harbor Dry Dock. He spent several months in making a study of this problem, in the very thorough manner which was one of his most notable characteristics, and submitted a voluminous report to the Secretary of the Navy.

After the completion of the plans for the New Welland Canal he was employed by the Canadian Government to report upon all the plans and the projects as a whole. His report on this work to the Minister of Railways and Canals was dated May 13th, 1913. He had, previous to this, advised the Canadian Government on the foundations for the New Quebec Bridge, after the fall of the old bridge and while the plans were being drawn up for the new structure just prior to the letting of the contracts.

He was engaged on New York City work from October, 1909, until his death. The city made use more particularly of his ability as an expert in tunnel matters, first, on the many miles of tunnel for the Catskill Aqueduct north of the city and the deep tunnels under the Boroughs of Manhattan and Brooklyn and the East River, and, secondly, on the subway tunnels, especially the four East River tunnels known as Routes 33 and 48.

The first of the water-power projects involved a study of the regulation of Lake Superior for the Michigan Northern Power Company. This problem covered four years of continuous work, and the report, filling three large volumes, is now filed with the International Waterways Commission. A surprisingly large proportion of this work was done by Mr. Noble personally; if he had a weakness, it was in this habit he had formed of doing possibly too much work himself.

He visited California twice to examine and report upon projects for the Big Meadows Dam for the Great Western Power Company, and gave a large part of his time, extending over a year, to the study of a power development on the Susquehanna River. He also made a study of an extension of the plant at Niagara Falls; a study of power possibilities on the St. Lawrence River; and a report on a plant at Grand Falls, New Brunswick.

Aside from the 160 million dollars, more or less, which will be the cost of the Catskill Aqueduct, and which he cannot be said to have passed upon as a whole, the value of the work referred to him for his judgment during the four years totals nearly 100 million dollars. This is mentioned only as giving some idea of the magnitude of the responsibilities which were placed upon him, and as an indication of the value placed upon his judgment.

It is almost past believing that all this work should have been performed by one man in 52 years; and that of those 52 years three were given to military service in time of war. Such a record attests the wonderful mental and physical power of the man, his steadfastness to duty, and his ability to endure the strain of such a life. There is enough in that record to have made several men great, had those activities been equally apportioned to them.

Now let us record the honors which he won so worthily and wore so modestly:

Honors Conferred—

President, Western Society of Engineers, 1898.
President, American Society of Civil Engineers, 1903.
Honorary Member, Institution of Civil Engineers, Great Britain, 1911.
President, American Institute of Consulting Engineers, 1913.
Degree of LL.D., University of Michigan, 1895.
Degree of LL.D., University of Wisconsin, 1904.
Awarded John Fritz medal for "notable achievements as a civil engineer," 1910.
Awarded Elliott Cresson medal of Franklin Institute for "distinguished achievements in the field of engineering," 1912.

Other Distinctions—

Member of Tau Beta Pi.
Chairman, Joint Conference on Uniform Methods of Tests and Standard Specifications for Cement, 1914.
Member of Special Committees of American Society of Civil Engineers, reporting on Uniform Methods of Tests of Cement, 1885 and 1912.
Presented general report on "Dimensions to be assigned, in any given country, to canals of heavy traffic. Principles of operating. Dimensions and equipment of the locks" to the XIIth International Congress of Navigation, at Philadelphia, 1912.
Member, Board of Managers, American Society of Mechanical Engineers, 1912-14.
Vice-President, Engineering Section, American Association for the Advancement of Science, Annual Meeting, 1914. (Died before he could serve; succeeded by F. W. Taylor.)
33d degree Mason.
Vice-President Engineers' Club of New York.
Director, American Highway Association, 1912-13.

Membership

Western Society of Engineers.
American Society of Civil Engineers.
American Society of Mechanical Engineers.
Canadian Society of Civil Engineers.
Institution of Civil Engineers.
American Institute of Consulting Engineers.

Permanent International Association of Navigation Congresses.
American Highway Association.
Engineers' Club of New York.
University Club of New York.
Century Club of New York.
Chicago Club.
Chicago Engineers' Club.
Alpha Delta Phi Fraternity.
Tau Beta Pi.
Various national and local scientific and economic organizations.

These all were his, but no word of his ever betrayed pride in their possession, although he prized every manifestation of the love, esteem, and honor with which his fellow-men regarded him.

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MARKED CHARACTERISTICS OF THE MAN.

Modesty.—We have spoken of his modesty, and would further emphasize it by a few quotations:

"Not the least of his great virtues was inherent modesty. * * * Not long after entering on his engineering work he was offered a professorship, under conditions which led him to look upon the offer with favor, but his friends of those days—of which I am proud to have been one—felt that Noble was destined to become an active participant in the great construction work of his profession, to a much greater extent than his natural modesty permitted him to admit, and fortunately our counsels prevailed."—(A. Mackenzie, Maj.-Gen. (*Retired*), Corps of Engrs., U. S. A.)

"While Mr. Noble undoubtedly understood and knew of his marked ability, he never appeared to realize that he excelled or to assert it, but had a quiet, unassuming, reserved and kindly personality which was most attractive."—(Joseph Ripley, M. W. S. E.)

"He was probably one of the most modest men in the profession, and never failed to accord to his chief all credit for the conception of the work and the principal administration of it."—(Prof. William H. Burr.)

"In his case, the boy was father to the man. He was modest, kindly, industrious, and capable, as boy and man."—(Justice William R. Day.)

Industry.—

"He always came to the office first and usually left last. No matter how some of us tried to be on the work ahead of him, we always found Mr. Noble there. * * * No work was too trivial or too irksome for him. Nothing was neglected or passed over."—(Ralph Modjeski, Past President, M. W. S. E.)

"Throughout the whole laborious operations of the first Isthmian Canal Commission, Mr. Noble bore his full share from the beginning to the end, and his services aided much in giving to the report its high value."—(Prof. William H. Burr.)

"His professional work upon this [Isthmian Canal] Commission was of a very high order. With untiring industry he mastered the details of every branch of the investigation, and then with sound judgment and judicial temperament he reached conclusions which could not be shaken. * * *

"My subsequent association with Mr. Noble, aside from the Panama Canal, related particularly to the hydraulics of the Great Lakes, and confirmed me in the conviction that, for the solution of any engineering problem involving long and careful analysis, he had no superior."—(O. H. Ernst, Brig.-Gen. (*Retired*), Corps of Engrs., U. S. A.)

"While at the 'Soo," Mr. Noble did the work of three or four expert engineers. He worked twelve to eighteen hours every day."—(Joseph Ripley, M. W. S. E.)

General Mackenzie says of him:

"So frankly honest was he, that his whole life was an open book from the time he quietly entered upon his chosen profession at the Sault. Ste. Marie Canal—while still a student—up to and through his career as a world-known master."

Ability to Handle Men.—

"His treatment of his subordinates was exceedingly kind without being lenient. Always ready to help with word of advice or to turn up his sleeves and join in the work if he saw he could help."—(Ralph Modjeski, Past President, M. W. S. E.)

"He chose his assistants with care, and required a great deal of them, although not as much as he demanded of himself. When he had once given a man his confidence, he was entirely willing to leave to him the carrying out of his instructions, and such suggestions as he made were always conveyed in a kind, generous manner, which made it a delight to talk over any point with him."—(Henry Goldmark, M. W. S. E.)

"When several hundred men were employed on the work [at the 'Soo'], he knew and called every one by name, and could tell the value of each man as a workman. He was always pleased to find any employe taking special interest in his work, and would cheerfully aid in furthering that interest by explanation, by teaching, or in other ways. * * * He was a great and most successful leader. It was no wonder that all his employees were loyal to him, willing to give the uttermost possible to acceptably serve him."—(Joseph Ripley, M. W. S. E.)

Cheerful Serenity and Kindly Humor.—

"With his great qualities and achievements, he had a gentle vein of humor that made him the most agreeable of companions."—Mr. Justice William R. Day.)

"He was not only the experienced professional man, but most gracious and invariably kindly in his relations with every member of the Commission. He was patient in times of difficulty, and frequently lightened the troubles of many unwelcome conditions by bits of quiet humor in which he was wont to indulge."—(Prof. William H. Burr.)

"During the trip there were some trying experiences from wind and weather, but throughout these, as well as during the sunshine, Mr. Noble displayed the same kindly good humor and thoughtful consideration for others that characterized all his relations with his fellowmen."—(James H. Brace, M. W. S. E.)

"Throughout these expeditions [Nicaragua and Panama] Noble's equanimity never for a moment deserted him. His sweetness of disposition and generosity of temper endeared him to all."—(O. H. Ernst, Brig.-Gen. (*Retired*), Corps of Engrs., U. S. A.)

Sense of Obligation.—

The largest obligation received loyal discharge from him, and the least was never forgotten nor neglected.

Ralph Modjeski says:

"Another characteristic incident: When Mr. Noble was going to Panama, he asked me to keep his club dues paid, 'For,' he said, 'I should not like to be posted as delinquent, and again I should dislike *not* to be posted if I deserved it."

Generosity.—

"He was generous. By accident I have learned of several instances where he has contributed considerable sums of money regularly for one or more years where employees have been injured, or who had dependent families sorely in need of assistance."—(Joseph Ripley, M. W. S. E.)

"He was most scrupulous and generous in money matters. Always ready and desirous to give more than he received, not only in money matters but in everything else."—(Ralph Modjeski, Past President M. W. S. E.)

Mr. S. H. Woodard says:

"In addition to all of the above, he found time * * * to undertake, in a public-spirited desire to benefit the profession, a large number of gratuitous tasks, such as serving on various committees. The amount of labor which he gave to this work was very great, amounting to about one-third of his total time. This will be appreciated only by those who were associated with him."

J. Waldo Smith, Chief Engineer, Board of Water Supply, New York City, says:

"He was generous and kindly, and more considerate of others than he was of himself. * * * I remember a little incident which occurred about a year ago, shortly before the change in the city's administration. He told me he could see that there was to be a strong cry for economy in all of the operations of the city, and that, whether it was advisable or not, strong pressure would be brought on our board for a reduction of expenses, and so he suggested that, as he was the last of the three Consulting Engineers to be appointed he would retire, in order that the others might not be disturbed. Neither the members of the board nor I would listen to such a proposition, as we believed that his counsel was too valuable to lose at a time when the work was to be put under test, and his services might be very necessary."

Faithfulness.—Just one instance, characteristics of the man:

Logan Waller Page says:

"In the death of Alfred Noble the American Highway Association has lost its greatest and most useful member. * * * He attended the founders' meeting, and was there elected a member of the Executive Committee, on which he served to the time of his death. During the four years that he served on this committee he never missed a meeting."

A greater than all has said: "He that is faithful in that which is least is faithful also in much." The law of faithfulness is not limited by magnitude; it obligates from the least to the greatest, from the greatest to the least.

Spontaneous Expressions of Sorrow and of Sympathy.

"The name of Alfred Noble will live in our memories, and in history, with those who possessed the finest qualities of heart and intellect."—(Charles S. Carter.)

"My relations with him for many years past had been very close, in connection with the New York tunnel, in which we were so closely associated. He was a man for whom every one entertained the highest respect, not only for his professional ability and talents, but for his many endearing personal qualities as well.

"The profession has sustained a great loss in Mr. Noble's death, and I beg to assure you of the very deep sense of loss which I feel personally."—(Samuel Rea.)

"I first knew him as the great engineer, but came to know him also as the biggest, broadest, and most human man with whom I ever came in contact." —(Paul G. Brown, M. W. S. E.)

"Like every one else that knew Alfred Noble, I not only admired him as a man and as an engineer, but had for him a real deep affection as a friend, and I feel that I too have suffered a loss today."—(William Barclay Parsons.)

"He stood for nothing but the straight, unvarnished truth, and I am sure there was not a man who knew him but felt he was the better for having known him and the better for following him."—(James Forgie.)

"There has been nothing that I have felt more than his death; he was so good, kind, generous, always thinking of your comforts."—(George Kemp.)

"I too, have keenly felt the loss of my great, good friend and chief, for the death of your father was a sad personal bereavement to me, the severing of an acquaintance of thirty-eight years.

"Alfred Noble was my ideal of a man, a grand character embodying the best traits of human intelligence and personality. He measured up to the perfect standard of a Chief Engineer, with full technical and practical ability, ready with right expedients, always successful, with never a failure, with unassuming modesty, with a living honesty of intent and deed, bright and spotless as sunlight, and an inborn gift of leadership which inspired loyalty to him and his work in every employee, however humble or important the position occupied might chance to be, and imbuing a spirit of service willing to go to the limit of uttermost endurance. I recall the tribute paid by a noted speaker in 1871 to the memory of a beloved teacher, and the words fittingly describe Mr. Noble's kind, gifted and forceful personality:

'Ah! one I saw and still can see,
As a picture dim he seemeth to me
By the hand of a Master painted.
Around the picture a halo clings,
And the face that memory backward brings
Is like the face of the sainted.
A richer wealth than the gold of fools,
A wiser wisdom than dwells in schools,

A nobler honor than place confers,
And a power a Prince might boast was his.
So deeply cultured in word and thought,
Each taste and talent so finely wrought,
So ran the purity of his life,
So sweet the harmony of its strife,
So grand the result of his being's task.
The world for ages was greatly blessed.' "

—(Joseph Ripley, M. W. S. E.)

"Somehow, it seemed hard to think he was gone, and that it ought not to be. I was an admirer of him and attached to him in kindly feelings of long acquaintance. He was to me a remarkable man, whom I counted as one of the few really great men I have known; and I always rejoiced in learning of the deserved recognition of him by others. While he undoubtedly understood and knew his marked ability, he never appeared to realize that he excelled, or to assert it; but had a quiet, unassuming, reserved and kindly personality which was most attractive to me. He was really a man that none knew but to love and none named but to praise. It is a gratification to remember that he won appreciation and distinction in his life work and did his life work grandly. To us who knew him so long, his going leaves a special sadness, and I can particularly understand the feeling of lonely sorrow and great loss of a close friend in your case. I deeply sympathize with you; and join with you in the sentiment that one of the grandest, and most useful, men of this country has gone."—(J. H. Steere.)

"His services to the City and State were permanent and lasting, and he will be greatly missed by the many friends who fully appreciated his high character."—(William R. Willcox.)

"It is very possible that you have never heard my name, but as it was a great privilege for me to know your father, I want you to know that I am one of a legion of men who owe to your father a debt of gratitude. The great simplicity, truth, honor, and ability which Mr. Noble stood for was not only an inspiration to me, but has done a great deal to establish and re-establish my faith in my fellow-men."—(Walter F. Dillingham.)

"He was one of those great men whose modesty, gentleness, and kindliness vested his greatness with a charm, and made all those who knew him love him as a man as strongly as they admired him as an engineer.

"His loss makes a huge gap in our ranks, in our hearts, and it is hard to realize how it can ever be filled."—(R. S. Buck.)

"It was a very great pleasure for me to have met your father, for I esteemed him very highly as a man and as an engineer."—(J. S. Langthorn.)

"A great loss to the Engineering Profession and to the community."—(F. W. Carpenter.)

"Since chance has thrown us together, and I have had the pleasure of knowing him rather intimately, I have been struck with admiration for his great abilities and his splendid character as a man."—(Josephus Daniels.)

"I am mourning the best of men and the best of friends."—(Ralph Modjeski, Asst. President, M. W. S. E.)

"It is impossible to think of any one in the Profession who will be more sadly missed."—(Arthur S. Tuttle.)

"I cannot express to you what I feel, in the loss of your noble father, and can only say now that his life has been an inspiration to all those who have had the good fortune to know him, as I have.

"Let me add that while his presence has gone, his personality will ever be a precious memory to us."—(Eugene W. Stern.)

"I esteem it a great privelege to have known him and to have been, even to so small an extent as I personally have been, associated with the one man who in my opinion outranked all the other engineers in this country. His splendid character and honor have been a great influence for good in the Profession, and we will all miss that fine guiding spirit very greatly. * * * In his death there still remains to you and to us the memory of one of the finest men that ever lived, finishing his course in the full possession of all his powers and at the summit of his fame. What can any one of us desire for himself better than that."—(J. Vipond Davies.)

"I am greatly shocked by your announcement of the death of Mr. Alfred Noble. I have found great satisfaction in the fact that during my term of office as President of the A. S. M. E. Mr. Noble sat at our Council Board. Meeting him there gave me the first opportunities I have had for gaining his acquaintance. I, of course, knew of his work as an engineer and of the fine reputation he has always sustained as a man; but as my acquaintance with him increased, and as I came under the influence of his personal charm, I appreciated as never before the significance of his presence at our meetings and, in a larger way, of his life among men."—(W. F. M. Goss, M. W. S. E.)

"Mr. Noble was not only one of our great engineers, but the highest type of man in every respect, and his quiet, lovable ways endeared him to all. He will be greatly missed, and it will be very difficult to fill the position he has occupied in the engineering world."—(Ambrose Swasey.)

"He was certainly one of the greatest men in our Profession, and his unassuming personality, coupled with his wonderful achievement, should make him a model for all of us to follow.

"I know of no single man who, it seems to me, will be a greater loss to our Profession."—(Fred. W. Taylor.)

"I am desired to inform you that at the first Meeting of the Council of this Institution after the death of our distinguished Honorary Member, Mr. Alfred Noble, the following Resolution of Condolence was passed:

"Resolved: That the Council record the deep regret with which they have learned the death of Mr. Alfred Noble, Honorary Member, who always evinced the warmest interest in the affairs of The Institution since he was elected a Member in 1901."—(J. H. T. Tudsbery, *Secretary*, Inst. C. E.)

"As a classmate of my father's at the University of Michigan, his name is familiar to me from my earliest recollection, and my personal acquaintance with him, dating from my first employment in Nicaragua sixteen years ago, was a source of great pleasure to me. I value greatly the opportunities that I have had to know him there and in Panama, and later in this city."—Henry Welles Durham.)

"I knew him well, and he was a splendid man. We will all miss him very much."—(Ralph Peters.)

"Although an entire stranger to you, I trust you will permit me to express my profound and sincere sorrow because of the death of your honored father, the late Alfred Noble, than whom I never knew a finer gentleman or better engineer. Truly we have lost our best.

"My acquaintance with him was but slight, * * * and although I have met him but seldom in recent years, I have cherished the memories of my slight association with him, and never failed whenever I saw his name to experience a thrill of pleasure as I recalled the genial face and pleasant smile of him who, above and beyond all his other rare qualities and attainments, was always four-square to every one."—(W. L. Smith.)

"I feel it myself a great deal. I had known him for over thirty years and feel more admiration and affection for him than I can tell."—(Edwin Duryea, Jr.)

"Many of us, who had the privilege of association with your father sympathize with your sense of separation and loss. We loved and respected him as a man and a counsellor. * * * His fine, long record of usefulness has been and will be an inspiration to many."—(Alfred Douglas Flinn.)

"I know of no one who had a higher regard for your father than I had, and I shall miss him greatly. He was a man who lived up to his name, and his loss is world-wide."—(Louis H. Barker.)

"I cannot refrain from telling you of the great admiration I had for your father and the high affectionate esteem I, and all others who knew him, had for him."—(Daniel E. Moran.)

"Your father was great, not only in respect to his achievements, but also in that he commanded the love and honor of every one whose privilege it was to know him."—(Waldo C. Briggs.)

"We have always considered Mr. Noble one of the big, strong, capable men in this country, and as such, he won the esteem and admiration of every one, including ourselves."—(Bradley Contracting Company.)

"I believe that the world has lost in your father its foremost civil engineer, and we all feel that we have lost a valued personal friend."—(S. P. Brown.)

"I am very sorry to hear of the death of Alfred Noble. He was the dean of American engineers and has left a record of brilliant usefulness upon which it is inspiring to dwell. I had at one period much official relationship with him and came to respect him most highly as a man and as an engineer. His professional advice in respect to the type of the Panama Canal and the security of the foundations of the Gatun Dam was followed by the Government and has been vindicated completely by the event."—(Wm. H. Taft.)

"I have for many years held Mr. Noble in high esteem, both as a man and as an engineer. The country is under great obligations to him for his wise and far-sighted course in relation to the Panama Canal. As a member of the International Board of Consulting Engineers, assembled by President Roosevelt in 1905, he threw the weight of his long experience and acknowledged engineering ability in favor of a lock as against a sea-level canal and wrote the report of the minority members of that body, in which the plan of the canal as constructed was outlined. As a member of a special commission of three sent by President Roosevelt to the Isthmus in 1907 to make a special investigation of the lock and dam sites, his signature to a report declaring the foundations safe and stable had great effect in reassuring public confidence."—(George W. Goethals.)

"I had the honor and pleasure of knowing your father, and the opportunity of seeing and understanding some of the splendid traits of character.

"He has been so highly regarded and in so many cases loved by those associated with him, that the human sides of his life shine out as well as do his attainments in his profession."—(William F. Ford.)

"I believe that every one who had the privilege of knowing your father will feel that he has lost a friend. I have been trying to think of another man in the engineering profession who is or has been so universally respected, admired, and even loved as was your distinguished father. My own association with him has been such that I have received a profound impression, not only of his great ability, but of his lovable personal qualities, and I am quite confident that I am simply one of a vast number of engineers and men of other professions who feel the same way."—(Nelson P. Lewis.)

"I send you my deepest sympathy in your great bereavement, and assure you of the same from every member of our profession as well as the innumerable personal friends who like myself have felt the high privilege and honor of friendship with your father, a great and noble personality and the most successful and eminent engineer of this generation."—(Frank W. Skinner.)

"For over twenty years I have watched Mr. Noble's career with interest, and know that, to the younger members of the profession, he has always been a source of inspiration."—(E. G. Haines.)

"Your father was the acknowledged dean of our profession in this country, and I have always felt that it was a privilege and an inspiration to have worked under him."—(T. Kennard Thomson.)

"I wish to write you a few words of appreciation of your father and the kind fortune that threw me with him at various places, four of five years altogether, in the period 1883-1892. At Snake River and Second Crossing, I felt that I knew him intimately, and that it was a pleasure to renew this friendship some years later at Cairo and in this city, and in the past twenty years I have felt a keen satisfaction in his successes and in the eminence he attained in his profession, a satisfaction the greater because I knew there was nothing fortuitous about his success, which came as a natural tribute to his high character and great ability, hidden though they were beneath exceeding modesty.

"During the past ten years I have twice been East and on each visit stopped over for the purpose of seeing your father. On both occasions he was out of town and I failed to see him, much to my disappointment. I feared what has happened would happen—that I would not see him again. I wish that the happiness that came to him in his success had not been clouded by your mother's illness. In a letter written some years ago he mentioned his disappointment and sorrow that in later life he could not realize his early ambition of giving her some compensation for the nomadic, and in some ways most unsatisfactory, life that is apt to be the lot of a civil engineer for the first half at least of his active career."—(Sanford Morison.)

"I have known and admired your father for many years, and cannot speak too highly of his ability and of his personal qualities. There are few men in the country to whom the Nation owes a greater debt for large services rendered."—(Charles Whiting Baker.)

"We who have passed the meridian of life have met in our journey many men whom we respect for what they have accomplished, and among them a few whom we respect for what they have done and love for what they are, and your father was one of these latter to me, and I know that he was so regarded by a host of others.

"It was a painful shock to me when I learned, only this morning, that he had joined the silent majority. I feel that I have lost a true friend and the engineering profession its foremost American representative."—(Isham Randolph, *Past-President,* M. W. S. E.)

"As one of the thousands of engineers who knew and loved and admired Alfred Noble, I tender your my sincerest sympathy."—(Onward Bates, *Past-President,* W. S. E.)

APPENDIXES

Resolutions Adopted by the Board of Direction of The American Society of Civil Engineers, June 2nd, 1914.

"Whereas: By the death of Alfred Noble, the Engineering Profession in America has lost its most prominent member, and

"Whereas: Mr. Noble has been connected with this Society for forty years, and has served upon its Board of Direction for nine years, as Director, Vice-President, President, and finally as a Past-President, be it

"Resolved: That the Board of Direction of the American Society of Civil Engineers acknowledges the indebtedness of the Profession to this wise counselor, active and tireless worker, who, during his connection with this Board and subsequently, gave ungrudgingly and unselfishly so much of his valuable time for the general good, and be it further

"Resolved: That this Board desires to spread upon its records its sense of profound sorrow in the great loss, not only to the Profession of Engineering, but to the world, of one who by his strong and intellectual personality, earnestness of purpose, sterling honesty, and great heart, has set an example for Engineers of the future, and in so doing endeared himself to all with whom he came in contact."

MEMOIR FROM *Engineering News*, APRIL 23RD, 1914.

"The American engineering profession looked up to Alfred Noble.

"The news of his sudden death will bring a sense of personal loss to thousands of engineers who had never met Mr. Noble personally, but who appreciated the great public service which he had rendered and realized that his great ability and strong personality had done much to raise the engineering profession in public esteem.

"Elsewhere in this issue, in presenting to our readers a recent portrait of Mr. Noble, we have given a brief record of his life and professional achievements. It is fitting, however, that something more should be said in this place concerning the unique public service which Mr. Noble rendered. We believe it is within bounds to say that there are few men to whom the people of the United States owe a greater debt of gratitude for important services rendered at a time of crisis than to Alfred Noble.

"In 1895, Congress was on the point of passing a bill providing for a government guarantee of the bonds of the Nicaragua Canal Co. There was a very strong sentiment in favor of the passage of the bill among members of both the House and Senate. The assurances held out were that the entire cost of building a ship canal across Nicaragua connecting the two oceans would be only $65,000,000. There were, however, in Congress, a few statesmen who were not swept off their feet by the great pressure exerted in favor of the passage of the bill. They put forth the plea that before the United States should lend its credit to the enterprise it should investigate the project through a board of engineers of its own selection.

"This proposition was so entirely reasonable that it sufficed to defeat the bond-guarantee bill. In its stead an act was passed creating the Nicaragua Canal Commission, to be composed of one engineer from the Army, one from the Navy, and one from civil life. This Commission with a very small appropriation and a very limited time in which to work, was required to report as to the feasibility of the Nicaragua canal enterprise. President Cleveland appointed as the members of that Commission, Colonel (afterwards General) William Ludlow from the Army, Mordecai T. Endicott from the Navy, and Alfred Noble from civil life.

"The situation was one which demanded engineers of ability with sufficient independence to form their own opinions and not be swerved from a straight course by the strong influences brought to bear by the corporation whose plans were under investigation. The report made by this commission showed that the advantages of Nicaragua as a canal route had been greatly over-estimated and that the cost of building a canal there would be far greater than the estimates made by the canal company.

"Those interested in the Nicaragua Canal enterprise adopted every possible means to discredit the report; but they were never afterward able to command a large measure of public support. The sound advice of these engineers saved the nation from lending its credit to a private corporation which, if it had undertaken the Nicaragua work, would have inevitably met failure.

"The second great opportunity of Mr. Noble to render public service came when in 1899 Congress created the Isthmian Canal Commission, with instructions to find the best possible route for a ship canal across the Central American Isthmus. Mr. Noble was appointed one of the members of this commission and he and the late George S. Morison were recognized as its leading engineers. Without doubt, Mr. Noble's large experience, tactful firmness, and ability had large influence in determining the conclusions of the Commission.

"It was this commission which after two years of surveys and investigation recommended that the United States should adopt the Panama route. The experience which has been gained since that time has fully confirmed the wisdom of the recommendations made by that commission.

"It was seven years later when Mr. Noble had the opportunity to render what was, without doubt, the greatest public service of his life. The government had started construction work on the Panama route, and the question came up for decision as to whether a sea-level canal or a lock canal should be undertaken. To advise upon this momentous question, President Roosevelt created an International Commission of engineers, made up of five eminent members of the engineering profession representing foreign countries and eight prominent American engineers.

"As most of the readers will remember, all the foreign engineers and three of the American engineers, united in a majority report advising the construction of a sea-level canal. Five American engineers with Mr. Noble at the head stood out in favor of a lock canal. We say 'Mr. Noble at the head', because from his strong experience in connection with the lock at Sault Ste. Marie, he was better able than any engineer upon the commission to speak authoritatively with respect to the construction and operation of great ship canal locks. To Alfred Noble's discerning wisdom and independent judgment and to his willingness to stand in a minority in defense of what he believed to be right, the country owes it to-day that it did not undertake what we now know would have been the folly of a sea-level canal at Panama.

"In the struggle which followed the submission of these two conflicting reports, Mr. Noble's ability and strong forceful personality had much to do with the final decision by which those in authority rejected the majority report and adopted that of the minority.

"In reviewing these three great public services rendered by Alfred Noble to the nation it will be universally agreed that his name deserves high prominence in connection with our greatest national engineering work, the Panama Canal. It detracts nothing from the honor due to those who have borne the burden and heat of the days and years during the long period of construction at Panama to give honor to the great engineer whose sound judgment and incorruptible integrity enabled the nation to steer a straight course in undertaking this hugest of engineering feats and avoid the disgrace attendant upon disastrous failure.

"It can be said of Mr. Noble, without fear of contradiction, that he won his way to the foremost position which he occupied as the leading American civil engineer of his time by sheer force of ability. Mr. Noble was always a quiet and modest man, absorbed in his professional work. He never tried to advertise himself nor attempted to put his professional work in any way on a commercial basis. The great responsibilities which were laid upon him came to him because he was a man who inspired confidence in both his ability and his integrity.

"For a dozen years in his early professional career he worked steadily, patiently and practically unknown as an assistant engineer on government work; but it was the experience which he gained there, even more than that which he gained in fields of other engineering work, which in later years, enabled him to solve correctly the vast problems which were laid before him in connection with the Panama Canal enterprise.

"We may not take space to speak at length here of his other great works as an engineer, such as the Pennsylvania terminal in New York City. It is worth while, however, to emphasize the high regard in which he held his profession. Much of his time in recent years had been devoted to work for the benefit of the profession in connection with the engineering societies of which he was a member. Last year, he was President of the American Institute of Consulting Engineers and he had been for two years one of the Managers of the American Society of Mechanical Engineers. In 1903 he was President of the American Society of Civil Engineers.

"One of the last pieces of work which he undertook and to which he had devoted a great amount of time and energy was in connection with a joint committee of the national engineering societies organized to frame a model code for the registration of engineers. Mr. Noble was the chairman of this committee and he devoted to the task a great amount of painstaking thought. It was characteristic of the man that with all the great responsibilities laid upon him, he was willing to give liberally of his time and energy to benefit the members of his profession."

MEMOIR FROM *Engineering Record,* APRIL 25TH, 1914.

"Alfred Noble, master civil engineer, universally respected because of his ability, loved and honored by those who knew him, died in New York, April 19. Apparently in vigorous health, despite the attainment of his Scriptural years, he was stricken rather suddenly during the first week in April. On April 9 it was deemed advisable to perform an operation and though he rallied for a time his condition hardly became encouraging.

"His early career and his experience until the close of his work on the Pennsylvania Railroad's improvements in New York were recounted admirably by Dr. Rossiter W. Raymond, secretary-emeritus of the American Institute of Mining Engineers, when the John Fritz medal was presented to Mr. Noble on Nov. 10, 1910.

"Since the close of the period covered by that biography, Mr. Noble has been in general consulting practice, serving also on retainer as consulting engineer for the New York Board of Water Supply. For this service his experience in tunneling, in the building of masonry structures and the examination of foundations proved invaluable. His knowledge of foundations, too, brought him a most important retainer last year from the Federal Government. Great difficulty was experienced in the construction of a drydock at the Naval Station, Pearl Harbor, Hawaii, ending in the eruption of the bottom and the stoppage of the work. Mr. Noble was sent to Hawaii to advise as to the method by which the work should be completed.

"Among the other large works which had recently engaged his attention was the enlargement of the Welland Canal, upon which he reported for the Canadian Government, thus linking his name with another of the world's great waterways. The Public Service Commission of the First District, New York, which is building a $165,000,000 subway system, also called him into consultation.

"Many honors conferred upon him by his colleagues are recounted in Dr. Raymond's biography. Following his selection for the John Fritz medal, the highest American honor for an engineer, he was selected an honorary member of the Institution of Engineers of Great Britain, a distinction enjoyed by no other American engineer. In 1912 the Franklin Institute awarded him the Elliott Cresson medal.

"In recent years he was particularly interested in anything affecting the status of engineers and it was largely through his influence that the American Institute of Consulting Engineers entered so actively into public affairs. This organization within the past year addressed communications to the President of the United States, the Governor of New York, and the Mayor of New York City, urging the appointment of engineers to such public offices as their training particularly fitted them for. Activity was displayed, too, on the licensing of engineers and Mr. Noble, as a representative of the Institute, journeyed more than once to Albany to plead for proper legislation."

"Dr. Raymond's biography follows:

"Alfred Noble was born in 1844 at Livonia, Wayne County, Michigan. His father, Charles Noble, was a farmer, like most of our pioneer settlers in the West. But he and his fellow farmers made of their adopted State a notable center of intelligence and industry. When Alfred Noble was born Michigan had been but seven years a State of the Union; yet she had already begun that course of material and intellectual culture which soon placed her in these respects abreast of the most favored sections of the country. A splendid public-school system, crowned with numerous excellent high schools and colleges, and a great University represent one of these achievements. What wonder that this farmer's boy, taught in the district free school and the village high school, dreamed of the University, as the gateway to an honorable professional career!

"Yet in him, as in so many American boys at that time, and, I doubt not, at *this* time, there was one passion stronger than personal ambition—the love of country. When the first call to arms was sounded by Lincoln, Alfred Noble was too young to be accepted. But in August, 1862, when he was eighteen years old, answering the more important call, and volunteering, not for a brief, easy and victorious campaign, but for long, hard service of the Union, he enlisted as a private in the Twenty-fourth Michigan regiment.

"Oh, those Michigan farmers' sons, who far from home, and defending not the soil of their own State, but the wider, grander cause of the nation, grimly, loyally, saw the thing through, until the last straight furrow had been plowed and the last field sowed for the harvest of peace! In the West and in the East are the honored graves of a host of them who fell by the way; but not who survived. The Twenty-fourth Michigan belonged to the sorely tested and grandly faithful Army of the Potomac; and through three terrible years Alfred Noble served with his regiment in the famous First Corps of that Army, consolidated, after Reynolds fell at Gettysburg, with the Fifth corps under Warren. During the first day at Gettysburg, this regiment lost 300 in killed and wounded, out of the 460 who went into the fight. The figures speak for themselves, and what they mean, perhaps only an old soldier fully understands.

"At the close of the war, Mr. Noble was discharged with the rank of sergeant, and his patriotic duty having been well done, he resumed the purpose of his youth. His record as a veteran, together with his proved character and capacity, secured for him a clerical position in the War Department, which he filled for more than a year, earning the money, and by diligent use of his leisure time, acquiring the necessary scholastic preparation for a university course. In this way he more than fulfilled the requirements for a freshman, and in September, 1867, he was admitted as a sophomore into the University of Michigan, where he was graduated in June, 1870, as civil engineer. Yet, during these three years, he was obliged to earn his expenses as a student by much outside work, as recorder on the U. S. Lake Survey, as clerk, and afterward as assistant engineer in river and harbor work on the east shore of Lake Michigan.

"After his graduation, Mr. Noble continued his work on the harbor surveys conducted on Lakes Michigan and Huron by the U. S. Corps of Engineers, and in 1870 was placed in local charge of the improvement at Sault Ste. Marie. This position he retained for twelve years, a period covering the construction of the great masonry lock at the Sault, at that time by far the largest canal lock in the world. In 1882, after its completion, Mr. Noble resigned his position to become resident engineer for Mr. G. Bouscaren in the construction of the truss bridge over the Red River at Shreveport, La. Early in 1884, he was appointed general assistant engineer of the Northern Pacific Railroad, of which the late General Adna Anderson was then chief engineer. During the next three years Mr. Noble had charge of the building of important bridges, including the truss bridge, with draw, over the Snake River, near its junction with the Columbia, the bridge over Clark's Fork of the Columbia River, the bridge over St. Louis Bay on Lake Superior, and also the foundation and construction of the Marent Gulch viaduct, near Missoula, Montana.

"In August, 1886, Mr. Noble removed to New York, to become and remain until July, 1887, resident engineer in the erection of the Washington steel arch bridge over the Harlem River, under the late W. R. Hutton as chief engineer. He then took charge for Messrs. Morison and Corthell of the erection of the bridge at Cairo, on the Ohio River. This brought him into association with the late George S. Morison, whom he served in the erection of the great cantilever bridge over the Mississippi at Memphis, and other bridges at Bellefontaine, Leavenworth, and Alton. Mr. Morison's high opinion of his colleague and assistant is matter of record.

"It is worthy of note that in this continuous activity of nearly 25 years, Mr. Noble had neither won or sought a newspaper reputation. He had never been advertised as chief engineer of anything. He had merely done his part, loyally and efficiently, in every enterprise with which the had been connected, impressing himself upon his superiors and associates as a man of thorough training, wide experience and absolutely trustworthy character. A reputation thus acquired wears well. Engineers were not surprised when, in April, 1895, he was appointed by President Cleveland a member of the first Nicaraguan Canal Commission. Of Mr. Noble's work in that capacity, and of its important results, I shall not here speak. Nor can I, in the brief time at my disposal, discuss his work as a member of the Isthmian Canal Commission of 1899, which resulted in the adoption by our Government of the present scheme of the Panama Canal. When this subject came up for discussion in Congress, Maj. W. H. Wiley, a member of the House of Representatives, presented a letter from Mr. Noble, stating clearly and tersely the argument in favor of a lock-canal. This letter was printed in the 'Congressional Record', and is said to have influenced decisively the action of both Houses.

"But I must go back a little in order to mention what seems to me to be one of the greatest, if not the very greatest, of the engineering investigations with which Mr. Noble has been connected. I refer to the labors of the U. S. Deep Waterway Commission appointed in 1897 to conduct surveys for a deep waterway from the Great Lakes to tide-water. This body spent half a million dollars in its investigations; fixed 21 feet as the most economic depth; proved the most practicable route to be *via* Lake Ontario and the Oswego and Mohawk rivers; examined by borings, etc., every part of that route, and determined the nature and cost of the work (in every particular except the price of the private property to be purchased or condemned for it) so accurately that a contractor might safely have based his bid for any section upon its report. I have never encountered in the literature of engineering, and I doubt whether that literature contains a discussion so thorough, exhaustive and conclusive. Before that report had been prepared the estimates of engineers—I mean such guesses as engineers sometimes permit themselves to make—had varied by a hundred million dollars as to the cost of the proposed waterway; and it is my impression that even this wide variation did not bring them within a hundred millions of the truth. Be that as it may, the report of this commission, published in 1900, will always remain a monument of professional thoroughness and a model for professional imitation.

"Among other engineering enterprises with which Mr. Noble was connected at this period, I may name the great seawall, built to protect the City of Galveston, Texas, against a recurrence of the disastrous flood of 1900, and the bridge across the Mississippi at Thebes, Ill., which was erected by him in partnership with Ralph Modjeski. Moreover, he has been employed as consulting engineer in connection with the difficult problems presented by the foundations of some of the lofty office buildings of New York City—structures which certainly need to be planned with more care and knowledge than ordinary architects and builders bring to such tasks.

"But the latest of Mr. Noble's labors is also, perhaps the most important. He was appointed in 1902 a member of the Board of Engineers directing the operations of the Pennsylvania Railroad Company (through auxiliary corporations in New York and New Jersey) in tunneling under the North and East Rivers, and under the borough of Manhattan, establishing a great railway-station on Seventh Avenue. The plans approved by this board, and executed under its direction, have been so fully described in recent papers before the American Society of Civil Engineers and the American Institute of Mining Engineers as to need no recapitulation here. Mr. Noble, besides serving as a member of the board, was, as chief engineer of the East River Division of the Pennsylvania, New York and Long Island Railroad, directly in charge of the construction of the tunnels from Seventh Avenue under Manhattan and East River to the portals of Long Island, the approaches from the east, and the immense terminal yard at Long Island City. This part of the great undertaking is reported to have cost more than $30,000,000. One thing I believe I may safely say—that the difficulties encountered in the quicksands and the decayed and fractured gneiss pierced by the tunnel under the East River were much more serious, though much less widely reported in the newspapers than those presented by the glacial silt which forms the bottom of the Hudson. True to his record, Alfred Noble advertised neither his trials nor his triumphs, but simply finished his work without interlocutory appeals to the public. At the end of 1909, that work being done, he resigned his position as chief engineer. The directing board of engineers, having concluded its work, had closed its offices, and, I believe, ceased to exist six months earlier. Such a quiet, business-like, unboastful termination of a colossal engineering enterprise was worthy, in its simplicity, of the great men who planned it and the great men who carried it out.

"Perhaps I may be allowed to say that, in this particular work, Mr. Noble came nearest to the heart of us mining engineers. For several years he and his associates made of New York and its vicinity one of the great mining camps in the world. True, in all their tunneling they were only making a hole—not extracting gold or silver or copper from it. Yet, can we say more for most of our mining tunnels? Do they not too often leave us with the hole only as a net result? After all, we mining engineers do not control the commercial results of our borings and excavations. Yet we are often unjustly held responsible for such results, and we cannot but congratulate this mining engineer, whose employers ask only that he shall put his job through and will look for their dividends afterwards, not to the contents of the hole, but to the use of the hole itself. In other words, Mr. Noble has been, in this work, an ideal mining engineer, unhindered by the assayer, the millman, the economic geologist, the mining law or the stock market. We greet him, not without a touch of envy, as our brother!

"In this connection let me voice the opinion of mining engineers as to the manner in which Mr. Noble conducted, under land and sea with the minimum of disturbance to the surface, his extensive operations. Some of us (I among the number) have suggested from time to time, with the freedom of those who were not responsible for the results, ways in which this work could be still more quietly and safely done. But all of us agree that in these respects such work never has been better done and we have sense enough to admire and praise the man who directed it.

"Mr. Noble's merits have been recognized in various ways by those whose judgment he would most highly value. In 1895 his university conferred upon him the honorary degree of Doctor of Laws, an honor which was repeated in 1904 by the University of Wisconsin; in 1898, he became president of the Western Society of Engineers; in 1903, he was elected president of the American Society of Civil Engineers (of which he had been made a junior in 1874 and a member in 1878). His membership in the ancient Institution of Civil Engineers of Great Britain certifies his professional standing abroad. And we have elected him a member of the Engineers' Club of New York City in testimony that he is not only an eminent engineer, but a congenial companion and a true friend. Yet I fancy that not one of these distinctions—perhaps not all of them put together—will outweigh in his esteem the honor conferred upon him to-night, with the hearty professional approval, and the personal esteem and affection of American engineers."

LETTERS TO ENGINEERING RECORD.

"I am very sorry to hear of the death of Alfred Noble. He was the dean of American engineers and has left a record of brilliant usefulness upon which it is inspiring to dwell. I had at one period much official relationship with him and came to respect him most highly as a man and as an engineer. His professional advice in respect to the type of the Panama Canal and the security of the foundations of the Gatun Dam was followed by the Government and has been vindicated completely by the event."—Wm. H. Taft.

"I have for many years held Mr. Noble in high esteem both as a man and an engineer. The country is under great obligation to him for his wise and far-sighted course in relation to the Panama Canal. As a member of the International Board of Consulting Engineers, assembled by President Roosevelt in 1905, he threw the weight of his long experience and acknowledged engineering ability in favor of a lock as against a sea-level canal and wrote the report of the minority members of that body, in which the plan of the canal as constructed was outlined. As a member of a special commission of three sent by President Roosevelt to the Isthmus in 1907 to make a special investigation of the lock and dam sites, his signature to a report declaring the foundations safe and stable had great effect in reassuring the public confidence."—George W. Goethals.

"It was with the deepest regret that I learned of Mr. Noble's death. My relations with him had been very close for many years during our association on the important New York tunnel work on the Pennsylvania Railroad. He was a man for whom everyone entertained the highest respect—not only for his personal ability and talent but for his modest and lovable personal characteristics. In my judgment the profession has sustained a great loss in Mr. Noble's death."—Samuel Rea.

"From twenty-five years of professional association with Alfred Noble my judgment is that, considering all his sterling qualities, he has had very few equals in those solid, reliable traits of character that make for usefulness of a high order to the civil engineering profession and to the world at large."—E. L. Corthell.

"In the entire engineering profession there is probably not another man whose death would be more sincerely mourned than that of Alfred Noble. Above everything, he was a man and beloved by all who came in contact with him, a man to whom every one in trouble might go and gain something from the wealth of his experience. He was the most conscientious engineer I have ever known. He never rendered snap judgment, even on matters of small importance. Any advice given or judgment rendered was always the result of the most careful consideration. Material things of the world were, with him, always a minor consideration and he repeatedly refused lucrative engagements for the sole reason that he felt that he could not give them the study and the attention which they demanded. His advice was sought not only by the young, struggling engineer, but also by those of wide experience, not in engineering matters alone, but in any matter where experience and good judgment were desirable. He had the greatest breadth of mind and his keenness of vision caused him to see problems in their true light. His acquaintance was world-wide, and his death will be regretted by thousands of engineers who have at some time or other come under his influence. My intimate association with the late Charles L. Harrison brought me into close touch with Mr. Noble and I cannot express by words my appreciation of his influence and of his help. I trust that his influence may live after him."—J. Waldo Smith.

"In the passing away of Alfred Noble our Profession has lost one of its best and highest representatives—the leader in his special work, true to his friends, a gentleman, a man in all that the word implies. He has left a vacancy in our ranks that cannot be filled."—John F. Wallace.

Proposed Memorial to Alfred Noble;*

Tributes from Brother Engineers and Co-Workers.

A committee appointed at a recent meeting of the Board of Direction of the American Society of Civil Engineers, consisting of Messrs. T. Kennard Thomson, chairman; Charles Warren Hunt and J. H. Edwards, has reported as follows:

"That, in the opinion of your Committee, such a Memorial is desirable, and should be undertaken by this Society, and should be on no small scale. Your Committee suggests that the Civil Engineers of the world be asked to subscribe to the funds for this purpose, and that the Memorial take the form of an appropriate bronze statue to be erected in some suitable place.

"In view of the fact that much of Alfred Noble's professional practice was National in character; that he was an adviser of Presidents, and consulted in some of the most important engineering work of the country, your Committee believes that such a recognition of him personally, and of the Profession of Engineering, would meet with universal approval.

"It is therefore the opinion of your Committee, that the Capital of the Nation is the proper location for such a statue, and that the Congress, or other body in authority, be requested to provide a suitable site. Your Committee, therefore, makes the following recommendations:

"(1) That this Society undertake the erection, in a suitable location, of a statue to the memory of Alfred Noble—the Engineer and the Man.

"(2) That the Board of Direction immediately set aside the sum of one thousand dollars ($1,000) as the first subscription toward the necessary funds.

(3) That the funds for this purpose be secured by subscription from the engineers of the world.

"(4) That a Committee of five be appointed by the Board, in whose hands the carrying out of the project be placed."

The report was received and its recommendations adopted by the Board of Direction at the meeting of June 2nd. A permanent committee was appointed to carry the resolutions into execution, consisting of Messrs. Onward Bates, of Chicago, Ill.; Robert Moore, of St. Louis, Mo.; Samuel Rea, of New York City; Samuel H. Hedges, of Seattle, Wash.; F. H. Newell, of Washington, D. C., and Charles Warren Hunt, Secretary of the Society.

The Joint Conference on Uniform Methods of Tests and Standard Specifications for Cement, consisting of Arthur P. Davis, Olaff Hoff, Richard L. Humphrey, Asa E. Phillips, Clifford Richardson, George F. Swain, George S. Webster and Rudolph J. Wig, has adopted the following resolution:

"The Joint Conference on Uniform Methods of Tests and Standard Specifications for Cement hereby records with profound sorrow the irreparable loss sustained in the death of its Chairman, Mr. Alfred Noble, and its deep gratitude for the privilege of having known and been associated with one who was the exponent of the highest ideals as a man, as a citizen and as an engineer.

"Mr. Noble has given much to the engineering profession and his unselfish work in the development of the methods of testing cement has been of incalculable value. Many of his contributions to the Engineering Profession, to be found in the *Transactions* of the American Society of Civil Engineers, relate to this branch of engineering. He was a member of the Special Committees of this Society which presented reports on Uniform Methods of Tests of Cement in 1885 and 1912.

*Engineering News, June 18, 1914.

"The members of this Conference find themselves unable to adequately express their loss. This intimate association with Mr. Noble has left in the memory of each member an indelible impression of his patient, sweet, endearing nature, of his simple, forceful, dignified personality, and of the grandeur of his character."

Memoir from the Journal of the American Society of Mechanical Engineers, May, 1914.

"There passed away on April 19, 1914, in New York City, Alfred Noble, an esteemed member of our council and a man whose loss will be deeply felt and deplored not only by the engineering profession of which he was one of the most distinguished members, but by everyone who had the good fortune to know him.

"He had a very interesting career, and the story of his life, if adequately written, would be typical of that of many of the great men and builders of this nation.

"He was born August 7, 1844, at Livonia, Wayne County, Michigan, where his parents resided on a farm. His early education was received in the district school of his native place, and during his spare time he worked on the farm.

"In 1862, when only 18 years of age, he enlisted in the Civil War in the 24th Michigan Volunteer Infantry. From that time until 1865 he served in the Army of the Potomac, taking part in all of the hard and desperately fought battles which that army engaged in against Lee and Stonewall Jackson. At Gettysburg his regiment lost a very large percentage of its numbers. At Chancellorsville, it was by the merest accident that his brigade was not captured by Stonewall Jackson's men, but he was lucky in serving through the war without being wounded, and was mustered out of the service in June, 1865, with the rank of sergeant. He then prepared to enter the University of Michigan, and in 1867 became a sophomore, graduating in 1870, with the degree of C. E. He received the degree of LL. D. from his alma mater in 1895, also from the University of Wisconsin in 1904.

"From 1868 to 1870 he was assistant engineer on river and harbor work on the Great Lakes. From 1870 to 1872 he was in charge of improvements on St. Marys Falls Canal and St. Marys River. During this time the first great masonry lock at the Sault, then by far the largest canal lock in the world, was built. On completion of this work he became resident engineer on the construction of an important bridge at Shreveport, La., over the Red River.

"From 1883 to 1886 he was general assistant engineer on the Northern Pacific Railroad, and from 1886 to 1887 resident engineer on the construction of the Washington Bridge over the Harlem River, at that time the largest arch bridge in existence.

"From 1887 to 1894 he was resident engineer on the construction of several very large and important bridges over the Mississippi at Memphis and Alton, over the Missouri at Bellefontaine and Leavenworth, and over the Ohio at Cairo.

"He was appointed a member of the Nicaragua Canal Board by President Cleveland in 1895. This board visited Central America and examined the route of the Nicaragua Canal and also the Panama Canal and then returned to the United States, completing its work November 1, 1895.

"In June, 1899, he was appointed by President McKinley a member of the Isthmian Canal Commission which was charged with the selection of the best canal route across the American isthmus, and it has been substantially on the route selected by this commission that the Panama Canal has been constructed. While on this commission, Mr. Noble with his colleagues visited Europe to examine the existing canals there, and the data which the French Canal Company had in Paris, and also made several trips to Central America to examine more fully the various canal routes.

"In 1905 he was appointed by President Roosevelt a member of the International Board of Engineers to recommend whether the Panama Canal should be constructed as a sea-level or a lock canal. This board consisted of thirteen members, of whom five were nominated by foreign governments. Mr. Noble was one of the minority of five Americans who recommended the adoption of the lock plan. Their views were adopted by the Government and the canal has been built in accordance with their recommendations. In March, 1907, he was one of the three appointed by President Roosevelt to visit the Panama Canal to investigate the conditions regarding the foundations of some of the principal structures. This duty was completed in a few weeks. He was obliged to decline a similar appointment two years later.

"From the very inception of the plan by this country to build an Isthmian Canal, and from the commencement of the preliminary investigations and surveys, to the adoption of the final plan and the beginning of the actual construction of the Panama Canal, Mr. Noble was continuously identified with the project and deserves as much credit for the solution of the engineering problems as any other one who has been connected with this great work.

"In July, 1897, he was appointed by President McKinley, a member of the United States Board of Engineers on Deep Waterways, which made surveys and estimates of cost for a ship canal from the Great Lakes to deep water in the Hudson River.

"In November, 1901, the city authorities of Galveston, Texas, appointed Alfred Noble along with Henry C. Ripley and General Robert, as a board of engineers to devise a plan for protecting the city and suburbs from future inundation. They recommended the building of a solid concrete wall over three miles long and seventeen feet in height above mean low water, the raising of the city grade, and the making of an embankment adjacent to the wall; the whole to cost about three and a half million dollars, which plan has since been carried into effect.

"From 1902 to 1909 Mr. Noble was chief engineer of the East River Division of the New York extension of the Pennsylvania Railroad, and was in entire charge of this most difficult piece of work, involving as it did, a very accurate survey across Manhattan, and the construction of the foundations of the Pennsylvania Station, of the land tunnels, and of the East River tunnels which were very troublesome.

"Since 1909 he has been engaged in general practice as a consulting engineer, the firm name being Noble and Woodard. Probably the most important work dealt with was in relation to the dry docks built for the United States Government near Honolulu. He was also for a time consulting engineer to the Quebec Bridge Board, also consulting engineer for the Board of Water Supply, New York City, and for the Public Service Commission of the First District of the State of New York.

"He was a past-president of the Western Society of Engineers, the American Society of Civil Engineers, and the American Institute of Consulting Engineers. He was elected to the Council of this Society in 1912 and had served several years on the Library Committee.

"In 1910 he was awarded the John Fritz Medal for notable achievements as a civil engineer, and in the same year was elected an honorary member of the Institution of Civil Engineers of Great Britain, a distinction which no other American has had. In 1912 he received the Elliott Cresson Medal of the Franklin Institute in recognition of his distinguished achievements in the field of civil engineering.

"Mr. Noble was deeply interested in anything affecting the status of the engineering profession. His unfailing good humor, his kindliness and sweetness of dispostion, his sound common sense and good judgment, his youthful mentality, his quick and very sure perception, and his modesty, invariably impressed his colleagues with whom he worked on many committees, and commission in which he was so active.

"He possessed a combination of strength, gentleness, tact and discernment rarely met with. He was universally respected by all who had any business dealings with him. The plain workman, the man with the pick and shovel, the contractor under him, the highly trained technical engineer, or the president of a great corporation, all appreciated the nobility, simplicity, and rugged honesty of his character. His personality was such as to evoke the faithful and enthusiastic loyalty of his subordinates, and the deep, strong, and lasting affection of all those who were honored with his friendship.

"At the funeral services on the evening of April 21, the Society was represented by Jesse M. Smith, Past-President and member of the Council; Leonard Waldo, Chairman, and E. G. Spilsbury of the Library Committee, Charles Whiting Baker, Rudolph Hering, J. Waldo Smith, C. M. Wales, W. L. Saunders, and Calvin W. Rice, Secretary."

Resolutions of the Council of the American Society of Mechanical Engineers, Adopted October 9th, 1914.

"In the death of Mr. Alfred Noble, the engineering profession has lost one of its greatest members, one of its wisest associates, and one of its most modest scientists.

"Mr. Noble was a man of generous impulses, always interested in the success of younger engineers, always ready to help them with advice, and to put before them an opportunity for their success. He was without the slightest professional jealousy, and so in love with his chosen calling that he always hailed the achievements of others with delight because engineering had by them been advanced and the world benefited. His personality was most charming and The American Society of Mechanical Engineers will long miss his delightful talks and wise advice at its Council meetings, where he was a most welcome member. He may be aptly described as a lovely man, full of gentleness and dignity, and yet possessing a forceful character which fitted him so well as a cherished adviser.

"It may not be generally known that Mr. Noble had an influence in the decision of Congress to abandon the sea-level plan and adopt the lock system for the Panama Canal. The subsequent events have shown the wisdom of Mr. Noble's advice. A member of Congress and a personal friend of Mr. Noble asked him to state his reasons for advising the lock system in the form of a letter. This was done in a most concise form and was read in the House of Representatives, and thus became incorporated in the Congressional Record, with the result that it convinced the members, and by a large majority they adopted the lock system. Copies of the Record marked at Mr. Noble's letter were given to each Senator, and the argument was equally convincing, so that the Senate confirmed the House action by a large majority.

"A glance at Mr. Noble's history will be most edifying to a young engineer as it will be gratifying to his hosts of friends."*

* * * * * * * *

"He was married May 31, 1871, to Miss Georgia Speechly, of Ann Arbor, Michigan. They had one son, Frederic Charles, a graduate in Engineering of University of Michigan, 1894, now following his profession in New York City.

"There is little to add to this epitome, but it shows the forceful character of Mr. Noble throughout. He won the various honored and honorable positions he so ably filled by merit and perseverence, and his career, cut short in this untimely manner, is an encouragement to every young engineer and a stimulus to the exercise and cultivation of those manly and

*Here there is a brief history of Mr. Noble's career, which will be found on pages 585-6.

fearless qualities in the possession of which Mr. Noble so excelled and which have so firmly established him in the affections and admiration of all engineers."

Resolutions Adopted by the United Engineering Society Library Board, on May 7th, 1914.

Alfred Noble.

1844-1914.

"Earnest boy—Youthful patriot—Full-serviced soldier for the Union—Determined student—Teacher—Discerning and courageous engineer—Safe adviser in great enterprises—Receiver but not seeker of highest honors—Friend and up-builder of young men—Guardian of the honor of the Engineering Profession—Organizer of this Library Board.

"Others who have been impressed with the compass of Alfred Noble's scientific imagination, whether shown in the mid-Pacific docks, or in the choice of a continental passageway or in the water system of a great metropolis, or the sinuous frames on which the commerce of our nation is woven, will spread afar the record of his great engineering career; but it is for us, his messmates at the club, his comrades in our council for the diffusion of most useful knowledge, to see as well as we may at this close vision and with dimmed eyes, and to testify to that great soul which we know was with us, and which we shall increasingly feel has gone.

"He earnestly believed the spreading branches of this tree which he planted here with us would bear increasingly richer food for the minds of men, and that as the centuries pass on future generations will say that together we builded better than we knew. To quote his own words—

"'Our Library is coming out all right. I will help you all I can. I shall not be with you at the next meeting for I have some important work to do. I go a-fishing'

and with that smile on his face, which has since become a benediction, we saw him for the last time.

"Would that some sculptor had preserved for us, and for those who knew him less, the unfathomable smile, the gentle humor, the roused dignity, the life below the outward surface of that fine face.

"His three score and ten years of life of greatest attainment seemed the embodiment

"'Of toil unsevered from tranquility;
Of labor that in lasting fruit outgrows
Far noisier schemes, accomplished in repose
Too great for haste, too high for rivalry.'

"To his tenderly loved wife and to their son, to whom the Angel of Light has brought the message of final promotion, we speak our deep sympathy in this grievous sorrow of separation.

"We are comforted to think that in their spirtual hearing, as in ours, must be echoing the words

"'Well done, good and faithful servant, enter thou.'

"'There lies not any troublous thing,
Nor sight nor sound to war against thee more,
For whom all winds are quiet as the sun,
All waters as the shore.'"

From E. W. Stern.

"Replying to your letter of May 1st, I willingly send you whatever information I have regarding Alfred Noble.

"I gave most of the facts I knew to *Engineering Record* and this information was embodied in the issue of April 25, 1914, copy of which I enclose you herewith.

"Dr. Raymond of the American Institute of Mining Engineers is the one man who knows Mr. Noble's war history, and I believe he could give you more facts than what are given in the above article.

"As you know, Mr. Noble was very loath to speak of his war experiences, and it was during the course of the last three years of rather close acquaintanceship with him that from time to time I was able to glean a few incidents. It appeared to me that he wanted to forget the Civil War. The humorous side he was more inclined to dwell upon. He never wore a Grand Army button, to my knowledge. He told me the following incidents:

"Some years ago, when he was Resident Engineer on the Memphis Bridge, a man wearing a Grand Army button, claiming to have been a Colonel or Brigadier General during the War, came to see Mr. Noble about some matter or other in connection with some material he was selling —I think it was paint—'He told me,' said Mr. Noble, 'That he had been at Chancellorsville, and mentioned a certain incident which I knew did not agree with the facts, which I told him. He seemed rather astonished at my information on this point, and asked me how I knew, and I told him that I was there. He asked me to what Army Corps I belonged, and what rank I held. 'I am the last surviving member of it,' I said. He seemed curious to know, and I replied, 'The great Corps of Privates.'

"On another occasion, in talking with him about the requisite qualities of a good soldier, he said, 'Ability to withstand hunger, fatigue, and hard marching, are very essential qualities, but to be a good runner was also often a very useful attribute.' At Chancellorsville, had his brigade not been swift-footed, including his Brigade Commander, they would have been encircled in Stonewall Jackson's flank attack, and along with 10,000 others been made prisoners of war.

"I was often impressed with a quality he had of being able to listen very carefully and then to give an opinion very quickly afterward. This innate faculty, together with his splendid ability in handling men was no doubt developed by his war experiences. He frequently made use of a remark which impressed me on this point. In speaking of individuals he would sometimes say that such a one 'had the qualities of mind essential in a capable military leader; namely, of being able to listen carefully, think quickly, act promptly, and be nearly always about right.'

"Of Stonewall Jackson he said that there was no Corps Commander in the Northern or Southern Armies who was to be compared with him. He stood in a class by himself.

"Of the war, he said that it might have been avoided.

"Of course you know more of him personally than I do, so I shall not go any further."

From Edgar O. Durfee.

"Yours of the 25th inst. asking me to give you certain data relative to the late Alfred Noble was received.

"I have known Alfred Noble as long as I have known anybody. His farm home was about a mile from the farm on which I was brought up, and I saw him very often. Some of the time we attended the same district school and the winter of 1861 attended the graded school in Plymouth where we were in the same class in higher algebra. From his earliest school days he always excelled in all of his studies. He was very studious, and as a boy was the same as a man, always truthful and always lived up not only to the letter but to the spirit of his promises. One little thing illustrates his character in that regard. He was eighteen years of age on the seventh day of August, 1862, on which day he enlisted in Company C, Twenty-fourth Michigan Infantry. His mother was thoroughly imbued with the idea that card playing was the greatest vice in the army—although we of the rank and file learned that the games played there were only euchre and old sledge. She asked him not to play cards, and he promised her he would not play cards while in the army. He lived up to this promise strictly, although he watched the boys play and learned more of cards than most of them, and as much as any of them. As soon as he was discharged from the army, July 1st, 1865, he joined with the other boys in the card games above referred to.

"His life on the farm was the usual boy's life, hard work and very little play. His school life until he went into the army was confined to the district school in his neighborhood and the graded school in Plymouth some three and a half miles away. In the army he did his duty at all times and during a part of 1864 was an orderly on the staff of General Warren then commanding the Fifth Army Corps and was discharged as a sergeant. He returned home and went to work on his father's farm in the harvest field. This work, he informed me afterwards, did not strike him as his particular line of work and he was anxious to do better. He went, I think, in July to Washington, D. C., and obtained a clerkship in the War Department where he remained two years, in the meantime studying so that in 1867 he entered the University of Michigan in the Engineering Department—Sophomore year—graduating in 1870. During his first two years as I learned, although I was not in college with him, he did not attend the University more than half of the time, being employed at other times in river and harbor work carried on by the Government in order to procure means to pay his expenses in college. He spent his whole time in college during his senior year. Probably all of the professors in his department at that time are gone and I do not know of any of his classmates now living who are handy to get at. My impression is that Justice Day of the United States Supreme Court was a classmate and intimate friend of Mr. Noble's and he could give you more valuable information as to his college course than I can.

"I think he was the best boy and man I ever knew, taking him all in all. He was very quiet, not given to boasting, was a warm friend, and had as fine a sense of humor as any person I ever knew. I am sure that everybody who came in contact with him as a boy and man was his friend.

"I think the foregoing will give you sufficient points in his early life as well as any particular details that you will want. You can no doubt work it out so that it will be readable."

Letter from Joseph Ripley, M. W. S. E.

"Replying to your favor of May 25, 1914, I will send you a synopsis of Mr. Noble's life at Sault Ste. Marie, Mich., at as early a date as possible.

"As you are undoubtedly aware, Mr. Noble served in the Civil War, enlisting on his eighteenth birthday as a private in one of the Michigan regiments. After the close of the War, he served as a clerk in Secretary Stanton's office for a couple of years. I suggest that you write to Mr. Noble's cousin, Mr. W. Durfee, who enlisted at the same time he did and who has been Judge of Probate in Detroit, Mich., for over thirty years, as he can give you full particulars of Mr. Noble's army service."

Sketch by Joseph Ripley.

"Alfred Noble, the pre-eminent engineer and man, was born at Livonia, Michigan, August 7, 1844. His parents, Charles and Lovina D. Noble, were prominent among the intelligent farmers who settled in that part of the state. Mr. Noble's fine physique was well developed by his boyhood life on a farm and his educational training was well grounded during the short term attendance of the country district and village schools. Enlisting as a private in the 24th Michigan on his eighteenth birthday, Mr. Noble served three years in the Army of the Potomac, taking active part in many battles. At Gaines' Mills he was in the rear guard protecting the retreat of the federals' and five times during the day, while busily firing, found himself with a squad of about six men at the very apex of the defense with the rebel advance charging within fifty feet of them. One night while on sentry duty after a hard day's march, and with his system filled with malaria, combined with the sleepiness of a growing youth, drowsiness overcame him, but an alert comrade on the next post awakened him just a moment before discovery by the officer on round of duty and thus escaped being shot the next morning with another sentinel who had been found sleeping at his post in the presence of the enemy. Mr. Noble was mustered out as sergeant. His army service also included nearly two years' service as clerk in the office of Secretary of War Stanton, and while in Washington he prepared for entrance in the University of Michigan. He attended class recitations fourteen months of the four years' course, as he was employed during the working season of each year on Government work, principally at Milwaukee, but also at several harbors along the eastern shore of Lake Michigan and on the survey of Lake Superior, at a salary during his junior and senior years of one hundred and fifty dollars a month. Mr. Noble received the degree of Civil Engineer with the class of 1870. The honorary degree of LL. D. was conferred by the University of Michigan in 1895 and by the University of Wisconsin in 1904. He was placed in local charge of the proposed canal and river improvements at Sault Ste. Marie, Michigan, in the fall of 1870. Mr. Noble married Miss Georgia Speechly of Ann Arbor, Michigan, on May 7, 1871, and their only child, Mr. F. C. Noble, is a distinguished engineer now in charge of one of the five field divisions of the subway construction by the City of New York. While at the 'Soo', 1870-1882, Mr. Alfred Noble designed and built the Weitzel lock, St. Marys Falls Canal. It was a bold undertaking, for in lift and size it was a wide departure from any existing locks. Previous lifts in locks had been limited to about 10 feet, the 'Soo' locks provided for 20 feet at extreme lift. It was 515 feet long between hollow quoins, 80 feet wide in the chamber narrowing to 60 feet at the gates and with depth of 17 feet of water on the miter-sills. The masonry was of the finest of its kind ever built in this country. The filling and emptying culverts located under the floor of the lock, the gate hangings and the hydraulic operating machinery were all new features. The gate and valve engines have been in constant use every season since 1881, and have worked easily, efficiently, and rapidly, without any failure and without repairs except the annual repacking of the cylinders and occasional renewal of minor parts such as bolts and cables. Among other improvements to the canal was the deepening, widening, and straightening of the old State Canal, the replacement of the paved side slopes with vertical walls of timber revetment, and the building of a movable dam consisting of a swing-bridge carrying a modified form of a Chanoine wicket, which was designed by Mr. Noble for a barr.. against Lake Superior in case of wreckage of lock gates.

"The survey of St. Marys River, extending from Lake Superior to Lake Huron, a distance of 65 miles, was made in 1879, and the Lake George route was deepened from that of 12 to a navigable depth of 17 ft. and the narrow, tortuous channel was materially straightened and improved to a general width of 300 ft.

"Mr. Noble was in charge of operating the canal for a year and a half.

"The expenditures on the canal and river improvements made by Mr. Noble totaled about $3,000,000. His salary was gradually increased to the munificent sum of $3,000 a year. He resigned in August, 1882, to accept a position as resident engineer under Mr. Bouscaren on construction of the Shreveport, La., bridge at a salary of $2,100 a year.

"While at the 'Soo' Mr. Noble did the work of three or four expert engineers. He worked twelve to eighteen hours every day and his only vacations were taken during the last three years of his stay there, when he spent about a week of each year trout fishing along the east shore of Lake Superior.

"He was a remarkably fine mathematician, a rapid and accurate computer, an expert draftsman and penman, and had the gift of writing concise, plain and accurate statements and reports.

"He had the engineering sense to grasp the broad and controlling feature of a great work and the rare faculty of also grasping all the intricate details pertaining to the problem. Whenever a question was asked him about any part of the lock work he could give at once a correct statement without stopping to think it over before being able to recall the particulars and their related bearings. When several hundred men were employed on the work he knew and called every one by name, and could tell the value of each man as a workman. He was always pleased to find any employe taking special interest in his work, and would cheerfully aid in furthering that interest by explanation, by teaching, or in other ways. He was always pleasant, genial and sympathetic. He insisted on honest integrity, industry, clean and pure living in a man. He seldom spoke disparagingly of any person. I only knew of three men whom he personally disliked, and those three he believed to be dishonorable and hypocritical. He was generous. By accident I have learned of several instances where he has contributed considerable sums of money regularly for one or more years where employees have been injured, or who had dependent families sorely in need of assistance. I have known him to be tried by all kinds of aggravating conditions and subjected to most trying annoyances, but his wonderful patience mastered them all. Only once have I seen him thoroughly angry, and then he showed it only by his silence, limiting his remarks to 'yes' or 'no' for three days. He was a great and most successful leader. It was no wonder that all his employees were loyal to him, willing to give the uttermost possible to acceptably serve him. No military officers could possibly obtain such service from men under their command."

Letter from Joseph Ripley.

"Replying to your request of May 25 for a short synopsis of Mr. Noble's activities at Sault Ste. Marie, I am enclosing herewith a statement relating to his work at that place, and some other information relating to him, leaving it to you to cull out such parts as you may desire to use.

"While Mr. Noble undoubtedly understood and knew of his marked ability, he never appeared to realize that he excelled or to assert it, but had a quiet, unassuming, reserved, and kindly personality which was most attractive.

"I first met Mr. Noble in 1872 and have had intimate acquaintance with him since 1876. Those of us who have been attached to him in the kindly feelings of long acquaintance counted him as one of the few really great men we have known, and believe that one of the grandest and most useful men of this country has gone from us.

"The lock Mr. Noble built at the 'Soo' was named for Godfrey Weitzel, who was the ablest and broadest of all the officers in the Corps of Army Engineers, and he always gave Mr. Noble full credit for his part of the work at the 'Soo.' (See Johnson's Encyclopedia; Article on St. Marys Falls canal, which was written by General Weitzel.)

"When the first boat, *The City of Cleveland,* was locked through to the Lake Superior level, the occasion was made quite an event, and about twenty engineer officers were present. Mr. Noble did not ride with the officers on the steamer, but stayed on the wall, watching locking operations. I heard Major (later General) Roberts, author of 'Roberts' Parliamentary Rules', congratulate General Weitzel on the completion of the greatest lock in the world, a work which would be a great personal honor and give renown to General Weitzel personally and, through him, be credited to the Engineer Corps and add much prestige to it. General Weitzel replied that 'Alfred Noble deserved all the credit for designing and building the lock.' Other officers present joined with Major Roberts in strenuously objecting to General Weitzel's statement, saying that he (General Weitzel) was entitled to all the credit and honor for the success as he had the entire responsibility and would have had to have taken all the blame and discredit if there had been a failure. General Weitzel forcibly remarked that his risk as to failure did not count for anything, because he had Alfred Noble for his Engineer.

"When General Sherman made a tour of the Western forts, Mr. Noble was directed by General Weitzel to meet the party on arrival at the 'Soo' and to show them about the lock works. Mr. Noble delegated his assistant, Mr. Davock, to meet General Sherman while he (Mr. Noble) went up to the head of the canal and stayed there all day, so as not to put himself at all forward in the presence of so notable a man.

"You are of course familiar with Mr. Noble's experience on bridge work in his practice as consulting engineer and also with the part he had to do with the movable dam located near the head of the Water Power Canal at the 'Soo' and the remedial works located across the head of the Rapids. His study and report on the hydraulic conditions resultant in the change of the regimen of the river due to the construction of the Power and Ship Canals at the 'Soo' was a complete treatise on the intricate problems relating to river and lake reservoir hydraulics.

"Mr. Noble's one recreation was trout fishing, and every year since 1902 he has spent from two to six weeks in camp along the north shore of Lake Superior with a small party of old associates. Each outing trip greatly benefited his health and the last time I saw him, on March 31, he planned the details of the anticipated trip in July.

"I suggest that the 'Western Society' or else the 'American Society of Civil Engineers' publish a memorial volume for Mr. Noble."

From A. Mackenzie, Brig.-Gen., U. S. Army.

"Your letter of September 3d reached Washington during my absence in Europe and itself became something of a wanderer, taking some time to come into my hands.

"I grieve over Noble's death; though our lives lay apart for many of the last years of his life, memory and occasional happy meetings kept fully alive the strong bonds of friendship, which were established back in the seventies, when we were first thrown together and worked side by side in Detroit and at the 'Soo.' None of his legion of friends found more pleasure than myself in watching Noble rise to the top round of his profession and at the same time win the hearts of all through his personality.

"So frankly honest was he, that his whole life was an open book from the time he quietly entered upon his chosen profession at the Sault Ste. Marie Canal—while still a student—up to and through his career as a world-known master.

"Not the least of his great virtues was his inherent modesty, which, as is known to many of his friends, threatened at an early day to draw him to a different line of engineering work from that to which he proved himself so perfectly adapted and in which he succeeded so grandly. Not long after entering on his engineering work he was offered a professorship, under conditions which led him to look upon the offer with favor, but his friends of those days—of which I am proud to have been one—felt that Noble was destined to become an active participant in the great construction work of his profession, to a much greater extent than his natural modesty permitted him to admit, and fortunately our counsels prevailed.

"No life's record brings to the individual or to the engineering profession more honor than that of Alfred Noble."

From Ralph Modjeski, m. w. s. e.

"Although I had met Mr. Noble as early as 1887, I did not come into close contact with him until 1892. He was then resident engineer of the Memphis Bridge and I was one of his numerous assistants. It was then that I came to love the man for his great and unusual qualities. He always came to the office first and usually left last. No matter how some of us tried to be on the work ahead of him, we always found Mr. Noble there. His treatment of his subordinates was exceedingly kind without being lenient. Always ready to help with word of advice or to turn up his sleeves and join in the work if he saw he could help. No work was too trivial or too irksome for him. Nothing was neglected or passed over. His great accuracy and quickness of figures were proverbial.

"It was my good fortune to occupy with Mr. Noble the same office in the Monadnock Building in Chicago from 1900 until he was called away to New York on the Pennsylvania Tunnel work. In 1901 we formed a partnership under the firm name of Noble & Modjeski, and were given the contract for the engineering of the Mississippi River Bridges at Thebes, Illinois. Previous to that Mr. Noble was on the Deep Waterways Commission and later designed some regulating gates and other work for Sault Ste. Marie Power Company.

"During the constructing of the substructure, Mr. Noble and I took many trips to Thebes together. On one of those trips we had a drawing-room. As Mr. Noble was a very large and an older man than I, I insisted he should take the large bed and I slept on the narrow couch. On the return trip, however, Mr. Noble sneaked into the drawing-room very early and went to bed on the couch. I noticed the manœuvre too late, and no amount of persuasion or pleading could make him give up the couch for the larger bed. This is given as characteristic of the man.

"Another characteristic incident: When Mr. Noble was going to Panama, he asked me to keep his club dues paid, 'For,' he said, 'I should not like to be posted as delinquent, and again I should dislike *not* to be posted if I deserved it.'

"Our partnership continued until the opening of the Thebes Bridge in May, 1905. As mentioned above, Mr. Noble moved to New York to take charge of the Pennsylvania Tunnels in 1902. Even after that date, he visited Thebes from time to time and aided me with his valuable advice in completing the work.

"He was most scrupulous and generous in money matters. Always ready and desirous to give more than he received, not only in money matters but in everything else.

"I know of no instance when Mr. Noble declined to see anybody who called on him, or to discuss with any one even the most trivial subjects. He never refused to give advice when asked for it, even on purely personal matters, and my experience has been that his advice was always good. He gave it very clearly, being apparently able to grasp the situation at once and his reasoning was always convincing. Yet when, on very rare occasions, he was mistaken, he never hesitated to admit it. Although always very busy he never made his callers feel it. On the contrary, he was always leisurely and kind when talking with them.

"When work was slack he studied or classified his engineering data and worked always. His knowledge of engineering matters was most thorough and was not confined to one branch of engineering only. Bridge work, water-power, harbors, canals, tunnels, railroads were, one might say, his specialties.

"He was a great man, and a great engineer. When I think of an ideal to work up to, both as engineer and as man, Noble comes to my mind first of all."

From O. H. Ernst, Brig.-Gen., U. S. A. (*Retired.*)

"I first came into close association with Mr. Noble in 1899 when the

Commission was created to examine and report upon all the routes for a ship canal across the Isthmus between North and South America. Besides Mr. Noble and myself the members of the Commission were Admiral J. G. Walker, U. S. Navy; Gen. Peter C. Hains, U. S. Army; Hon. S. S. Pasco, formerly U. S. Senator from Florida; George S. Morison, C. E.; William H. Burr, C. E.; Lewis M. Haupt, C. E., and Prof. Emory R. Johnson. The elaborate investigations which the Commission had to make involved long journeys in Europe and Central America in which the members were brought into remarkably close personal intimacy. In the journey to Central America and over the Nicaragua and the Panama routes, they lived for several months as a single family, and had every opportunity for observing the personal as well as professional characteristics of each other. The public accommodations were rarely sufficient for a party as large as ours, and the opportunities for the display of selfishness or bad temper were constant. Throughout these expeditions Noble's equanimity never for a moment deserted him. His sweetness of disposition and generosity of temper endeared him to all.

"His professional work upon this Commission was of a very high order. With untiring industry he mastered the details of every branch of the investigation, and then with sound judgment and judicial temperament he reached conclusions which could not be shaken. Mr. Morison, himself one of the most eminent engineers in the U. S., said to me one day that Noble would be a good man to build the canal. This is a fair illustration of the esteem in which he was held by his colleagues on that Commission.

"My subsequent association with Mr. Noble, aside from the Panama Canal, related particularly to the hydraulics of the Great Lakes, and confirmed me in the conviction that, for the solution of any engineering problem involving long and careful analysis, he had no superior."

From William R. Day.

"I have your favor of the 24th ultimo, and am glad to know that the National Engineering Societies of this country have appointed a committee to prepare a suitable memorial to the late Alfred Noble.

"It was my privilege to be a classmate of his in the University of Michigan, where we graduated together in the class of 1870. I have met him from time to time since, and have known of the great career which he has had in his profession, and am glad to know that it is the opinion of his associates that he was among the first engineers of this country.

"I well remember when Alfred Noble came to the University of Michigan, where he entered the Sophomore class in 1867. He was somewhat older than the rest of us, and, in my opinion, far more able than any of us. He had had three years' experience in the army, and those who knew him there said that he had been a faithful and valiant soldier. I do not think any of his classmates ever heard him speak of his army career. He probably regarded it as merely a part of his duty, and not a thing to be talked about. Moreover, he was at all times the most modest and retiring of men. Those of you who knew him, I think, will have marked this characteristic.

"I was with him on a number of occasions after he had become a famous engineer, and know that he was ever reluctant to have any exhibition of special honor to him, when, as everybody knew, he deserved it.

"As I say, he was older than the most of us, and I think his army experience had matured him at an earlier age than men usually reach a proper view of the responsibilities of life. In college, while he was always friendly, kind, and helpful, his time was given to the faithful pursuit of his studies when he was not employed, as he was at times in his college course, in government work.

"In his case, the boy was father to the man. He was modest, kindly, industrious, and capable, as boy and man. I need hardly say to you that he had particular aptitude for the science of engineering, and unusual skill in the higher mathematics. While he was easily, in my opinion, the first man in our class, I do not think there was any of his fellow-students who had the slightest feeling of envy or jealousy toward him. By common consent he was our intellectual leader. We all liked him, and the more we emulated his example and tried to reach his attainments in scholarship, the better it was for us.

"The last time I saw Alfred Noble, was at the great Michigan banquet in New York in 1911, when as a member of the New York committee he did very much to make that function the great success it was. With his great qualities and achievements, he had a gentle vein of humor that made him the most agreeable of companions. In person, as you know, he looked his part, and was a most attractive man. To have known him and had his friendship is one of the most pleasant and valued recollections of my life. I was much saddened to learn of his death, and, as I have said, I am glad to know that the profession which he honored is taking measures to provide a permanent record of his great career."

From James H. Brace, m. w. s. e.

"While thoroughly appreciating all the benefits of several years' close connection with Mr. Noble in some of his later works, the writer likes best to think of a month's vacation spent with him in fishing and sailing or rowing along the solitary north shore of Lake Superior.

"The happiest years of Mr. Noble's life were doubtless those in which he was employed at and about Sault Ste. Marie, Michigan. When he first went to live there, the country was very much isolated, particularly in the winter season, as there was then no railroad nearer than Cheboygan on the Southern Peninsula. After navigation closed the only means of communication was overland either by sleighs or on snow shoes. Mr. Noble frequently had to make the trip overland to Detroit on Government business.

"In the summer he often found it necessary to make surveys along the beautiful shores of the St. Marys River and through the bush that even yet covers most of the back country. In those days he occasionally found time to make short fishing trips along the rugged shores of the great lake to the north. It was here, too, that he formed some of his most intimate friendships, partly among the residents of the town, and partly with his associates.

"After he had made an assured success in his profession, Mr. Noble formed the habit of spending a month or six weeks every summer along the northeast shore of Lake Superior. A sort of informal club was composed of his old friends of earlier years. Among these were Chase Osborne, George Kemp, Judge Steer, and Joseph Ripley.

"A comfortable outfit composed of a sail boat, row boats, tents, etc., was gathered together at the 'Soo.' Mr. Noble spent much of his spare time from early spring planning for this trip.

"He took especial pleasure in a friendly rivalry with George Kemp in seeing who could secure, for a present to the other, the most novel or outlandish fly or other device supposed to be attractive to trout.

"Mr. Noble liked well to bring his friends of later years on these trips and one could not please him better than by genuinely enjoying the outing. The guides and cooks were obtained from among the Indians and half breeds living near the 'Soo.' Many of them were well known to Mr. Noble, and had formerly been employed under him on the construction of the Weitzel Lock.

"On this occasion the actual trip took about three weeks from the time of leaving Sault Ste. Marie to the return to Michipicoten Harbor. During this time the party was continually out of touch with civilization, as no mail, telegrams, or telephone messages could reach it. Here Mr. Noble took complete relaxation from his usual cares and duties, and this was practically the only time through the year that this was the case.

"It was by no means an idle time, however, for there was the early plunge in the cold water of the lake, then breakfast and a prompt start for the day's business. If the party was to move, camp was broken at once. The day was fully occupied either with fishing or traveling.

"Mr. Noble took especial delight in properly rolling his blankets in the way he had learned to do in the Army. As fond as he was of fishing, nothing could induce him to go out when there was an ample supply for food for two or three days in advance.

"During the trip there were some trying experiences from wind and weather, but throughout these, as well as during the sunshine, Mr. Noble displayed the same kindly good humor and thoughtful consideration for others that characterized all his relations with his fellow-men.

"In the long twilight after supper, Mr. Noble could sometimes be induced to talk of his war experiences. He was very reluctant at all times to discuss this subject. He seemed to believe that it was every good citizen's duty to serve, then when the war was over, go about his regular business as though nothing had happened; that the country owed him nothing for his services, and that there was no good in keeping up the old spirit.

"The most vivid impression, however, was that of the earnestness of purpose that actuated both Mr. Noble and the members of his company that was mainly recruited from the farming district adjacent to Detroit. There was apparently no glamour about it. They knew exactly what they were fighting for, believed in the right of their cause, did their utmost in a humble way for its success, and most of the original company were more than glad, when that cause had triumphed, to return to the ways of peace.

"Mr. Noble also gave some idea of his struggles for an education, both before leaving home and after the war was over.

"He commented quite freely on many of his associates, and although some of his experiences must have been unpleasant, he was always generous in his praise of their good points.

"In conclusion one could not come back from these few weeks of close association with him in this solitary region without feeling a lasting influence for good."

From J. Waldo Smith, Chief Engineer, Board of Water Supply, New York City.

"I beg that you will excuse me for the delay in answering your letter of October 24, asking me to contribute information which might be of assistance to you and the other members of the committee in preparing a suitable biography of the late Alfred Noble, with particular reference to his work in connection with the Board of Water Supply.

"Mr. Noble accepted employment as one of the Consulting Engineers of the Board of Water Supply in September, 1909, at the time when the Pennsylvania Railroad improvements in New York City were nearing completion. Previous to this, he had been repeatedly urged by Mr. Bensel, the President of the Board, and myself to investigate certain special conditions, but he advised us that he felt that all his time and energy belonged to the Pennsylvania Railroad, and refused to entertain any offers made to him. This was characteristic of the man—conscientious almost to a fault, always rendering a high order of service, and refusing to devote his energies to, or do, anything which would detract from his usefulness on the particular work which he had in hand, no matter how strong the financial inducement might be.

"At the time Mr. Noble's services were sought, some misgivings had arisen in the minds of the members of the Board as to the practicability and ultimate success of the tunnel underneath the Hudson River between

Storm King and Breakneck Mountains, and a bridge crossing the river at that point was being considered somewhat seriously. The Commissioners all agreed that they were entirely satisfied to be guided by the advice and conclusion which Mr. Noble might reach after making a careful investigation of the whole subject. By reason of his long experience in the design and construction of large bridges, as well as his recent experience in connection with the Pennsylvania tunnels, and more particularly because of his sound judgment, exercised only after the most careful study of all the details and conditions, he was ideally fitted to undertake such a task. For myself, I was prepared to place absolute confidence in his findings, because through my intimate knowledge of his work here in New York, as well as my close association with him, through the late Charles L. Harrison, I had been very strongly impressed by the soundness of his judgment, the breadth of his knowledge of engineering matters and the care with which he pursued his investigations, and was convinced that he would render an absolutely impartial judgment and not be swayed by prejudices or any political considerations. His report to the effect that every expedient should be exhausted before the deep pressure tunnel was given up practically settled all questions which had been raised.

"His advice was most valuable in connection with many of the details of the design and construction of parts of the work, particularly in connection with the large pressure tunnel (18 miles in length) running under the city of New York and the large dams at Ashokan and Kensico. He never rendered snap judgment on any problem or question. His advice was given only after painstaking consideration and careful study of all the details and conditions. He would never attempt to give advice on any matter for which he was not thoroughly fitted by experience. His attitude was always one of helpfulness, and he gave largely of his store of experience and skill without price to any one seeking information.

"If there was a wreck or failure, he did not condemn the whole structure; he sought to save what was good and would stand the test of sound engineering principles and design. He possessed a very keen intuition, and was not unmindful of practical considerations of business or even political conditions that surrounded any problem, but his findings were never tempered by prejudice. He was always constructive, always working for something better; he was never destructive.

"Mr. Noble was not demonstrative. He talked but little, but what he did say was always very much to the point. He was generous and kindly, and more considerate of others than he was of himself. He hated deceit and misrepresentation in every form. I remember a little incident which occurred about a year ago, shortly before the change in the city's administration. He told me he could see that there was to be a strong cry for economy in all the operations of the city, and that, whether it was advisable or not, strong pressure might be brought on our Board for the reduction of expenses, and so he suggested that as he was the last of the three Consulting Engineers to be appointed, he would retire, in order that the others might not be disturbed. Neither the members of the Board nor I would listen to such a proposition, as we believed that his counsel was too valuable to lose at a time when the work was to be put under test, and his services might be very necessary. It is undoubtedly true that there was no other man in the profession who was held in higher esteem or who was so generally liked and respected."

From Charles P. Light.

"It is very hard to write an appreciation of a man as modest as Mr. Noble was, this very trait having the effect of keeping one from saying a good many things that he might have otherwise given expression to. He endeared himself to all of us through the deep interest that he took in the work of our Association. The demands upon his time were multitudinous, yet he never missed a meeting of the Association. Mr. Saunders of the Ingersoll-Rand Company, gave voice to a sentiment concerning him that I most heartily concur in, it being as follows:

"'Obituary

"'Alfred Noble

"'At three score years and ten a useful life
Has run its course. And as we think of him
The sorrow and the flowing tears of friends
Are turned to joy that such a one as he
Has lived and wrought. Here was a man who led
In building up, a mind endowed to see
And think and do in all the larger things,
A captain leading men on nature's fields
To win in building monuments of peace.
This engineer has shattered nature's works
To make the world a better dwelling place
For all of us. His life was gentle and
No thought of self within him dwelt. He won,
Scarce knowing why, the plaudits of the world.
Upon his monument let it be writ:
He was an engineer. He was a Man.'"

From W. H. Burr.

"My acquaintance with Mr. Noble began when he was engaged on the work of construction of the Washington Bridge across the Harlem River at New York City. This, however, was but a casual meeting on two or three occasions at most. My close acquaintance with him began only after he had completed the Memphis Bridge and had returned to Chicago to commence his independent consultation practice. I remember particularly meeting him in Chicago in December, 1896. We talked much about the foundations of the Memphis Bridge on which he had recently been engaged and for the success of which, it may properly be said, he was mainly responsible. It was not in accordance with his nature to make such a statement, but I write it as being just to him.

"He was probably one of the most modest men in the profession, and never failed to accord to his chief all credit for the conception of work and the principal administration of it.

"The conception of the design of the Memphis Bridge, both superstructure and substructure was, of course, Mr. Morison's, and he was responsible for the general administration of the work, but I think it may be properly said, without in any way detracting from the credit due to the chief, that there were exigencies in the course of the substructure operations when Mr. Noble's presence and personal supervision and his fine engineering judgment were literally the saving of more than one threatening situation.

"At the period when he was engaged on this bridge he had reached mature age and had enjoyed abundant opportunity, through experience in many important works, to develop a well-trained judgment effective for the wide range of engineering operations for which he was noted during the last twenty or more years of his life.

"It was but three years later when the first Isthmian Canal Commission was appointed by President McKinley with Mr. Noble as one of its members. His fitness for this Commission was greatly enhanced by the fact that he had already been a member of the Nicaragua Commission for the purpose of examining and reporting upon the Nicaragua route for a ship canal between the Atlantic and Pacific Oceans.

"The work of this first Isthmian Canal Commission extended over about a year and three-quarters, although it had official existence for about two years longer.

"It was as a colleague on this Commission that I came to know Mr. Noble most intimately. The work of the Commission was of a pioneer nature. Little was authoritatively known of the Nicaragua route and grossly exaggerated statements, to say the least, regarding the French work at Panama had greatly obscured knowledge of the Panama route. It was the duty of this Commission, therefore, not only to make the most thorough physical examinations of the Nicaragua and Panama routes, but also to visit Costa Rica and the Isthmus of Darien. Large engineering forces were at work for many months in both Nicaragua and Panama, securing data by surveys, borings, and other examinations which required extended treatment subsequent at Washington in the preparation of the report. In all this work in Central America and at Panama, and subsequently in the reduction and preparation of data in Washington, Mr. Noble was skillful, wise and tireless. He was not only the experienced professional man, but most gracious and invariably kindly in his relations with every member of the Commission. He was patient in times of difficulty, and frequently lightened the troubles of many unwelcome conditions by bits of quiet humor in which he was wont to indulge.

"He was one of the most companionable of men and while he could express himself with vigor whenever occasion might demand it, his nature was to accomplish his purposes through quiet and gentle procedures. In fact, he may properly be characterized as a gentleman in the best sense of the word.

"Although he would have been one of the last men to assert the possession of mathematical ability or of mathematical tastes, as a matter of fact, on a number of occasions, I have seen him exhibit greater power of mathematical analysis than is found among most engineers. It became necessary in preparing the report of the first Isthmian Canal Commission to consider the treatment of some hydraulic questions of magnitude and of much more than ordinary difficulty. Some of this work came under the scrutiny of Mr. Noble, and his treatment of the requisite analysis did credit to his mathematical ability.

"I saw the same quality exhibited in connection with some preliminary work for the Barge Canal of the State of New York while I was a member with him of a Board to which some questions connected with that work had been submitted. This analytic quality of Mr. Noble's mind, I think, has not often been recognized, even by many of those of his own profession who knew him well. It is of interest in connection with the deprecatory observations usually made regarding the possession of mathematical capacity by engineers. The possession of that faculty certainly did not trench seriously upon the excellence of Mr. Noble's engineering judgment.

"Throughout the whole laborious operations of the first Isthmian Canal Commission, Mr. Noble bore his full share from the beginning to the end, and his services aided much in giving to the report its high value.

"After becoming a member of the Isthmian Canal Commission he resided uninterruptedly in New York City, and my acquaintance with him was continually close until his death. During the last four years of his life we were associated on the Board of Consulting Engineers of the Board of Water Supply of New York City, Mr. John R. Freeman being the third member. This professional work included much deep tunneling for which Mr. Noble was finely equipped by his experience in the construction of the East River Pennsylvania tunnels and the tunnels connecting them with the Pennsylvania Station. This work, like all that he had done before, was characterized by great thoroughness. Whenever a problem arose his treatment of it was characterized by a patient thoroughness which could scarcely fail to lead to effective solution of any troubles which might be encountered. It seems to me that he possessed a capacity for deliberate and searching consideration of all the elements of engineering problems seldom equalled by any member of his profession. I have thought that this was largely due to the mathematical quality of his mind to which I have already alluded, but which seldom found expression by mathematical formulæ.

"He possessed unlimited stability and poise of mind. He could not be surprised into a conclusion not justified by his judgment, and it was unthinkable that he should reach an unwise conclusion through crude impulse. In endeavoring to find what qualities gave him the prominent position in the profession which he held, I think one must look chiefly to his perfect stability of character and judgment, his kindly nature unfailingly exhibited to all those with whom he came in contact, his uncompromising right principle, and his fine analytic capacity which he brought to bear on all engineering questions. He was not a man equipped with what may be called a brilliant searchlight of genius, challenging admiration by his phenomenal mentality and thus becoming an acknowledged leader of men in spite even of opposition. Alfred Noble was not of that type. He won his position of professional prominence by the more substantial and never failing qualities of personality and character and by his kindly good will, which always made him attractive. He was not a leader in the aggressive sense of the word, but the profession of which he was so long an honored member accorded him a high position because he had won it by the excellence and real worth of all that he did and was."

From Robert Ridgway.

"Some time ago Mr. J. Waldo Smith showed me your letter to him of October 24, 1914, requesting him to contribute information to assist you and other members of the committee to prepare a biography of the late Alfred Noble, and suggesting that I might be able to contribute something as well. He has also given me a copy of his reply of December 10th, which is so complete regarding Mr. Noble's connection with the Board of Water Supply work that I can add nothing to it.

"I presume you know that Mr. Noble was retained by the Public Service Commission for the First District, State of New York, on the recommendation of its Chief Engineer, Alfred Craven, to act as consulting engineer to him. This appointment became effective November 1, 1912, and terminated with his death. He entered upon his duties with the conscientious thoroughness that was so characteristic of him, and his advice was a great assistance in solving some of the large engineering problems of subway design and construction in connection with the execution of the Dual System of Rapid Transit for New York City. Particularly is this true of his work on the specifications and features of design for the new East River tunnels and their connections which are a part of the Dual System. Each tunnel, or rather pair of tunnels, will consist of two single-track cast-iron-and-concrete-lined circular tubes of a type generally similar to the present subaqueous transportation tunnels about this City. The tubes for the Interborough Rapid Transit Company's system will extend from Whitehall Street, Manhattan, to Montague Street, Brooklyn; those for the New York Municipal Railway Corporation's system will run from Old Slip, Manhattan, to Clark Street, Brooklyn. I presume you have whatever details you may need of these tunnels, but if not, I will be pleased to furnish them if you desire me to do so. The engineering features of the contracts and specifications and the general designs were prepared under the direction of the Chief Engineer by Mr. Alfred Noble's son, Frederick C. Noble, then Engineer in charge of our Sixth Division, which included the East River Tunnels, and they were carefully reviewed by Mr. Alfred Noble, and in their final form are the result of his advice. His experience with the construction of the Pennsylvania

Railroad tunnels under the East River gave added value to his advice. These contracts have since been let to the Flinn-O'Rourke Company, Inc., at the bid price of $12,444,725.

"You have known Mr. Noble so long and so well that anything I might say about his personal characteristics would simply confirm what you already know. He was considerate of the honest opinions of others, and was always ready to give full credit to his subordinates, including the laborers in the workings, for whatever of good they suggested or accomplished.

"He was intolerant, however, of incompetency and pretense.

"If there is any further information you desire that I can furnish, please command me. I am sorry this letter has been delayed, but when I read Mr. Smith's letter to you I was under the impression it gave you all the information that I could give you. It occurred to me only recently that perhaps what I have told you of his work with this Commission might be of interest to you."

From Henry Goldmark, m. w. s. e.

"As suggested by you, I consulted with Mr. F. C. Noble with regard to the data desired in connection with the life of his father. There were a few dates as to which I was able to make Mr. Noble's notes more complete. I do not know that I can add very much to such information as you already have.

"My own acquaintance with Mr. Noble dated back to the early 80's. At that time he had recently left the government employ and was with the Northern Pacific Railroad, engaged in active construction. I was inspecting the ironwork for a bridge at the south crossing of Clark's Forks, while he was in charge in the field. This bridge was designed by Mr. Geo. S. Morison. I was even then greatly struck with the manner in which Mr. Noble followed up every detail on this bridge. From 1888 to 1892, Mr. Noble was resident engineer for the Memphis Bridge, while I was stationed at Kansas City as Bridge Engineer for the Kansas City, Fort Scott and Memphis Railroad and allied lines. Mr. Geo. H. Nettleton, President of both Companies, and one of the finest men I ever met, often spoke to me about Mr. Noble, expressing his admiration for the latter's high qualities. The way in which he handled that big bridge was a revelation to me, especially his thoroughness and the total absence of friction in the organization. While the plans were made elsewhere, the successful completion of this difficult work was due very largely to Mr. Noble.

"It was not until 1897 that I worked directly under Mr. Noble, when he was one of the United States Board engaged on plans and surveys for a ship canal between the Great Lakes and New York Harbor.

"He was very anxious that the subject of lock gates should be thoroughly investigated from a broad, practical standpoint, and was quite willing that ample time should be spent upon this study. I am sure those engaged on it would never have had the perseverance to finish the laborious task except for Mr. Noble's own example.

"Apart from his very lovable personal traits, I have never met any one who, as an engineer, combined an infinite capacity for detail with the broad, common-sense view of the points involved in an engineering undertaking. While not without prejudices and strong opinions, he was always willing to discuss debatable points, and was readily convinced when the weight of the evidence called for a change of opinion. He chose his assistants with care, and required a great deal of them, although not as much as he demanded of himself. When he had once given a man his confidence, he was entirely willing to leave to him the carrying out of his instructions, and such suggestions as he made were always conveyed in a kind, generous manner, which made it a delight to talk over any point with him.

"Personally, I have felt his loss severely, and the world is to me poorer since the chance of meeting him from time to time has gone."

From Logan Waller Page.

"In the death of Alfred Noble the American Highway Association has lost its greatest and most useful member. It was not alone through his eminent reputation as an engineer, or the mere lending of his name to the undertaking, that made the Association succeed. Before the founding of the Association was decided upon, Mr. Noble's sound advice and inspiration guided the few interested in the movement to direct their efforts along practical and useful lines. He attended the founders' meeting, and was there elected a member of the Executive Committee, on which he served to the time of his death. During the four years that he served on this committee he never missed a meeting. The last meeting that he attended was in Detroit, Michigan. He made the long trip from New York City to Detroit and return for the sole purpose of attending this meeting, and at a real sacrifice to his private interests.

"When the Joint Congressional Committee on Roads, Congress of the United States, invited the Executive Committee of the Association to advise it in regard to Federal aid legislation, Mr. Noble attended the hearing and submitted to a long cross-questioning on the subject.

"These few examples of his generous and continued effort are given to illustrate the deep interest he took in work of a purely public service character. Not only did he give freely of his time and best judgment to the affairs of the Association, but he was always liberal in his financial support. He also drew many of his friends, who were among the most eminent men in the country to the councils of the Association. He was many times asked to accept the presidency of the Association, but, in his modest way, declined to accept any position of prominence, saying that he could serve the Association just as well on its Executive Committee as he could as its president. The loss of his counsel, advice, and deep interest has been the greatest blow the Association has sustained."

From Ralph Modjeski, m. w. s. e.

"In answer to your recent reminder as to information regarding Mr. Noble's connection with the Thebes Bridge, the following may be of use.

"Mr. Noble and I formed a partnership for the purpose of engineering the Thebes Bridge over the Mississippi River at Thebes, Illinois, in November, 1901, at which time we were engaged jointly to design and build that bridge. From that time until January, 1905, Mr. Noble devoted a great deal of time to preliminary work on that bridge, and to designing of the substructure. There had been a tacit understanding between us that Mr. Noble would take care of the design of the substructure, leaving the superstructure largely to me. In January, 1905, he was called away to Galveston in connection with the new sea wall, and while there he received a proposition from the Pennsylvania Railroad to take charge of their East River Tunnel in New York. He did not wish to accept that proposition until he had ascertained that it would be acceptable to the railroads who were building the Thebes Bridge, and to myself, and until he received assurances from the Pennsylvania Railroad that he could be permitted to come to Thebes from time to time, to supervise the work in a general way. He finally made arrangements to that effect, and left for New York in February, 1902. He came to Thebes from time to time during the construction of the bridge, and devoted considerable time to making a final settlement with the contractors for the substructure.

"I feel that to Mr. Noble's wide experience and wisdom is largely due the success with which the work was carried on to its completion, and it was mostly due to his great tact that the very complicated situation with the substructure contractor—due to delays caused by high water and other circumstances—was finally settled in a manner satisfactory to all concerned.

"The bridge was completed in April, 1905, at which time our partnership was automatically dissolved."

From Hugh L. Cooper.

"American Engineers will be universally shocked as the news is conveyed to them of the death of Alfred Noble, a man who has been honored with the presidency of the American Society of Civil Engineers, and who in his lifetime achieved a far greater honor in the universal respect in which he was held by every one who knew him or knew of him.

"It was not my good fortune to know Mr. Noble personally, except in a very casual way, but his life work has been an inspiration and an exalted example to me for twenty-five years, as I have no doubt it has been to hundreds of other engineers.

"Growing out of this feeling, it has occurred to me that it is a very opportune time for the engineering profession in some unusual way to recognize the value of his service to the world at large, as well as to engineering. Can we not now inaugurate a strong movement having for its purpose the erection of some suitable monument or memorial illustrating in some degree to generations to come the great work Mr. Noble performed and the loss the nation suffers in his death?"

From James Forgie.

"I am honored by a request from Mr. Modjeski, Chairman of the Biographical Committees of three engineering Societies, as a one-time Britisher representing the Institution of Civil Engineers (in America), to give a contribution in writing to the memory of Mr. Noble. It includes tributes to the following British Engineers—Mr. Charles M. Jacobs, Mr. E. W. Moir, Sir Maurice Fitzmaurice, and Mr. Henry Japp, who all have kindly permitted me to incorporate them in this memoir.

"Some people, maybe the weaker of us, are greatly influenced by the lives of others, in youth, maybe, by a biography such as the 'Lives of the Engineers' (Smiles); and again in youth and in manhood, by actual touch with the real lives of men. I must confess to this weakness, and among not a few Engineers of rare good character and technical ability it has been my good fortune to know, profit by their example, and work with, and which include those highest in the Engineering profession here and in Britain, there is none more dear than the late Mr. Alfred Noble. I was closely associated with him socially and often professionally for about twelve years and to me he embodied all the many qualities.

"Any one who knew Mr. Noble is restrained from eulogy regarding him for two reasons: first, his character, to which obituary may do and usually does injustice, and, second, the disfavor with which he would view our biographying him. For the common good of us all and future generations of engineers, this restraint must be laid aside.

"I have received from Mr. Chas. M. Jacobs, who was associated with Mr. Noble on the great Pennsylvania Railroad extension into New York City, his appreciation of the characteristics of Mr. Noble. It follows:

"'What do we live for if it is not to make lives less difficult for each other' (George Eliot).

"'That was the spirit of Alfred Noble in my personal experience during daily intercourse with him from January, 1902, to March, 1910, the time we were associated Chief Engineers, as well as Members of the Board of Engineers on the Extension of the Pennsylvania Railroad into New York City and Long Island.'

"'In all my experience, extending for a period of over 40 years, I have never been in contact with one so singularly independent and with such simplicity of character.'

"'One of the chief characteristics of his great professional attainments was the painstaking care which he devoted to the minutest detail of the subject under consideration, and his research on the many questions and new conditions that had to be dealt with.'

"'I have sat for hours, I may say days, with Mr. Noble, taking under consideration the multitudinous phases of the complex questions that were involved in order to reach a solution of the problems before us on the Pennsylvania work. He had to be absolutely convinced of the correctness of every detail before a final decision was reached.'

"'I can say here that, at our last meeting, the fact that during the entire period of our association, not a single word of anger or harsh criticism had passed between us was mutually a matter of sincere congratulations.'

"'As a man he was of the highest standard of honor and integrity, and was the very personification of humility. I can only add my testimony to the fact that the United States of America, and the profession generally, have lost one of the most distinguished engineers of this generation.'

"To those, young and old, who knew Mr. Noble, the memory of his character and professional methods will remain fresh and helpful.

"Because of the character influence of engineers of the past on the lives of following generations of engineers, one cannot but hope that by some means Alfred Noble's exemplary and vigorous life may be presented to future generations of engineers in such a way as to be helpful and encouraging and serve as a reminder that the 'right' can never be 'wrong', despite consequences of following one's conscientious judgment.

"Perhaps no engineer of foreign training was for so long a time continuously in touch with Mr. Noble, professionally and socially, as myself, with the result that, of the many blessings of fellowship enjoyed here, none has been of more moral value to me than this association with him.

"To illustrate his most sensitive fairness, permit the following: He consulted me, for not more than two hours at the most, on a certain matter with which I happened to be also familiar and, to my surprise, sent me a check for half his fee, which, to satisfy his pride, I had finally to accept.

"He was an aristocrat of honor, but an autocrat toward those who, while knowing better, did not exercise it. Much may be said, and rightly, of his tolerance, helpfulness, and keen sense of humor, but it should not be forgotten that he in no sense overlooked a wrong.

"Mr. Noble was always an unstinting admirer of the oldest association of Engineers, 'The Institution of Civil Engineers', long before that body did him the honor of election as its Honorary Member in America. Those who have read the biography of Telford, the first President of the Institution, and who knew Mr. Noble will find a considerable similarity of character in these men. May I also say his brevity and pungency of speech recalled to my mind the manner and character of the simple and great British Engineer of our times, Sir Benjamin Baker.

"While Mr. Samuel Rea, President of the P. R. R. Co., proposed making the dinner of the Members of the Institution of Civil Engineers in America an annual event, it is to Mr. Noble we members owe the inception of the first one given in honor of Professor Unwin (then President of the Institution) at the University Club, New York City, on September 12th, 1912, during a visit to this country. This annual event affords as much pleasure to the Institution in London as it does to those who actually share in it.

"At the University Club on August 29, 1912, it was my good fortune to be the only foreign-born guest on the occasion of a dinner assemblage of engineers given in honor of Mr. S. B. Williamson, engineer in charge of the Pacific Division of the Panama Canal. This was five days after the passing.

on the 24th, of the Panama Canal Act of 1912, in which exemption from tolls of coastwise vessels was among other matters enacted. In his address, at this dinner, and as first speaker, Mr. Noble, jealous of the honor of his country, stated in a most unqualified way that such exemption, no matter how desirable or undesirable it might be, was in direct contravention of the Hay-Pauncefote treaty. As every one knows, the honor and good sense of the country prevailed, and Mr. Noble lived to see this exemption part of the Act rescinded.

"Mr. E. W. Moir, who really won his spurs as an engineer in this country on the old Hudson Tunnel in 1890, and who, as a partner and chief representative of the contractors on the construction of the tunnels under the East River for the Pennsylvania Railroad Company, had to transact much business on this scheme with Mr. Noble, sends the following:

" 'I duly received your latest appeal for some remarks on our mutual and dead friend Noble. I think I have already said that my admiration for him is very great indeed. I will make some effort to put something on paper that will be worthy of him. I am afraid, however, anything that I can say will not add to the high opinion his countrymen have already of him and of his works.

" 'He was certainly one of the finest types of manhood that I ever met, either in the United States or anywhere else: able, kindly, strong-minded, sticking to his opinions with great determination no matter how persuasive the arguments on the other side, and very thoughtful of others and generous in his dealings with them. I should say he was much the same tent on the north shore of Lake Superior; and perhaps one gets

" 'I spent a few enjoyable days in camp with him, sleeping in the same tent on the north shore of Lake Superior; and perhaps one gets to know a man much more intimately if one practically shares the same bed in the wilds, than by months of association in a city like New York, with all its distractions and intensity of human endeavor.

" 'We went through some very strenuous times together when we were building the East River Tunnels—a most trying job for the nerves—and while we had some differences of opinion on engineering matters, we never differed enough to alter our mutual friendship in the slightest degree.'

"Sir Maurice Fitzmaurice, C. M. G., a Member of the Council of the Institution of Civil Engineers, sends the following tribute:

" 'I only had the pleasure of knowing Mr. Noble for about five years and only met him on five or six occasions. I was always struck by his great sincerity and the extremely fair way in which he examined any questions put before him. I felt that I should be quite satisfied to take his opinion as an arbitrator on any question which might be in dispute in which I might be one of the parties. I say this not only on account of his professional qualities, which were as well recognized in Great Britain as in the United States and Canada, but also on account of his fair mind and common sense.

" 'When a vacancy occurred among the Honorary Members of the Institution of Civil Engineers, some five years ago, I had the honor and pleasure of proposing Mr. Noble to fill the vancancy, and this nomination was unanimously accepted by the Council of the Institution and confirmed by the Members. We were very proud to have him as an Honorary Member, and only regretted that he filled that position for such a short time.'

"Mr. Henry Japp, Chief Engineer and Director for the Contractors of the P. R. R. East River tunnels, who submitted to the rulings of Mr. Noble on this work, sends what he calls his point of view: it is as follows:

" 'Noble by name and noble by nature, like all great men, he was entirely unassuming, patient, painstaking and hard working; kindly generous and unselfish; capable of meeting any obstacle and overcoming it; strong and reliable; courageous and never compromising with what he considered wrong.'

"Mr. Noble's technical missives were composed of the fewest possible words, and what was left unsaid was equally forcible as the 'said,' and now and again, but in consonance, contained a touch of humour between the lines.

"While the greatest factor in the preservation of, or criterion as to, the safety of investment is the character of management personnel, of no less value is the character of an advisory engineer. It was Mr. Noble's wealth of simple, robust, honest character which made him so valuable a technical advisor and a great asset to a great country. Such value has been concisely expressed:

"'We put too much faith in systems and look too little to men.' (Disraeli).

"'The worth of a State in the long run is the worth of the individuals comprising it.' (J. S. Mill.)

"Mr. Noble's value is amply demonstrated by his works, also by the affectionate admiration of engineers and others. It was the greatest privilege to have known him as an unconscious example and a helpful friend."

From Charles Warren Hunt, Secretary, Am. Soc. C. E.

"I am glad to pay, however inadequately, my tribute to the memory of Alfred Noble.

"My term of office as Secretary of the American Society of Civil Engineers began in January, 1895, and during that year Alfred Noble was elected one of its Directors. Five years later he became Vice-President (1900-1901), was elected President in 1903, and subsequently, as Past-President, served as a Member of the Board for six years (1904-1909). He was therefore a Member of the Board of Direction for ten years, the last nine of which were (with the exception of 1902) continuous.

"To sum up in a few words his influence in shaping the policy of the Society during that period, which was one in which a number of difficult situations arose, would be impossible; but it may be said that he gave to all his duties the benefit of his great capacity for detail, and that his broad and wise views, which were never expressed without careful and painstaking deliberation, and were always delivered in that modest, unassuming and convincing manner so characteristic of him, seldom failed to prevail. It seems to me that the key-note of Alfred Noble's nature, as shown in his attitude toward Society affairs as well as in all other relations of life was unselfishness.

"It was my good fortune, not only to have been thus associated officially with Alfred Noble, but to have shared with him several vacation trips, at times having been in camp with him alone for weeks, and this close contact gave me opportunity to form a correct estimate of his remarkable character.

"Of his professional ability, which was conspicuous, much will doubtless be written by others more familiar with the details of his work than I. The qualities in him that I like best to remember were his gentleness, genuineness, geniality, quiet humor, thorough sympathy with, and readiness to help others, by kindly advice or otherwise, wherever and whenever such help was asked or appeared to him to be needed.

"I feel that I owe much to him, and am proud to say that he was my friend.

"Doubtless there have been men of greater genius in some particular direction, men who were perhaps more deeply read, perhaps more broadly educated, men who, in their generation, have been more in the public eye; but as I am writing this I have tried to think of all the attributes of which a man would wish to be possessed, and have endeavored without success to find one which was not a feature of his character.

"Alfred Noble was the best balanced, most lovable, most dependable, most useful man I have ever known. To meet him even casually was always a pleasure; to have known him intimately was a great privilege."

September, 1915

BOOK REVIEWS

THE BOOKS REVIEWED ARE IN THE LIBRARY OF THE SOCIETY.

Purchasing. By C. S. Rindfoss. McGraw-Hill Book Co., New York, 1915. Cloth; 6 by 9 in.; 165 pp. Price, $2.00.

The purchasing agent is the "bete noire" of the construction and maintenance engineer, unless he is of the type of purchasing agent who has the good sense to know that an apparent saving of a dollar by his department at a cost of several dollars to the construction or maintenance departments is not for the benefit of his employer. Every engineer who has had much experience in construction or maintenance work knows of cases where work has been delayed at great cost while the purchasing agent haggled over a trifling difference in the price of an article without regard to the quality or the ability of the bidders to make prompt delivery.

The author states in the opening paragraph that ninety-nine purchasing agents out of ninety-nine work on the theory that price is the most important consideration. This theory leads to bad results, as it is equally important that the article purchased should be the one suited to the purpose intended. It is not good "purchasing" to buy an article "too cheap to be good" unless there are special circumstances warranting such action, nor, on the other hand, is it justifiable to pay the price for something that will last five years when a service of only one year is needed.

The author has produced a valuable as well as a very readable book, which is well worth the study of purchasing agents, engineers, salesmen and others interested in the subject.

The following are the subjects of the different chapters in the book, which also contain many sub-heads: "How to Obtain the Right Article," "How to Obtain the Lowest Price," "How to Obtain Prompt Delivery," "Making the Purchase Conform to Fixed Policy," "How to Obtain Favorable Terms," "Personal Characteristics and Qualifications," "Strategy," "Some of the Legal Aspects of Purchasing," "Departmental Organization," "Forms."

Practical Track Work. By Kenneth L. Van Auken. Railway Educational Press, Chicago, 1915. Cloth; 8 by 5½ in.; 216 pp.

This book is intended to appeal to men who are engaged in railroad track work, whether as engineers, or foreman, or in other capacities. It treats, however, of the so-called practical side of the matter and does not deal with mathematics. The author's aim is to reach the practical track man and the young engineer who will get his mathematics elsewhere, but who will find in this book much information on the actual handling of track work that he sometimes badly needs.

The reviewer well remembers certain cases in his younger days when he would have been very glad to get a surreptitious quarter hour look at this book when he was trying to set stakes for some complicated track work.

In the opening chapter the author considers the question of the quality of labor available at present as compared with the past and also the question of wages and of labor agencies and their abuses. Much of this chapter is of general interest to engineers and would well bear quotation if space permitted.

The author is one of the editors and writers who have successfully risen from the ranks of the laborer and he knows the viewpoint of the foreman from actual experience, while he is able to treat certain problems arising in the manner of the student who has given philosophical study to his subject.

The next five chapters go into the details of track-laying, including the question of tools, material, etc., and the general principles of economical and expeditious handling of work are well handled and apply equally well in many cases to other classes of construction work.

Two chapters are devoted to turnouts, crossovers, slip switches, etc., and instructions, given in great detail for installing them, will be useful to ambitious trackmen and also to young engineers who are called upon to stake out this kind of work, without having had much experience in it, as often happens.

A long "Glossary of Track Terms" is given, which the reviewer cannot commend, and which does not seem in keeping with the serious purpose of the other parts of the book, especially as a large part of these are merely local slang and others are so self-evident in meaning that there is no need to include them in a glossary.

Some useful tables are given and also a fair index, although this index should be revised somewhat in another edition, as there are some unnecessary repetitions which give it the appearance of having been prepared with less care than the other parts of the book. For instance, under "W" we find "What a slip switch is." It is obvious that nobody would look under "W" if looking for slip switches.

As the author states, he does not include "maintenance," and the book is much smaller, therefore, than some other standard books on track work, and can be carried in the pocket.

PROCEEDINGS OF THE SOCIETY

MINUTES OF MEETINGS.

Regular Meeting, September 13, 1915.

The first regular fall meeting of the Society (No. 909) was held on September 13th, 1915. The meeting was called to order at 8 p. m., by President Jackson, with about 135 members and guests in attendance.

President Jackson opened the meeting by welcoming to the Society rooms the members and guests present after the vacation season, but stated that there was one sad feature of the meeting: that being that we could not have present with us our fellow member, the man who has been our Secretary for so many years, Mr. J. H. Warder, who died on August 30th and who was buried at Cincinnati, Ohio, on September 2nd. The President called upon Mr. B. E. Grant, M. W. S. E., who responded as follows:

"The Society has certainly met with a great loss in the death of Mr. J. H. Warder. Mr. Warder was Secretary of the Western Society of Engineers for about fifteen years. At the time of his appointment Mr. Chanute was President of the Society and gave a great deal of serious thought to the Society's affairs. That there was, at that time, a very real need of a more active Secretary was freely admitted and the problem was to find the right man for the place.

"The Secretary's position is not an easy one to fill. Some of the qualifications the man should have are energy, tact, initiative, technical training, business ability, and a knowledge of library work. Besides all these things he must know something of accounting and editorial work.

"Many names were mentioned in connection with the position but for some time none seemed to be entirely satisfactory. Finally Mr. Warder's name was suggested by a former President of the Society who had noted his successful work as a member of the publication committee. So it was Mr. Warder's activities on one of the Society's committees that led to his appointment as Secretary.

"After his appointment, I believe that it was the unanimous opinion of the members that the right man had been found.

"From that time the Society began to build up. We had about 500 members at that time and the Society steadily grew, not in a sensational way, but with a good steady growth, the results being that today we have about 1,200 members.

"Mr. Warder's ancestors were Pennsylvania Quakers, and he inherited the strong qualities that belonged to his people.

"He was friendly, and his friends were numbered by the hundreds. I have often walked down the street with him, and in the course of a short block have seen him stopped by five or six people. He was a man with a great many friends. He was friendly, sympathetic and loyal.

"In his loyalty to the Society he could not be equalled. He worked here for hours every day. He was here early in the morning and late in the evening. Sundays and holidays were also devoted to the work of the Society.

When the rooms of the Society were rented to other societies, which would sometimes be for two or three evenings in the week, he thought it his duty to be here: he thought it was part of his job to be here and see that the rooms were taken care of. He was very conscientious in his duties to the Society.

"He was also very conscientious in his duties as a citizen. He took an intelligent interest in public affairs. When it came to voting he studied his ballot, and when it came to making out a tax report he made an honest schedule.

"He was identified with many clubs and societies formed for the public good. He was identified with the Art Institute and the City Club for many years, as a member at least, and at all times evinced great interest in public affairs.

"For the past year Mr. Warder's health had been failing to such an extent that the Board of Direction had found it necessary to relieve him of some of the duties and responsibilities of his position, but I think no one believed the end to be so near. He died on the morning of August 30th of valvular heart disease. The burial was in Spring Grove Cemetery, Cincinnati, and not many miles from the place where he was born 69 years ago.

"I feel that the Society lost a very loyal friend. I believe that every member of the Western Society deeply mourns the loss of Mr. J. H. Warder."

The Acting Secretary read the following applications for membership:

Maurice D. Blumberg, Chicago.
Arrago M. Young, Seattle, Wash.
Edward D. Uhlendorf, Chicago.
Hugh B. Holman, Rochester, Ind.
Earl F. Cathers, Coffeyville, Kans.
S. Wellford Randolph, Chicago.
Ralph H. Burke, Chicago.
Homer W. Benton, Harvey, Ill.
Jesse Lowe, Jr., Beardstown, Ill.
Lawrence C. Bond, Chicago.

and announced that the following had been elected to membership by the Board of Direction since the last regular meeting of the Society:

Herman N. Legried, Humboldt, Iowa............Associate Member
Louis Spira, Chicago............................Junior Member
John W. Wilson, St. Charles, Ill..................Junior Member
Ralph G. Culbertson, Ridgeville, Ind.............Associate Member
Harry E. Connors, Chicago.......................Junior Member
John A. Dailey, Chicago...............................Member
William A. Goss, Madison, Wis...................Junior Member
James A. Cook, Chicago.......................Associate Member
Homer W. Deakman, Chicago.....................Junior Member
Albert L. Wallace, Chicago.....................Associate Member
Roy A. Wilson, Chicago..........................Junior Member
Wm. M. Kinney, Chicago...............................Member
Frederic H. Newell, Urbana, Ill........................Member
Clyde C. Younglove, Sioux City, Iowa.............Junior Member
J. Frank Ward, Evanston, Ill................(Tr.) Junior Member
Glenn P. Beach, St. Paul, Minn.....................(Tr.) Member
Wm. W. Wilson, Mason City, Iowa..............Affiliated Member
William F. Harvey, Chicago............................Member
Fred Kellam, Valparaiso, Ind.....................Student Member
Arthur W. Nelson, Valparaiso, Ind...............Student Member
Theodore F. Schlader, Chicago.........................Member
Edward F. Carter, Montreal, Quebec....................Member
Edward J. Kelly, Chicago..............................Member
Otto A. Krueger, South Bend, Ind.................Junior Member
James B. Schaub, Chicago...................(Tr.) Junior Member

The program of the evening was then taken up, Lieut. Horace S. Baker, M. W. S. E., of the Engineer Company of the I. N. G., giving a talk on the

1915 Camp of Instruction for Engineer Troops of the National Guard at Belvoir Tract, Virginia, near Washington, D. C., illustrating his talk with many beautiful lantern slides. The talk was amplified by Capt. L. S. Marsh, Lieut. Guilfoil, Sergeant Saner and Private Tomlinson. The meeting adjourned at 10:15 p. m., when refreshments were served.

Extra Meeting, September 20, 1915.

An extra meeting (No. 910) of the Western Society of Engineers was held Monday evening, September 20, 1915.

The meeting was called to order by Mr. Chas. B. Burdick, at 8 p. m., with about sixty members and guests in attendance.

The chairman introduced Mr. Ernest McCullough, First Vice-President of the Society, who then presented his paper on "The Engineering Society, Its Past, Present and Its Future Activities." A written discussion of the subject, prepared by Mr. Wm. B. Jackson, President, was read by Mr. Layfield in the absence of the author. A very interesting discussion followed from Messrs. O. P. Chamberlain, B. E. Grant, W. E. Symons, L. K. Sherman, Albert Scheible and Arthur L. Rice of the Society and from Mr. Arthur Kneisel, Secretary of the American Association of Engineers. Meeting adjourned at 10:30 p. m., when refreshments were served.

Extra Meeting, September 27, 1915.

An extra meeting (No. 911), in the interests of the Hydraulic, Sanitary and Municipal Section of the Western Society of Engineers, was held Monday evening, September 27th, 1915, which convened about 8 p. m.

The meeting was called to order by Mr. G. C. D. Lenth, Chairman of the Section, with about 75 members and guests in attendance. There being no business brought before the Section, the Chairman introduced Prof. Earle B. Phelps, of the Public Health Service of the United States Government, who gave an address on "The Investigations of the International Joint Commission on the Pollution of Boundary Waters."

Discussion followed from Dr. W. A. Evans, J. W. Alvord, L. K. Sherman, H. S. Baker, Paul Hansen of the State Board of Health, Langdon Pearse, H. P. Letton, C. D. Hill, W. T. Barnes, S. A. Greely and W. W. DeBerard, with a closure by Prof. Phelps. Meeting adjourned at 10 p. m.

LIBRARY NOTES

The Library Committee desires to return thanks for donations to the library. Since the last publication of such gifts the following publications have been received:

NEW BOOKS.

D. Van Nostrand Co.:
Practical Surveying, Ernest McCullough. Cloth.

McGraw-Hill Book Co.:
Surveying Manual, Pence & Ketchum, 4th edition. Leather.
Manual of Surveying for Field and Office, R. E. Davis. Leather.
Irrigation Practice and Engineering, B. A. Etcheverry. Cloth.

John Wiley & Sons:
Water Purification Plants and Their Operation, Milton F. Stein Cloth.

Railway Educational Press:
Practical Track Work, Kenneth L. Van Auken. Cloth.

F. E. Austin:
Examples in Alternating-Currents, Austin. Cloth
Directions for Designing, Making and Operating High-Pressure Transformers, Austin. Cloth.

MISCELLANEOUS GIFTS.

Chicago Commission on Ventilation:
Report of Commission, 1914. Leather.

City of Portland, Maine:
Annual Report of Commissioner of Public Works, 1914. Pam.

Chicago Real Estate Board:
- Report on the Disposal of the Sewage and Protection of the Water Supply of Chicago, by Messrs. Soper, Watson and Martin, 1915, Cloth.

Chicago South Park Commissioners:
- Annual Report for Year Ending February 28, 1915. Pam.

Slason Thompson:
- The Railway Library, 1914. Cloth.

Onward Bates, M.W.S.E.:
- Annual Report, Water Commissioner, City of Ct. Louis, for the Year Ending April 1, 1915. Paper.

EXCHANGES.

American Electrochemical Society:
- Transactions, Vol. XXVII, 1915. Paper.

American Society of Mechanical Engineers:
- Transactions, 1914. Half-leather.

Brooklyn Engineers' Club:
- Transactions, 1914. Cloth.

New York Public Service Commission, 1st District:
- Annual Reports, 1914, Vols. I, II. 2 cloth.

American Society for Testing Materials:
- Membership List and List of Committees, etc., 1915. Paper.
- Year-Book, 1915. Cloth.

Illinois State Geological Survey:
- Bulletins 29 and 31, Purchase and Sale of Illinois Coal on Specification; Oil Investigations in Illinois in 1914. Cloth.

Florida Geological Survey:
- Seventh Annual Report, 1915. Cloth.

North Carolina Geologic and Economic Survey:
- Economic Paper No. 40, Forest Fires in North Carolina During 1914. Pam.
- Economic Paper No. 42, Organization of Co-operative Forest-Fire Protective Areas. Pam.

Canada Department of Mines; Geological Survey:
- A Geological Reconnaissance Between Golden and Kamloops, B. C. Paper.
- Geology of the Victoria and Saanich Map-Areas, Vancouver Island. Paper.
- Wabana Iron Ore of Newfoundland. Paper.
- The Yukon-Alaska International Boundary, between Porcupine and Yukon Rivers. Paper.
- Coal Fields of British Columbia. Paper.
- A List of Canadian Mineral Occurrences. Paper.

U. S. Geological Survey:
- Bulletins Nos. 611, 612, 613; Guide Books of the Western United States, Parts A B and C. 3 paper.

U. S. Public Health Service:
- State Laws and Regulations Pertaining to Public Health. Paper.

U. S. Commissioner of Education:
- Annual Report, 1914, Vols. I and II. Cloth.

Smithsonian Institution:
- Annual Report, 1914. Cloth.

International Railway Fuel Association:
- Proceedings, Seventh Annual Convention, 1915. Paper.

State of New Jersey:
- Annual Railroad and Canal Reports. Cloth.

Bureau of Surveys, Philadelphia:
- Annual Report, 1914. Cloth.

Philadelphia Bureau of Highways and Street Cleaning:
- Report for 1914. Paper.

Cleveland Engineering Society:
- Annual Register, 1915. Cloth.

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TEN YEARS OF EVOLUTION OF HYDRO-ELECTRIC UNITS

E. B. Ellicott, m. w. s. e., and Wm. B. Jackson, m. w. s. e.

Presented May 24, 1915.

The title of this paper insures that you will not listen to any original ideas or any assumptions further than are necessary to properly correlate the information gathered from numerous sources. The intention is to place before you the results of wide inquiry among manufacturers and designers, and their statements of the advance that has taken place in the design, construction and efficiency of hydro-electric units in the last years, together with a consideration of the relatively few authentic tests of water wheel generators in place that are available and of tests at the Holyoke testing flume.

This period of time has been chosen because it represents the greatest progress in hydro-electric development since the year 1,000, during which time power derived from water-driven wheels has been applied for various purposes. While history has no place in this paper, it may be considered necessary to substantiate the statement that the greatest progress has been made in the last ten years, to present something of the early development of water wheels.

The water wheels in general use are known as the reaction type, and the first one was built about 1836 by Samuel Howd of Geneva, N. Y. Similar wheels were later constructed by a number of makers without any attempt to design a wheel along scientific lines, until about the year 1840, when James Thompson, a brother of Sir William Thompson, set forth certain well defined theories, based on mathematical calculations, for the design of water wheels. This work was closely followed by James B. Francis, one of the earliest eminent engineers. Mr. Francis carried the work further along, proving the theories of design by actual tests, and small wheels designed at that time showed on test an efficiency as high as 80 per cent.

It is doubtful if any considerable improvement was accomplished in efficiency of water wheels from 1850 to 1905, except such as might be due directly to increased size of units. It therefore seems that in outlining the advance in water wheel construction during the last ten years the most important developments will be presented.

Water wheel units may be classified either as "high head" or "low head" units. High head units are those designed for hydraulic heads exceeding 50 feet. In this class of unit there has been great advancement in capacity, speed and efficiency, but no radical change in construction. It is now possible to build units for high heads at 8 per cent greater efficiency and as much as 50 per cent greater speed than was possible 10 years ago. This advancement has made possible the most economical construction from both hydraulic and electrical design. The most prominent feature in the later wheels seems to be in the wide variation in speed under which units may be designed to operate under fixed hydraulic heads. Instead of a fixed speed for a certain horsepower output, at a given head, it now appears practicable by improved design to construct a unit for any speed within the limits of the former fixed speed and approximately 50 per cent thereof without sacrificing either efficiency or output. This makes possible the most economical design of generator for direct connection, and leaves nothing further to be desired in high head units except a possible increase in efficiency.

Judging by the accomplishments of the last 10 years it is reasonable to assume that the designers of turbine water wheels will meet any demands for increased size of units, and will meet the speeds at which generators can be constructed for successful operation. The developments now in operation represent such extremes in hydraulic head, speeds, and size of units adapted to them, that it is safe to assume that many projects heretofore considered impracticable or impossible will soon be classed among normal conditions.

Previous to the introduction of the large vertical single runner wheels about five years ago, all large power units for low heads were designed with a number of small diameter runners mounted on a horizontal shaft, each runner in a separate casing and provided with individual gate mechanism. This design had many disadvantages, the unsurmountable one being the limitation in capacity with reasonable length of hydraulic unit. The lower heads did not permit a runner of over 60 inches in diameter on a horizontal shaft and each runner of this size, together with the discharge casing occupied so much shaft space that the maximum shaft length was reached with from four to six runners, with a total capacity of about 6,000 horsepower.

The limits of efficiency had been reached in this design because of the losses due to restricted discharge casings, interference with the discharge due to the shaft passing through the casing, and the sudden change in velocity of water at the points where the discharge from the different wheels met.

The demand for larger power units at low heads brought about the greatest advance in water wheel design, within the ten years just passed. As a concrete example 10 years ago the largest power unit under 34-foot head was a horizontal type with six runners, and total output of 6,000 horsepower, at an efficiency of 80 per cent. Today there are in operation fifteen single runner units which, under a similar head give 12,000 horsepower each at a claimed efficiency of 90 per cent.

The increase in capacity primarily has been made possible by the perfection of the step bearing to a point which permits the carrying of the great weight of the single runner and revolving field of the generator, and, therefore, of the construction of effective vertical water wheel generator units. Difficulties encountered in manufacture have been overcome and it is now practicable to cast runners in sections, assemble into a complete runner, and obtain the efficiency of the tested model. This method of construction has proven so satisfactory that one manufacturer has made a proposal to furnish a single runner unit of 50,000 horsepower capacity.

The efficiencies attained in single runner low head units is most remarkable and exceeds any predictions made. The result will be the development of many low head projects that were not considered feasible a few years ago.

The increased efficiency has been secured by the most thorough treatment of the design from the turbine chamber to the tail race. While the proper shape of the vanes of the runner has its effect upon the efficiency obtained it was found that in large units the manner in which the water entered and left the runner was of equal importance. Clearances between vanes and discharge casings, that had been ignored to some extent, were found to be of great importance. One of the most neglected and still most important effects on efficiency was found to exist in the size and shape of the draft tubes. While the losses due to these enumerated points exist in units designed for high heads they did not constitute as large a percentage of the total power, and, therefore, did not need to be given such careful consideration. In the development of low heads, where large volumes of water were to enter and discharge through a runner, these losses became a matter of serious consideration and the proper treatment in design has reduced them to the minimum that is considered attainable except when the size of runner may be increased and more water discharged.

Mechanical design has kept pace with improved efficiency, and the last ten years has seen greater improvement in both design and efficiency than in the preceding fifty years. Well authenticated tests show an efficiency of 92 per cent on large size units and this leaves little more to be gained. The turbine water wheel may be said to have completed the most important stage of its evolution in the last ten years.

The operation of a number of hydro-electric units in parallel required a perfect system of water wheel governing to the end that the load should be automatically distributed between the different units. The only means of governing the speed of the reaction type of water wheel is by varying the gate openings. It can be plainly seen that with individual governors on each unit there would be a tendency for one or two units to take a full gate opening, the other units absorbing the balance of the load; or, because of too sensitive adjustment, there would be a continual transfer of load from one unit to another. To correct this difficulty, former practice was to make a mechanical connection between governor controlling devices which caused all gates to be actuated in unison. While this method was operative it was not flexible and the attention of designers was directed toward securing a controlling device that was provided with a limiting adjustment which effectually prevented any unit from automatically accepting more than its proportion of the load.

The perfection of governors has lately reached the limits of regulation desired and it is now possible to operate any number of units in parallel with an evenly distributed load, or to adjust individual units to maintain certain proportions of the load, and maintain a given speed within 2 per cent under 25 per cent sudden variations in total load. This accomplishment has received little attention and yet it is one of the most important factors in the successful operation of the hydro-electric developments.

Remarkable results have been attained in design of runners to give the highest efficiency at a predetermined gate opening. Conditions frequently occur when the unit is required to operate 20 hours a day at three-quarter load, and 4 hours at full load. The designer will produce a unit that will give its maximum efficiency at three-quarter gate opening and its maximum power at full gate opening. The maximum efficiency may be obtained at any predetermined point between 60 per cent and 100 per cent gate opening, and this range covers practically all important operating conditions.

A test record from the Holyoke Testing Flume shows the following remarkable performance at different speeds and gate openings on a 35-inch wheel:

Opening	R. P. M.	H. P.	Efficiency
Full Gate	173	205.23	85.71 per cent
" "	190	208.91	85.51 per cent
" "	212	209.15	88.16 per cent
" "	237	206.37	86.24 per cent
0.889	192	200.34	90.86 per cent
"	206	202.90	91.81 per cent
"	220	191.62	88.15 per cent
0.833	150	172.16	83.37 per cent
"	195	192.08	93.07 per cent
0.778	148	162.42	82.55 per cent
"	190	184.72	91.78 per cent
0.667	158	146.99	85.83 per cent
"	170	153.08	88.47 per cent
"	195	147.20	87.93 per cent

This test shows the efficiency at 67 per cent gate opening to be slightly greater than at full gate opening, while the point of highest efficiency is at 83 per cent gate opening.

An excellent example of splendid water-wheel and generator efficiencies from tests of hydro-electric units made in place, is that of the water-wheels and generators at the great development at Keokuk, where a part of the water-wheels tested to an efficiency of 93.5 per cent and none of them less than 90 per cent, under a head of approximately 32 feet and the generators at 9,000 kv-a, and 100 per cent power factor tested to 97.25 per cent efficiency, with 1.35 per cent reduction at 80 per cent power factor—notwithstanding that these are very low speed units turning at only 56 revolutions per minute.

Another example of fine efficiencies found in tests of water wheel generator units in place, is referred to in a paper read before this Society by Mr. Lucius B. Andrus, and printed in the JOURNAL of the Society, Vol. XIX, page 18. Although the subject of generators is treated later in this paper, we here give the figures for both the water wheels and generators, since they are so closely related.

With few exceptions water power in considerable volume is so situated that manufacturing industries cannot operate economically under conditions that permit the power to be economically developed and transmitted mechanically to the machinery. A transmitting medium was found in the alternating current generator, high tension transmission system and the perfected alternating current motor. While such a system has been in use for about 25 years the greater and most important part of the development has been within the last ten years, which has seen generating units built as large as turbine water wheels could be built to drive them, and transmission voltages increased to the point that permitted the greatest power obtainable to be delivered hundreds of miles at almost negligible losses.

This result was not easily attained. As the size of the generating unit increased new problems arose in construction and successful operation. The fact that a 5,000 K. W. generator was operating successfully on a 60,000-volt transmission line was not conclusive evidence that a 10,000 K. W. generator similarly constructed would operate equally well on a 120,000-volt transmission line, and such conditions are now accomplished facts.

The large hydro-electric units of ten years ago were high speed, as compared with those of today. As turbine units increased in capacity the speed decreased, and this fact has required an entirely new development in generators. To build a generator of 5,000 K. W. output at 1,000 R. P. M. was relatively a simple matter, and to build for a speed of 300 R. P. M. not a difficult one. During the last ten years it has been necessary to design and construct generating units for 10,000 K. W. output at a speed of 57 R. P. M. This increase in output and great decrease in speed proves that designers of generators can and will meet any requirements demanded in hydro-electric developments.

To meet these varying conditions, and each development represents a different condition, the designers have been required to not only change the electrical design and determination, but to make the most radical changes in mechanical design to withstand the strains due to short-circuits, which always give full gate opening on the turbine and apply the greatest power to the generator when it is delivering its power to a circuit with practically no resistance to the flow of current, resulting in enormous stresses being applied instantaneously to all parts of the generator.

As the units have increased in size these stresses have increased many times and the designer has met them by limiting the maximum short-circuit current, and by the introduction of reactance coils in the generator leads. Without this improvement in design it is not probable that such large units could be safely operated.

To meet these extreme conditions of operation it has been necessary to increase the weight of the stator castings and introduce a different system of bracing, and also to improve the method of holding armature and field windings in place. New methods of holding the laminations securely in place have been adopted and this troublesome feature of loose laminations has been entirely overcome in the later designs of generators. Cast steel rotor spiders have been generally adopted in place of cast iron, and the diameter of shafts increased to give much greater factor of safety. This has increased the bearing surface beyond any factor of safety previously considered or proven necessary. The result of these changes in mechanical construction is a practically indestructible unit, and one that mechanically will outlast the turbine unit used to drive it.

The concentration of such great energy in a comparatively small space produced heating conditions that available radiating surfaces would not dissipate and the designers have met this obstacle by adequate systems of ventilation. So well has this succeeded, it is not unusual for a unit to operate continuously for a period of 30 days and still keep within the guaranteed heating limits and in every way effectively perform its functions.

There has been great improvement in the character of insulation used in the insulating of armature coils. Treated cotton, pressed board and varnished cambric have been displaced by the use of mica, which, properly prepared, withstands abrasion due to movement of coils and insures against burnouts due to heating to much higher degrees than had theretofore been possible. The practice of treating the formed coil to exclude all air pockets has become general.

One of the most important improvements made has been in the bracing of armature coils at points where they extend beyond the stator laminations. These sections of the coils are subjected to distortion by stresses due to rush of starting current, improper paralleling, sudden changes in load, and short-circuits. The opinions seem to be that the necessity of securing the end coils in place was not realized until some of the larger units were subjected to the stresses due to continued normal and occasional abnormal operating conditions which caused rapid deterioration in the insulation and damage to windings.

It is now possible to obtain generators which at constant speed will maintain the voltage within 5 per cent of normal from ¼ to full non-inductive load, although 10 per cent is well within ordinary operating conditions. However, many generators are designed for 15 per cent regulation or higher and have separate voltage regulators to maintain the required voltage which is practicable on account of the greatly improved voltage regulators now available.

A generator frame that will permit winding for a certain output at 5 per cent regulation will permit of winding for from 15 per cent to 30 per cent greater output at 20 per cent regulation. This reference is made to indicate the range of design that has been attained.

The best designed generators of today have a maximum efficiency of probably 2 per cent better than those of ten years ago and there has been very marked improvement in the lower load efficiencies; some of the best designed generators having almost a flat efficiency curve from one-half load to full load. These results have been obtained by

Reduction of windage loss,
Effective ventilating systems,
More accurate proportions,
Better materials, such as silicon steel,
Carefully laminated armature conductors.

Improvements in efficiency have been gained by the use of large generators, but the greatest gain there has been is in the advantages obtained in the development of large water powers.

Generator design and construction have reached the point of perfection where the total losses at maximum load do not exceed 3 per cent in large units. The construction is so perfect that generator trouble is the last consideration in plant operation and the repairs represent the smallest item of expense when total cost is considered. That it was possible to meet the requirements of the low head hydraulic developments and to operate under extreme high voltage conditions on transmission lines hundreds of miles long, would indicate that the last ten years has seen the completed evolution of the alternating current generator as required for hydro-electric developments now and in the future.

It is difficult to appreciate the comparison between the physical size of generator of ten years ago and those of today. The largest ten years ago for which record has been obtained was 20 feet 6 inches over all, and today there are units 37 feet over all in operation. The mechanical design and construction has been one of the problems most difficult to solve because of those extreme overall dimensions. In order to make shipment possible rotors and stators must be made in segments, and in some instances special cars have been constructed to transport individual parts too heavy or bulky for standard freight cars.

The different designers and makers agree in their opinions of the improvements required and made during the period covered, and they may be condensed in the following:

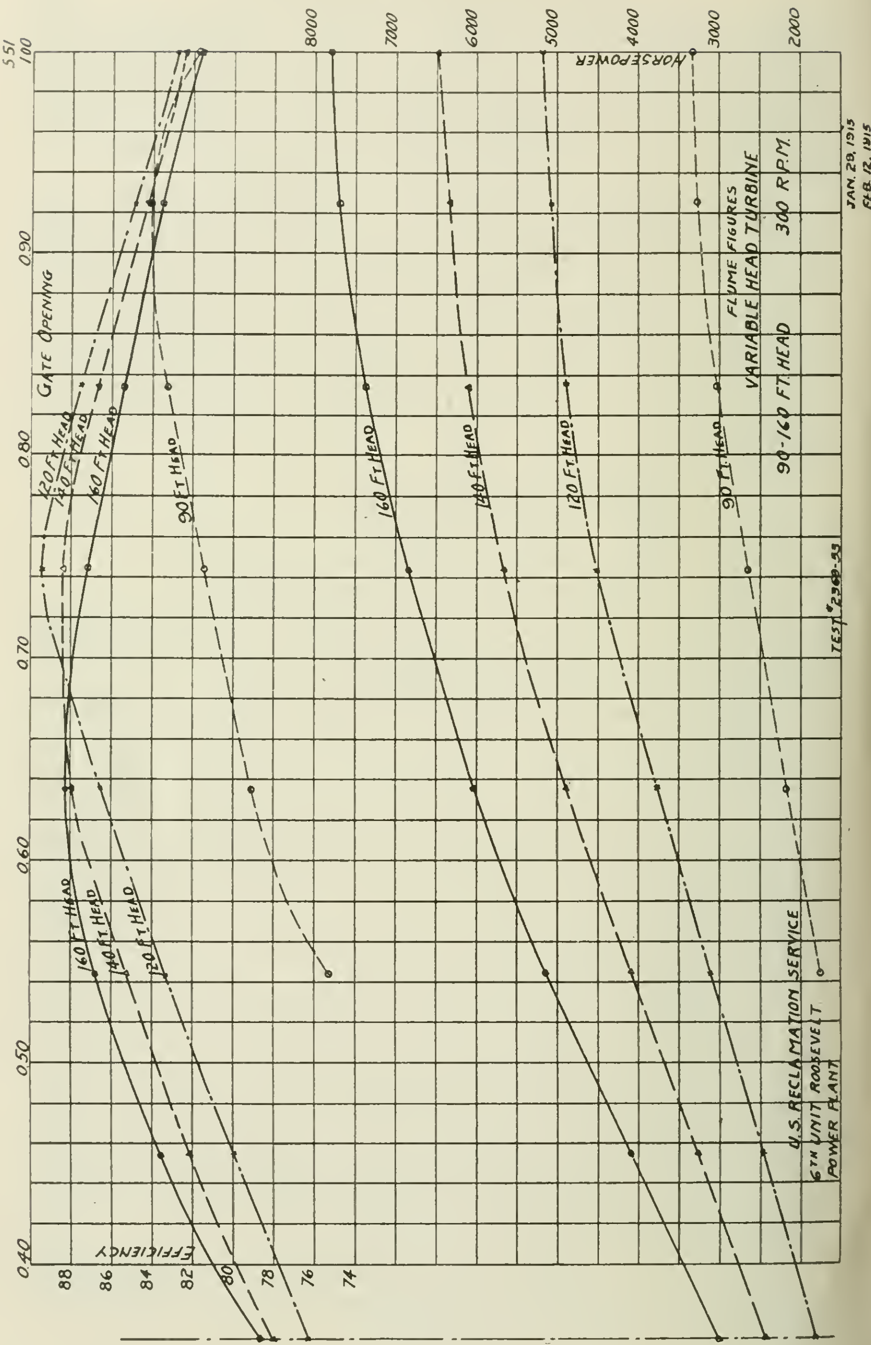

GATE OPENING
HORSEPOWER
EFFICIENCY
120 FT. HEAD
140 FT. HEAD
160 FT. HEAD
90 FT. HEAD
FLUME FIGURES
VARIABLE HEAD TURBINE
300 R.P.M.
90-160 FT. HEAD
JAN. 29, 1915
FEB. 12, 1915
U.S. RECLAMATION SERVICE
6TH UNIT ROOSEVELT
POWER PLANT
0.40
0.50
0.60
0.70
0.80
0.90
100
2000
3000
4000
5000
6000
7000
8000
88
86
84
82
80
78
76
74

Fig. 1.

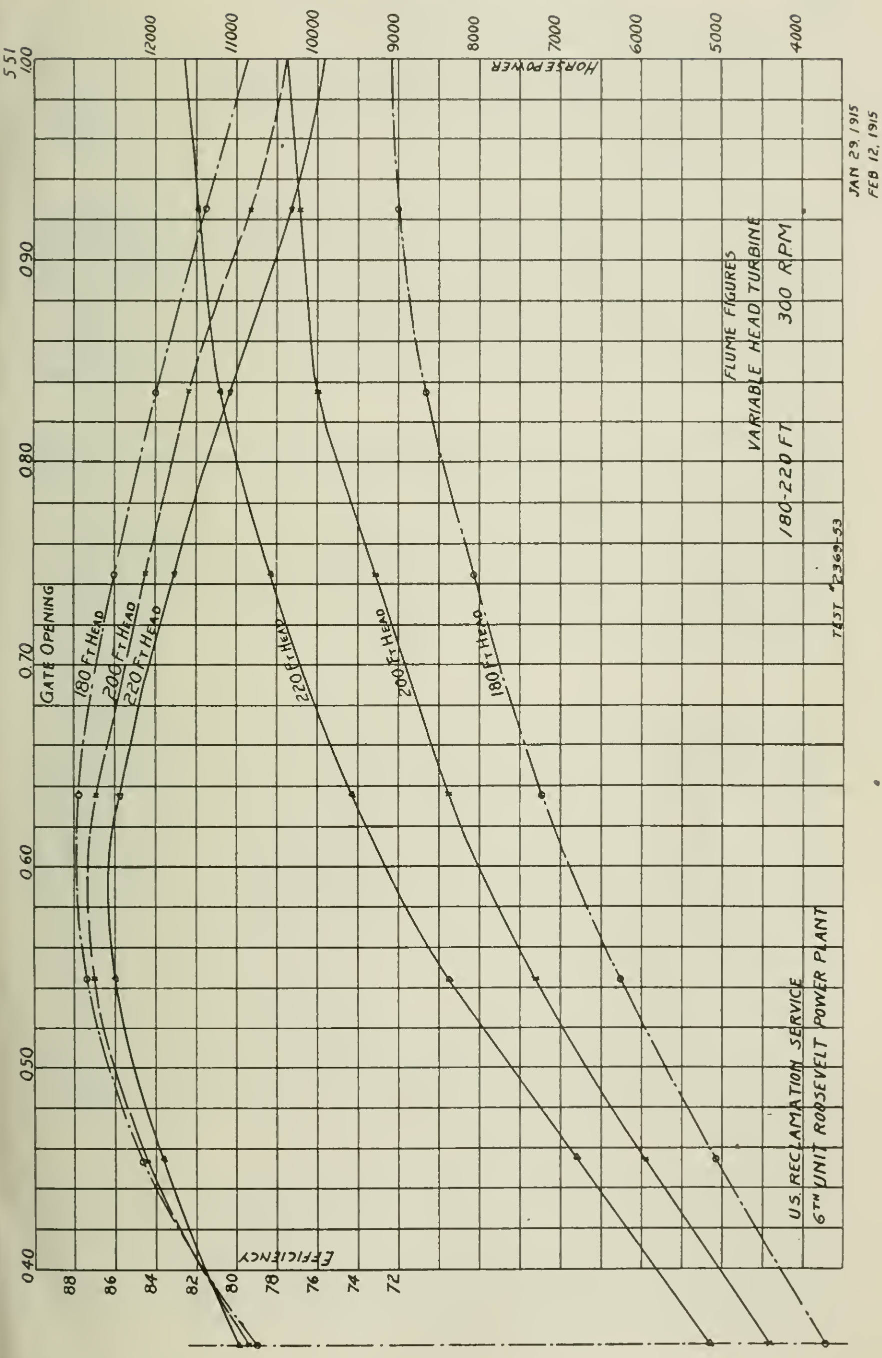

HORSE POWER
EFFICIENCY
GATE OPENING
180 FT HEAD
200 FT HEAD
220 FT HEAD
FLUME FIGURES
VARIABLE HEAD TURBINE
300 R.P.M.
180-220 FT
TEST #2369-53
JAN 29, 1915
FEB 12, 1915
U.S. RECLAMATION SERVICE
6TH UNIT ROOSEVELT POWER PLANT

Fig. 2.

1. Greater mechanical strength,
2. Improved character of insulation,
3. Extreme low speeds and large size of units,
4. Regulation and reactance,
5. Ventilation,
6. Efficiency.

It may seem strange that efficiency should be named last, but so relatively little has been gained that it may well have been ignored entirely rather than direct efforts from the other requirements that have proven so much more important and which have been so successfully accomplished by the different manufacturers.

We are indebted to the following companies who have furnished the information upon which the observations placed before you are based.

Turbine water wheels: S. Morgan Smith Company, I. P. Morris Company, Wellman-Seaver-Morgan Company, James Leffell & Company.

Generators: General Electric Company, Westinghouse Electric & Manufacturing Company, Crocker-Wheeler Company, Allis-Chalmers Company.

Several interesting curves of water wheel efficiencies and output are shown in Figs. 1 and 2.

DISCUSSION.

R. F. Schuchardt, M. W. S. E.: The Society owes its thanks to Mr. Ellicott and Mr. Jackson for this presentation, which brings us up to date in the matter of hydraulic turbine practice. I would like to ask the authors if the efficiency of 90 per cent applies to high head or low head wheels, or both. The authors stated that the successful design of a turbine operating at 50 per cent lower speed than was hitherto practicable marked a great step in advance. A fuller explanation of this would be welcome since in steam practice the advance has been made in the reverse direction, that is, by increasing the speed, with the result of lesser weight per unit of output.

H. M. Wheeler, M. W. S. E.: I understand that there is a chemical method of determining how much water goes through a water wheel in a given time, and that an accuracy of 99 per cent is claimed for such measurement. I am not familiar with the details, but would like to know just what standing the method has, *i. e.*, whether it is considered accurate and practicable.

Stafford Montgomery: The so-called "American" type turbine, which, I believe, is in most general use, was well developed fifty years ago. This type is adapted to moderate heads and discharges. The recent developments in American practice have been in the direction of low heads and large discharges. Therefore, installations under these conditions only need to be considered.

I believe that the typical large low-head installation in America ten years ago was a horizontal generator, driven through wooden crown-gears by two or more turbines having single 5-foot runners on vertical shafts. I remember some designed about 1900 having six vertical turbines.

I understood the author to say that the typical installation at that time was a generator mounted on the horizontal shaft of a single 5-foot turbine.

Low heads mean low turbine speeds, which would require a large and expensive generator unless gearing were used. The small discharge of a single 5-foot runner would not furnish power enough to drive a standard generator. Back-water during floods and the collection of air in the turbine would make the horizontal type undesirable for low heads.

I believe that most of the American developments in these large turbines have taken place in the last five, rather than the last ten years. In the fall of 1909 I designed a unit with an 18-foot runner for a head of about 12 feet. In searching the literature I found no American and very few European precedents for this design. Half a dozen American builders refused to estimate on the probable cost of construction, but advised the installation of several 5-foot turbines. It happened that a year or so later the Keokuk project on the Mississippi was developed with units of almost identical design.

A Member: Do you refer to a plant on the St. Lawrence river?

Mr. Montgomery: I do not refer to any particular plant, but there are several on the St. Lawrence and its tributaries, in which the typical low-head installation is used.

Peter Junkersfeld, M. W. S. E.: There has been more development, more new knowledge on insulation of hydro-electric, as well as steam turbine units than on any other feature of the generator design. The possibility for further improvement, made possible by better insulating material, is very good. Insulation is the starting point of such improvement. Best insulation means much higher allowable temperature, and hence less copper. Best insulation means much less space for insulated conductors, and hence much less material for armature and field laminations in frame; in short, much smaller and cheaper, as well as better, electric generators in the years to come.

Edwin W. Allen, M. W. S. E.: I should like to ask the authors if it would not be practicable for them to add a paragraph on the progress and development of direct current generators for direct connection to water wheels.

Inherent voltage regulation of alternating current generators seems to me to be of relatively little importance, as the regulation of even the best machines must be controlled by automatic voltage regulators.

E. B. Ellicott, M. W. S. E.: The period of ten years, as covered by this paper, was taken for the purpose of bringing together all the data in the development of large units. It is true that the greater part of the work has taken place during the last five years, but the preceding five years' work was a necessary preliminary and had much to do with the later successful results.

In the matter of efficiency at low heads, as compared with 50 feet and above, it appears that the designer has met the demands, and if allowed to name the speed will equal the efficiencies that are obtained with higher heads, unless there may have been some abnormal increase in the efficiency of the impulse type of turbine. On this particular type of wheel no data could be secured as the designers would furnish no information.

Mr. Schuchardt has asked about the variations in speed. The manufacturers naturally desired to build a wheel for the highest possible speed for a given head—this meant a small wheel for the desired power, but it did not mean the most efficient wheel. The gravity head fixes the velocity at which the wheel can discharge water, therefore, the speed of a wheel at which it will best use the water under a given head is fixed to a certain extent, subject only to reasonably slight modifications in the shape and number of buckets or vanes, the gate openings and the shape of the discharge tubes. While there is considerable range of speed at which the efficiency is practically the same, it is usually downward from a point fixed by the gravity head, at which the greatest power may be obtained at the highest efficiency.

Mr. Schuchardt has referred to the advance in steam prime movers in which the speed and efficiency have been greatly increased and the output much increased for the unit of weight. This is true, but in steam design they are dealing with the high temperature and velocity of steam, and designers have not yet reached the limits of its use. The power derived from steam is due to heat units, and as only a comparatively small part of the units appear in the form of power it is but natural that more effective use has and will be discovered. A water-wheel derives its power from the weight of water due to its head and the water-wheel has been so perfected that 90 per cent of the theoretical power is transmitted into effective power, but it can only accomplish this result under the speed which is practically fixed by the gravity head. The records of tests on the following page show the results of speed variations on both power and efficiency.

The comment has been made that the paper does not mention the results secured from units composed of a number of small wheels geared to a shaft from which generators are driven. I do not think this represents any part of the development in the period covered. This particular design was used on very low heads which prohibited the use of horizontal wheels, but the development of the generator for vertical shaft drive made it desirable to abandon the

TESTING FLUME OF THE HOLYOKE WATER POWER COMPANY.

Report of Tests of a Turbine Wheel.

Number of the Experim.	Proportional Part of the Full Opening of the Speed Gate. (In Per Cent)	Proportional Part of the Full Discharge of the Wheel. (In Per Cent)	Head Acting on the Wheel, in Ft.	Duration of the Experiment, in Min.	Revolutions of the Wheel, per Min.	Quantity of Water Discharged by the Wheel, Cubic Ft. per Sec.	Power Developed by the Wheel, H. P.	Efficiency of the Wheel, in Per Cent.
53	1.000	0.991	17.23	3	173.00	122.65	205.23	85.71
54	1.000	0.993	17.21	3	181.33	122.78	206.72	86.34
52	1.000	0.994	17.16	4	190.00	122.78	208.91	87.51
51	1.000	0.997	17.04	4	199.50	122.65	207.81	87.76
50	1.000	0.999	17.05	3	206.00	122.90	208.62	87.87
49	1.000	1.000	17.02	5	212.60	123.03	209.15	*88.16
48	1.000	1.002	17.03	4	218.50	123.27	208.63	87.71
47	1.000	1.004	17.04	5	225.80	123.52	209.07	87.67
46	1.000	1.008	17.03	4	237.75	124.02	206.37	86.24
45	0.889	0.900	17.26	4	156.75	111.48	185.95	85.30
44	0.889	0.907	17.28	4	171.50	112.33	193.53	88.00
43	0.889	0.911	17.28	4	185.75	112.82	198.86	90.03
40	0.889	0.913	17.23	3	192.33	112.94	200.34	90.86
39	0.889	0.915	17.22	4	200.00	113.18	202.54	91.72
42	0.889	0.917	17.27	4	204.00	113.55	203.64	91.65
38	0.889	0.917	17.20	4	206.25	113.42	202.90	*91.81
41	0.889	0.917	17.25	5	211.40	113.55	203.07	91.50
37	0.889	0.916	17.20	4	216.50	113.18	200.46	90.88
36	0.889	0.902	17.21	4	220.75	111.48	191.62	88.15
25	0.833	0.840	17.43	4	150.25	104.56	172.16	83.37
23	0.833	0.847	17.43	4	164.75	105.38	181.14	87.04
24	0.833	0.851	17.42	4	175.75	105.85	188.15	90.06
21	0.833	0.857	17.42	4	184.50	106.56	192.18	91.38
18	0.833	0.850	17.46	4	205.75	105.85	190.50	90.98
17	0.833	0.835	17.52	4	209.75	104.20	182.07	88.02
74	0.833	0.858	17.18	3	188.67	105.97	191.07	92.63
73	0.833	0.858	17.19	4	192.00	106.09	191.66	92.76
72	0.833	0.857	17.19	4	195.25	105.97	*192.08	*93.07
75	0.833	0.858	17.18	3	198.33	105.97	191.67	92.92
35	0.778	0.794	17.53	4	148.50	99.06	162.42	82.55
34	0.778	0.807	17.53	4	167.50	100.69	175.44	87.73
33	0.778	0.808	17.53	3	179.00	100.81	181.27	90.53
31	0.778	0.812	17.47	3	186.00	101.16	182.98	91.38
32	0.778	0.811	17.54	4	190.00	101.27	184.72	*91.78
30	0.778	0.812	17.44	4	191.50	101.04	182.85	91.58
29	0.778	0.798	17.46	4	196.50	99.41	176.25	89.62
28	0.778	0.781	17.54	4	203.25	97.45	170.55	88.06
27	0.778	0.764	17.57	4	211.75	95.50	165.42	87.01
26	0.778	0.761	17.58	5	229.00	95.16	159.02	83.90
62	0.667	0.683	17.67	4	158.75	85.54	146.99	85.83
63	0.667	0.689	17.66	3	165.00	86.31	149.91	86.80
61	0.667	0.691	17.65	3	170.67	86.53	153.08	*88.47
60	0.667	0.686	17.70	4	174.25	85.98	151.25	87.72
59	0.667	0.679	17.73	3	178.00	85.21	149.36	87.25
58	0.667	0.669	17.75	4	182.50	84.01	147.85	87.51
57	0.667	0.663	17.75	3	195.67	83.24	147.20	87.93
56	0.667	0.660	17.76	4	208.75	82.91	144.96	86.89
55	0.667	0.646	17.84	6	230.00	81.39	133.10	80.90
71	0.556	0.559	17.81	3	148.00	70.31	115.62	81.49
70	0.556	0.562	17.81	3	159.33	70.72	119.86	83.99
69	0.556	0.558	17.85	3	165.00	70.31	119.35	83.94
68	0.556	0.556	17.90	3	172.00	70.10	119.44	84.01
67	0.556	0.554	17.92	3	189.33	69.89	120.52	*84.93
66	0.556	0.542	17.95	4	199.75	68.47	115.59	83.01
65	0.556	0.531	17.95	3	217.67	67.04	107.07	78.53
64	0.556	0.521	18.00	3	235.33	65.94	95.33	70.89

Notes.—The proportional gates based on the measurement of gate. The turbine runner and dynamometer carried during test on ball-bearing.

October, 1915

geared wheel drive, and no plants of any consequence have been so designed in recent years.

Now as to the question of testing water wheels. Mr. Wheeler has mentioned a chemical test of reported accuracy. I know of but one instance where such a test has been made, and then it was under conditions that do not ordinarily apply to hydraulic developments. The method employed in this instance was to inject a certain amount of salt solution in the water at the head of a long supply pipe to the wheel. The wheel was operated until the discharge water showed by analysis that the solution was constant. The quantity of water in the entire length of the pipe was calculated and the solution stopped. As soon as the discharge showed free from solution it was assumed that the amount of water contained in the pipe, at the time of calculation, had been used and the power delivered by the water was measured. The test was repeated several times and the comparative results were such as to warrant the assumption that the test was practically correct, but not as close as 99 per cent. It is improbable that an analysis of the solution would be within 99 per cent correct. Very few plants have such conditions as those described and I do not think such a test can be recognized except under such conditions as will permit of an accurate check on the quantity of water to be used.

President Jackson has generously given me the credit for the work of assembling this data. I did not consent to take up the work until President Jackson assured me of his co-operation and the results are due as much to his efforts as to mine.

Wm. B. Jackson, M. W. S. E.: It is coming to be widely appreciated by engineers who are interested in hydraulic engineering that there should be a water wheel testing flume having greater range of capacity than that at Holyoke, which may be said to be now recognized as the official testing flume of this country. This flume is capable of accommodating only relatively small water wheels under a relatively low head and there is now being agitated the question of the desirability of the United States Government constructing and operating an effective water wheel testing flume of large capacity, both as regards volume of water and height of head. I believe that the Western Society of Engineers may very properly assist in every possible way in work that leads toward the construction by the government of such a plant.

As I remember the matter, the Holyoke flume was originated by the Holyoke Company simply for the purpose of testing the wheels that were to be installed in their property, but it has gradually become of nation-wide usefulness. It is, however, entirely inadequate for the testing of the vast majority of wheels which are now being used throughout the country. Whenever it is desired to test the design of a large wheel it is necessary to make a special model of a size capable of being accommodated by the testing flume and the test must be run at a head which can be obtained at the flume.

This means that in the case of most of our large wheels the tests which we hear of have not been made on wheels of the size of the original, but on smaller models of the same type, and generally the tests are not made on the same head for which the wheel is to be used. For instance, the tests which were made to determine what efficiency should be expected from the wheels installed at the Keokuk plant were made on models of a small fraction of the output of the original wheels and at a head different from that obtained at Keokuk.

Also it is my understanding that it is not uncommon that the testing of water wheels at the Holyoke flume must, at times, be delayed until sufficient water may be used for the test without unreasonably robbing regular water power users.

It does seem that the gathering of tests on full-sized models of water wheels designed for important hydro-electric installations is of sufficient importance to make it desirable for our government to provide a suitable testing plant for such purposes.

It is an interesting fact that our American manufacturers were considerably behind the European manufacturers in the design of water wheels to fit special conditions, and that the European manufacturers were, and always have been, far behind our manufacturers in developing standard lines of water wheels for general use. I chanced to be in the water-wheel department of the Ganz Company at Budapest in 1902, when the engineers of the Ganz Company were taking apart one of the Leffel Company's Samson turbines, in process of developing designs for a standard line of water wheels to be manufactured by the Ganz Company. They informed me that they were the first European water-wheel manufacturers to consider the manufacture of a standard line of water-wheels.

An interesting fact in this line was brought out in a paper before this Society by me in 1903,* in which was shown a complete layout for a water-wheel equipment to effectively utilize the water at the Great Falls of the Potomac, where the head varied between 40 and 80 feet. The design was worked out for me in 1901 by Bell & Company of Kriens, Switzerland, as a routine piece of work, whereas we had no water-wheel manufacturer in this country at that time who was prepared to undertake such a design except as a very unusual and special piece of work.

*Hydraulic Developments as Related to Electrical Installations, Wm. B. Jackson, Journal W. S. E., June, 1903.

A STUDY OF GRADE CROSSING ELIMINATION IN CITIES

By C. N. Bainbridge, Assoc. M. W. S. E.

Presented before the Bridge and Structural Section, June 24, 1915.

The question of separation of grade crossings in municipalities is vital and its importance cannot be denied. No single question affecting the relations of railroads to cities has received more consideration than this during the last decade. Various cities, utilities commissions and legislatures are issuing orders or passing laws requiring the railways to separate the grades of their tracks from those of the streets, where public convenience and safety demand it. In practically all instances where such orders are issued, they state definitely how this separation of grades shall be made, and fix the new grades of the streets affected.

The railroads recognize the fact that it is within the right of a city to interfere with the grade of the railway tracks only as is imposed by its duty to preserve, as far as possible, the safety of public travel upon and along the streets and avenues intersected by such tracks, but it has not been conceded that a city has statutory or other authority to determine whether such safety should be accomplished by elevation or depression of the tracks, the streets being carried over or under the tracks respectively, or that it has the right to choose between the two methods from any consideration of mere taste or appearance. The railways claim that they, and not the city, are entitled to the choice between two methods that are equally safe.

In almost all instances orders for such work are drawn up after extensive consideration has been given the proposition by engineers representing the parties interested, and are generally based on some plan which is acceptable to both the railway company and the city. In instances where an order is not satisfactory to the railway company they have recourse to the courts, where, if no material satisfaction is gained, the work is at least delayed for considerable time.

Numerous articles have been published covering single projects, but practically all of these are projects of track elevation and are special in character. Little, however, has been written concerning the other method of separation of grades; namely, by depressing the tracks partially or completely and carrying the street over the tracks on bridges or viaducts. It can not be said conclusively which method is the more satisfactory. Although track depression has found favor in several cities, few projects of this nature have been carried to completion, and it remains for time to determine whether track depression will be as satisfactory as track elevation has already proved itself to be.

It is the intention of the writer, in this paper, to set forth some of the general features which will arise, and which must be considered by the engineer, in studying a problem of grade crossing elimination, in order to determine the most desirable and feasible method to accomplish the end desired, at the minimum expense.

In general, grade crossings can be eliminated in two ways only, by carrying the tracks over the street, or the street over the tracks. The tracks may be carried across the streets by depressing the streets and leaving the tracks at their original elevation, or by elevating the tracks and leaving the streets at their original elevation, or by a partial elevation of the tracks and a partial depression of the streets. The streets may be carried over the tracks by a full elevation of the streets or by a full depression of the tracks, or by a partial elevation of the streets and a partial depression of the tracks.

In the following discussion, track elevation refers to the case where the tracks are carried across the streets, and track depression refers to the case where the streets are carried over the tracks.

Probably the biggest factor entering into a question of grade crossing elimination is the cost, this being the most vital to the railroads, who generally bear the greater burden of the expense. Practically all questions which arise, where two or more plans present themselves, are determined from this standpoint.

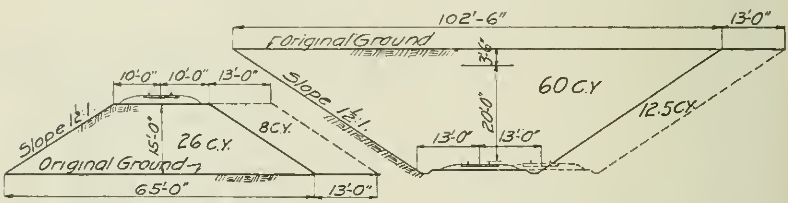
The geological character and topography of the country and the effect on the grade of the railroad are also big factors in selecting a plan for any grade separation project. In a flat low district situated as is Chicago, there is, however, little choice in selecting the method of separation. Track depression would be out of the question on account of difficulties which would be encountered by water and interference with the sewer system which would make the expense prohibitive. This leaves the alternative of track elevation, or partial elevation. Chicago, however, is only one city in many where grade separation is being carried on, and at other places where the tracks are at the summit of an ascending grade, the natural selection would be depression, unless this proved to be too expensive. There are still other places where the ground is high above water and the present tracks nearly level. In such cases either track elevation or track depression could be adopted without excessive gradients.

Numerous elements are involved in the study of a project of this nature and for convenience they will be considered in the following order:

Excavation or fill.
Clearances.
Bridges.
Right of way and retaining walls.
Changes in streets.
Apportioning of expenses.
Advantages and disadvantages.
Conclusions.

Excavation or Fill.

To carry the tracks over the street requires a vertical separation of grades of from 15 feet 6 inches to 17 feet 6 inches, allowing from 3 feet 6 inches to 4 feet for floor depth and 12 feet to 13 feet 6 inches for headroom. To carry the streets over the tracks requires a vertical separation of grades of from 21 feet 6 inches to 26 feet 6 inches, allowing from 18 to 22 feet for clearance and from 3 feet 6 inches to 4 feet 6 inches for floor depth. The difference of from 5 to 11 feet in the amount of vertical separation of grade, required for complete elevation and complete depression, together with the increased width of roadbed required for track depression over that required for track elevation, in order to provide for drainage, makes the amount of excavation, in the case of track depression considerably more than the amount of fill required for track elevation. Fig. 1 shows typical cross-sections required for track elevation, and track depression and illustrates the above statement for one and two track projects. From inspection, it is seen that the excess in yardage of track depression projects increases as the number of tracks increase.



CROSS SECTION-TRACK ELEVATION   CROSS SECTION-TRACK DEPRESSION.

FIG. 1

What appears at first glance to be a decided advantage for track elevation, may, on further study and consideration be an advantage for track depression. This depends largely on the source of material for fill, in the case of track elevation, and the distance it has to be hauled, and where material excavated—in the case of track depression—can be disposed of. Other things being equal, material can be excavated as cheaply in a cut for track depression as in the borrow pit for track elevation; but usually the cost of dumping material for fill will exceed the cost of wasting material from the cut, due to the fact that material for fill is usually dumped from a trestle, and the cost of the trestle is chargeable to the fill. The additional cost of a trestle will go a long way toward balancing the cost of additional yardage required in the project of track depression. This may be best illustrated by an example: Assuming that but one track is to be elevated or depressed, leaving the street in its original position and that the right of way is sufficiently wide so as not to require walls, the cross-sections required are shown in

Fig. 1. Assuming further that the cost of material for fill per cubic yard exclusive of cost of borrow pit and haul, and cost of handling traffic, is as follows:

Loading and shifting track at pit	=	$ .10
Unloading and distributing from trestle	=	.06
Trestle @ $6.00 per lin. ft. = 600/26	=	.23
Cost per cubic yard for fill in place, exclusive of cost of borrow pit and haul and cost of handling traffic	=	.39

Assuming that the cost of material excavated in the depression per cubic yard exclusive of haul and cost of land to waste on and cost of handling traffic is as follows:

Loading and shifting track in cut	=	$ .10
Unloading and distributing	=	.10
Cost per cubic yard of material removed from excavation, exclusive of haul and cost of land to waste on and cost of handling traffic	=	.20

From the foregoing it is noted that the cost of one cubic yard of material for fill, exclusive of the items indicated above, is practically twice the cost of one cubic yard of material from the depression, but from Fig. 1, it is noted that the quantity of material from one linear foot of depression is slightly in excess of twice the quantity of material for one linear foot of fill, thus making the cost for one linear foot of depression and one linear foot of fill approximately the same, exclusive of haul, cost of borrow pit and land on which to waste material, and cost of handling traffic.

Assuming further that the cost of haul is five mills per ton mile and that material weighs 2,500 lbs. per cubic yard, the cost of haul per cubic yard of material would be 0.625 cents per mile.

The cost of hauling material for one linear foot of embankment one mile = 26x.00625	=	$ .1625
The cost of hauling material for one linear foot of depression one mile = 60x.00625	=	.375

These figures indicate that, when the length of haul for material for fill is approximately equal to, or less than, twice the length of haul necessary to waste material from the depression, track elevation is cheaper.

For a two track proposition the same reasoning holds, and figures indicate that for equal hauls, track elevation is the cheaper if one trestle is used in making the fill, but when two trestles are used, track depression is the cheaper.

It has been assumed in the foregoing comparison that the cost of borrow pit and cost of land to waste material on would be approximately equal and would not enter into the above comparison. This, however, may not always be the case, and the cost of such land should be prorated to the estimated yardage for fill and excavation, and the value of the land, after the work is completed, credited to same. It is sometimes the case that a project of grade crossing elimination is carried on to advantage in conjunction with some other project, such as the construction of freight or storage yards, where considerable grading is necessary and material may be borrowed or wasted as the case may be, to good advantage and at small expense.

Further examples could be given, but the ones already cited will illustrate that the question of the source of material to be borrowed and place of disposition of material to be wasted is vital and should be considered for any project. Other items, such as difference in cost of bridges and walls, number of tracks, and cost of maintaining traffic, changes to sewers, and nature of material to be excavated, and depth of depression and amount of elevation will tend to throw the balance either one way or another for any particular case.

Clearances.

In recent years numerous state legislatures have passed various laws regarding vertical and side clearances. In some cases the requirements of these laws are more rigid than the present standard clearances of 22 ft. vertical and 7 ft. lateral, maintained by the majority of the railroads. The Minnesota law, one of the most recent ones, requires new tracks to be 14 ft. centers, 1 ft. greater than the present practice, and a side clearance of 8 ft. measured from the center line of track at the base of rail. This is 1 ft. greater than the present bridge clearance standards, 2 ft. 6 in. above the top of rail, and 3 ft. greater at top of rail. The clearance over tracks is fixed at 21 ft., which is not quite as great as the present railroad standard bridge clearance. This is typical of the laws being passed by various legislatures, although some specify but 7 ft. above the highest car for vertical clearance, which would reduce the clearance to about 20 ft. 6 in. In most cases, however, there is a provision in such laws which allows this clearance to be reduced in special cases, if approved by the city or railroad commission. For track depression projects the overhead clearance generally adopted is between 18 and 22 ft., but in some instances where passenger traffic alone is handled on the lines this is reduced to 16 ft., although this latter figure is somewhat scant if electrification is contemplated at some future date.

Where the tracks are elevated, the clearances of the bridge over the street varies in different localities, the usual clearances being 12 to 13 ft. for streets without street cars, and 13 ft. 6 in. to 14 ft. 6 in. for streets with street cars.

The following table, Fig. 2, gives the vertical clearances which have been used in the past for bridges over the tracks and for bridges over the streets in different localities under various conditions For proposed work there is little variation from the clearances shown for bridges over streets, but there is a strong tendency, as indicated by recent legislation, to increase the clearances under bridges over the track to 21 or 22 ft. wherever possible, unless the railway commission or some other competent authority permits a reduction in special cases.

CLEARANCES IN FEET OF BRIDGES OVER STREET			CLEARANCES IN FEET OF BRIDGES OVER TRACKS		
Location.	Sts. without St. Cars.	Sts. with St. Cars.	Location.	Clearances.	Side Clearance
Chicago	12 to 13	13.5	Chicago	16 to 18	....
Philadelphia	14	14	Philadelphia	20	....
			Rhode Island	18	....
			Connecticut	18	....
New York	14, usual, 11 and 12 special	14	New York City	16 to 18	....
			N. Y. State	21	....
			Massachusetts	18	....
Buffalo	13	14	Buffalo	15 to 18	....
Evanston	12 to 13	13.5	Minneapolis	18 to 18.5	....
			Minnesota	21	8
			North Dakota	21	8
Kansas City	13	14.5	Canada	22.5	....
			Kentucky	22	....
Cleveland	13	14.5	Cleveland	16.25	....
			New Hampshire	21	....
Detroit	13	14	Michigan	18	....
Milwaukee	12	13.5	Milwaukee	18	....
			Vermont	22	7.5
			Indiana	21	7

Fig. 2.

In 1910 it was attempted to pass national legislation governing clearances. The Martin bill was introduced in the national house of representatives, but was never brought to a vote. This bill stipulated that the maximum width of locomotives and cars should not exceed 10 ft. 6 in. and should not be higher than 14 ft. 2 in. It also stipulated that no structure of any kind should be closer than 6 ft. 11 in. to the center of the track, excepting platforms not over 3 ft. 11 in. high above top of rail, and the minimum vertical clearance was to be established at 20 feet. The interstate commerce commission was to be given authority to exempt individual obstructions from the provisions of this act if conditions rendered it necessary. This bill fixed 12 ft. 6 in. for distance between tracks, and also provided that all equipment, track and structures should be brought into conformity by Jan. 1912.

These requirements were not so rigid as to be a great hardship to the railroads if they had applied to new structures only, but the provision requiring all structures, track, and equipment to conform to the above, within a period of two years, was, in all probability, what killed the bill, for to conform to these requirements, would have meant an expenditure to the industries and railroads of many millions of dollars.

If legislation governing clearance must come, national legislation is preferable to state legislation. A railroad passing through six or eight states would not then have to conform to as many different laws for clearances, and trainmen would have some knowledge of what to expect in the way of clearances.

Bridges

Bridges for track elevation or track depression projects are in practically all instances of a permanent nature and are constructed of either structural steel or reinforced concrete; or a combination of both. A few of the roads are adopting concrete, wherever possible, to the exclusion of steel in structures of this class,

Fig. 3. Reinforced Concrete Bridge Crossing Humboldt Boulevard at Bloomingdale Road, Chicago, on C. M. & St. P. Ry.

as the first cost is the same as or less than steel, the maintenance is less, and it can be treated aesthetically to better advantage where such treatment is warranted by the nature of the district through which the road passes, such as across boulevards and in residence districts.

Figures 3 and 4 illustrate the latter statement in the case of track elevation. Figure 3 is a reinforced concrete bridge crossing Humboldt Boulevard in Chicago, and Figure 4 is a steel bridge crossing Grand Boulevard in Chicago. Numerous other examples could be presented, but the above are typical, and there is little question as to which presents the better appearance.

The same may be said for bridges crossing a depression of the tracks, although the need for aesthetic treatment is probably not so great, because fewer people will view the bridge from close range.

Figures 5 and 6, however, illustrate the two types. Figure 5 is a view of structure carrying Hennepin Ave., Minneapolis, across the depression of the C., M. & St. P. tracks, which was built in 1897. Figure 6 is the type of structure built by that road on its present project of track depression in the same city.

Bridges for track elevation can be divided into four types:

Type A. Structures spanning the full width of street with single spans.

Type B. Structures spanning the full width of street with two spans, supports being placed in the center of the street.

Fig. 4. Steel Bridge Over Grand Boulevard at 40th St., Chicago.

Type C. Structures spanning the full width of street with three spans, supports being placed at the curb lines.

Type D. Structures spanning the full width of street with four spans, supports being placed at the curb lines and at the center of roadway.

In practically all types it is desirable to:

1st. Keep the floor of the bridge as thin as possible;

2nd. Avoid any projections above the top of rail, which might be a menace to safety;

3rd. Select a type of bridge which can be readily altered to provide for additional tracks.

Bridges of Types A, B, and C, except in cases of narrow streets where comparatively short spans can be employed, have no alternative, except the use of steel girders, although they have been

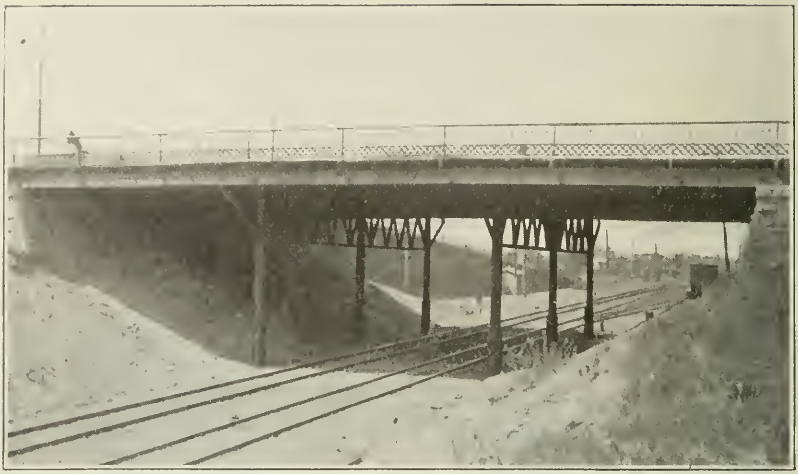


Fig. 5. Hennepin Ave. Bridge Over C. M. & St. P. Ry. at Minneapolis.

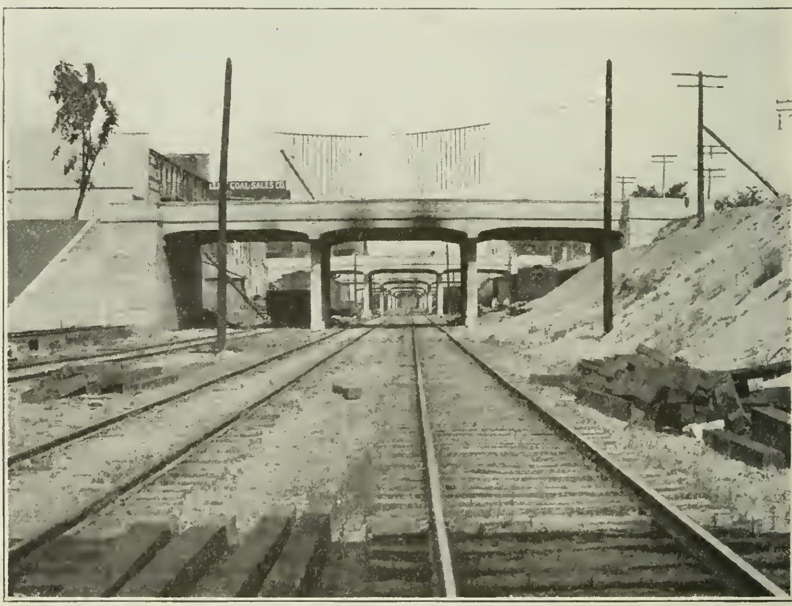


Fig. 6. Typical C. M. & St. P. Structure on Recent Work in Minneapolis.

used to some extent by resorting to a combination of structural steel and reinforced concrete, but not to the exclusion of the deep side girders. These types, however, have the first qualification of thin floors, but cannot in all cases meet the second qualification of no projections above the top of rail, nor do they meet the third provision for taking care of additional tracks without considerable alteration and expense.

Figure 7 illustrates how the projections above the bridge floor are a menace to safety, unless sufficient side clearance is maintained by spreading the track which, although an advantage, will

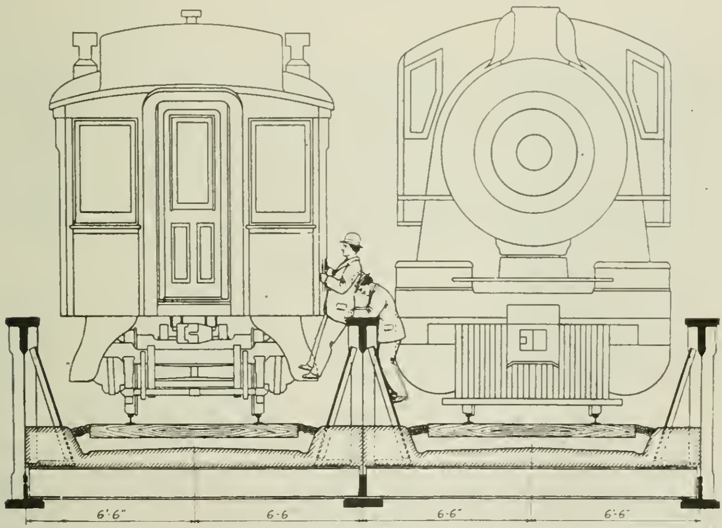


Fig. 7.

increase the cost of the bridge and embankment. Figure 8 illustrates conditions prevailing when deck type structure of type "D" is permitted.

Bridges of types "B" and "D" have the objection that the roadway is obstructed by the supports in the center of the street, but, with the possible exception of structures spanning boulevards, there is no serious disadvantage in this, provided the roadway on each side of the center supports is of sufficient width to allow two vehicles going in the same direction to pass each other. This objection would be even less for structures spanning streets with double street car tracks, although it requires the spreading of the car tracks. The car tracks themselves form a natural barrier in the center of the street, there being little occasion for traffic across the car tracks from one to the other, especially in the short distance occupied by the bridges.

Bridges of type "D" meet the three requirements of thin floors, no projections above top of rail and ease of alteration to provide for additional tracks. Due to the comparatively short spans, this type is well adapted to be constructed of either steel or concrete.

It has been recognized by practically all parties interested that tight floors are a necessity in bridges crossing city streets, not only to prevent grease, dirt and water from dropping through, but

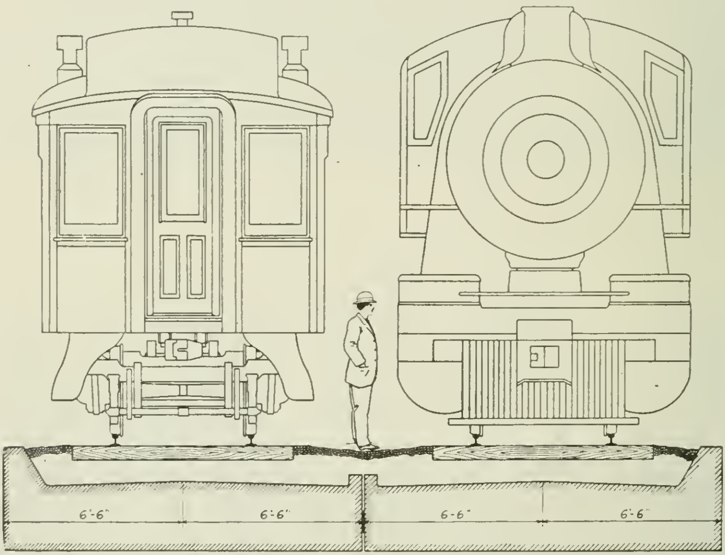
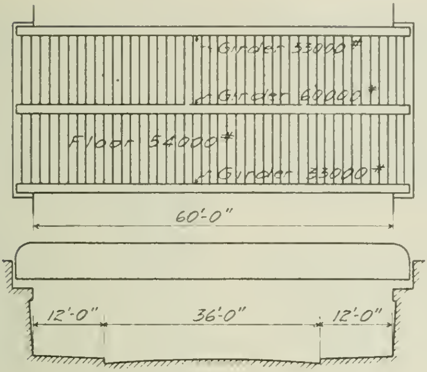


Fig. 8.

also to deaden the noise of trains passing at high speed across the bridges. Numerous types of floors have been used to accomplish these results, but only two types of floors, i. e., steel I-beams and concrete slabs for steel bridges and the solid slab for concrete bridges, will be considered here. There are numerous modifications of or variations from these selections which might be adopted, the various roads using the one with which they have had the better success, but in all probability floors as used in concrete bridges of type "D" will remain the cheaper.

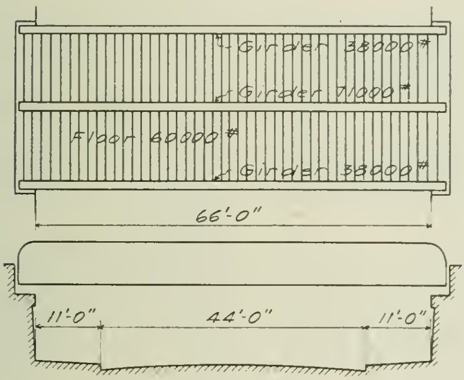
Structures spanning 60-ft., 66-ft. and 80-ft. streets are compared, these being the usual width of streets in cities.

The relative economy of the various types is shown from the following estimates:



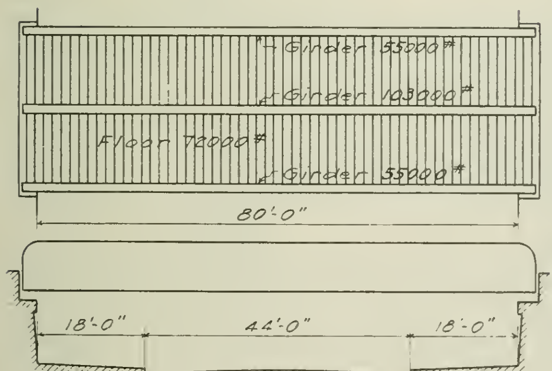
60'-0" Street

Estimate			
Material	Quantity	Unit Cost	Total
Struct Steel	180000#	3¢	$5400
Conc Floor	52 CY	$18.00	930
Conc Abut	530 "	$7.00	3710
Exc for Abut	350 "	$1.00	350
Backfill	120 "	25¢	30
Paving on R of W	400 S.Y	$3.25	1300
Sidewalk on R of W	2400 S F	15¢	360
Waterproof'g	1725 S F	20¢	340
Falsework	160 L.F	$8.00	1280
Eng & Cont		20%	$2700
Total			$16,400
Each add Track costs			$6000



66'-0" Street

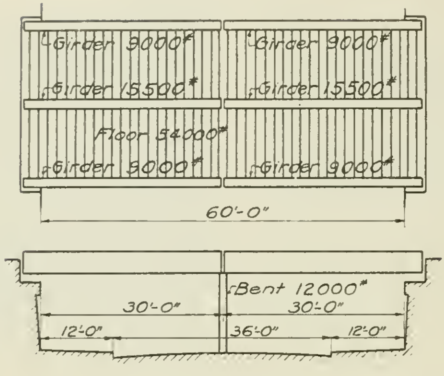
Estimate			
Material	Quantity	Unit Cost	Total
Struct Steel	207000#	3¢	$6210
Conc Floor	57 C Y	$18.00	1030
Conc Abut	530 "	$7.00	3710
Exc for Abut	340 "	$1.00	340
Backfill	120 "	25¢	30
Paving on R of W	490 S Y	$3.25	1590
Sidewalk on R. of W.	2200 S.F	15¢	330
Waterproof'g	1900 S.F	20¢	380
Falsework	172 L F	$8.00	1380
Eng. & Cont.		20%	$3000
Total			$18,000
Each add Track costs			$6,700



80'-0" Street

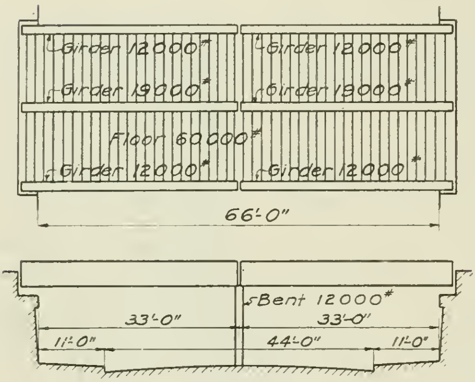
Estimate			
Material	Quantity	Unit Cost	Total
Struct Steel	285000#	3¢	$8550
Conc Floor	69 C Y	$18.00	1240
Conc Abut	530 "	$7.00	3710
Exc for Abut	340 "	$1.00	340
Backfill	120 "	25¢	30
Paving on R of W	490 S Y	$3.25	1590
Side walk on R. of W	3600 S F	15¢	540
Waterproof'g	2240 S F	20¢	450
Falsework	200 L F	$8.00	1600
Eng. & Cont		20%	$3650
Total			$21,700
Each add Track costs			$8200

TYPE A. Steel Structures spanning full Width of Street with Single Span
FIG 9



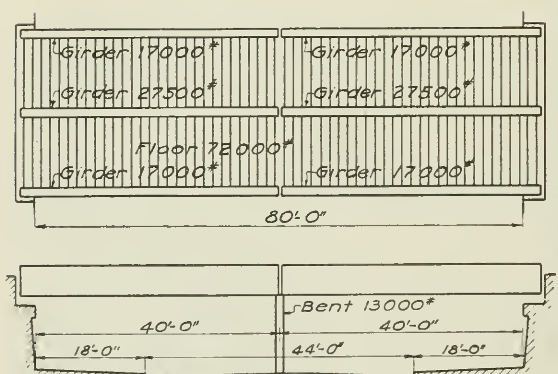
60'-0" Street

Estimate			
Material	Quantity	Unit Cost	Total
Struct. Steel	133000#	3¢	$3990
Conc. Floor	52 C.Y.	$18.00	935
Conc. Abut.	530 "	$7.00	3710
Exc. for Abut.	340 "	$1.00	340
Backfill for Abut.	120 "	25¢	30
Conc. in Pier Footgs	21 "	$8.00	170
Exc. for Pier Footgs	40 "	1.00	40
Backfill for Pier Foot'gs	20 "	25¢	5
Paving on R of W.	400 S.Y.	$3.25	1300
Sidewalk on R of W.	2400 S.F.	15¢	360
Waterproof'g	1725 "	20¢	340
Falsework	160 L.F.	$8.00	1280
Eng. & Cont.		20%	2500
Total			$15000
Each add. Track costs			$5300



66'-0" Street

Estimate			
Material	Quantity	Unit Cost	Total
Struct. Steel	158000#	3¢	$4740
Conc. Floor	57 C.Y.	$18.00	1030
Conc. Abut.	530 "	$7.00	3710
Exc. for Abut.	340 "	$1.00	340
Backfill for Abut.	120 "	25¢	30
Conc. in Pier Foot'gs.	23 "	$8.00	185
Exc. for Pier Foot'gs.	40 "	1.00	40
Backfill for Pier Foot'gs.	20 "	25¢	5
Paving on R. of W.	490 S.Y.	$3.25	1590
Sidewalk on R. of W.	2200 S.F.	15¢	330
Waterproof'g	1900 "	20¢	380
Falsework	172 L.F.	$8.00	1380
Eng. & Cont.		20%	2740
Total			$16500
Each add. Track costs			$5800

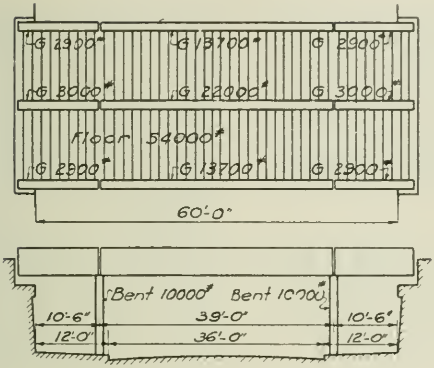


80'-0" Street

Estimate			
Material	Quantity	Unit Cost	Total
Struct. Steel	208000#	3¢	$6240
Conc. Floor	69 C.Y.	$18.00	1240
Conc. Abut.	530 "	$7.00	3710
Exc. for Abut.	340 "	$1.00	340
Backfill for Abut.	120 "	25¢	30
Conc. in Pier Foot'gs.	26 "	$8.00	205
Exc. for Pier Foot'gs.	50 "	1.00	50
Backfill for Pier Foot'gs.	20 "	25¢	5
Paving on R. of W.	490 S.Y.	$3.25	1590
Sidewalk on R. of W.	3600 S.F.	15¢	540
Waterproof'g	2240 "	20¢	450
Falsework	200 L.F.	$8.00	1600
Eng. & Cont.		20%	3200
Total			$19200
Each add. Track costs			$6900

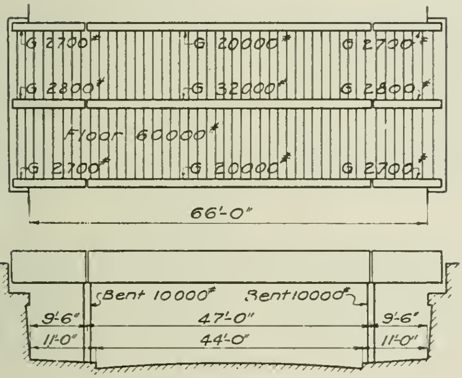
TYPE B. Steel Structures Spanning full Width of Street with Two Spans

FIG. 10



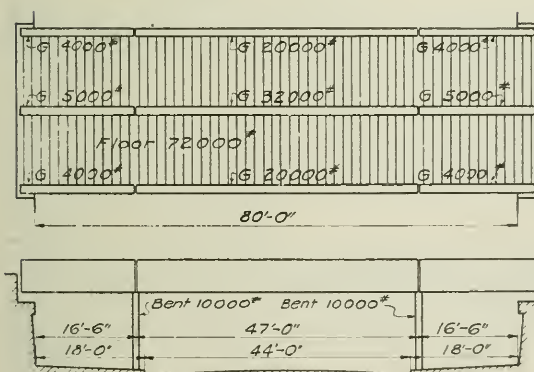
60'-0" Street

Estimate			
Material	Quantity	Unit Cost	Total
Struct Steel	141,000#	3¢	$4230
Conc. Floor	52 C.Y.	$18.00	930
Conc. Abut.	530 "	$7.00	3710
Exc for Abut.	340 "	$1.00	340
Backfill for Abut.	120 "	25¢	30
Conc in Pier Foot'gs	37 "	$8.00	300
Exc for Pier Foot'gs	70 "	$1.00	70
Backfill for Pier Foot'gs.	40 "	25¢	10
Paving on R. of W.	400 S.Y.	$3.25	1300
Sidewalk on R. of W.	2400 S.F.	15¢	360
Waterproof'g.	1725 "	20¢	340
Falsework	160 L.F.	$8.00	1280
Eng. & Cont		20%	2600
Total			$15,500
Each add Track costs			$5500



66'-0" Street

Estimate			
Material	Quantity	Unit Cost	Total
Struct. Steel	168400#	3¢	$5050
Conc. Floor	57 C.Y.	$18.00	1030
Conc Abut.	530 "	$7.00	3710
Exc. for Abut	340 "	$1.00	340
Backfill for Abut.	120 "	25¢	30
Conc. in Pier Foot'gs.	42 "	$8.00	340
Exc. for Pier Foot'gs.	70 "	$1.00	70
Backfill for Pier Foot'gs.	40 "	25¢	10
Paving on R. of W.	490 S.Y.	$3.25	1590
Sidewalk on R. of W.	2200 S.F.	15¢	330
Waterproof'g	1900 "	20¢	380
Falsework	172 L.F.	$8.00	1380
Eng. & Cont.		20%	2840
Total			$17,100
Each add Track costs			$6,000

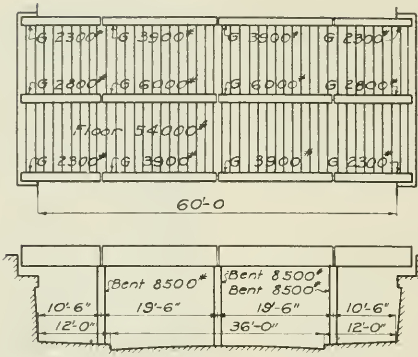


80'-0" Street

Estimate			
Material	Quantity	Unit Cost	Total
Struct. Steel	190000#	3¢	$5700
Conc. Floor	69 C.Y.	$18.00	1240
Conc. Abut	530 "	$7.00	3710
Exc for Abut	340 "	$1.00	340
Backfill for Abut.	120 "	25¢	30
Conc in Pier Foot'gs.	46 "	$8.00	370
Exc. for Pier Foot'gs	80 "	$1.00	80
Backfill for Pier Foot'gs.	40 "	25¢	10
Paving on R. of W.	490 S.Y.	$3.25	1590
Sidewalk on R. of W.	3600 S.F.	15¢	540
Waterproof'g	2240 "	20¢	450
Falsework	200 L.F.	$8.00	1600
Eng. & Cont		20%	3140
Total			$18,800
Each add Track costs			$6,800

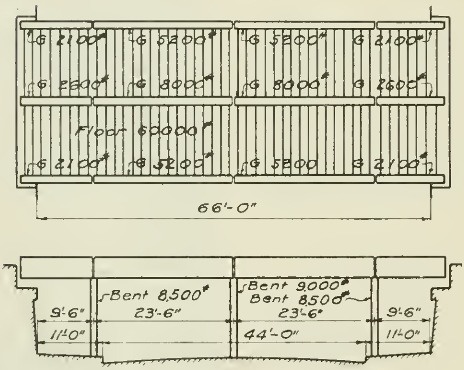
TYPE-C. Steel Structures Spanning full Width of Street with Three Spans

FIG 11.



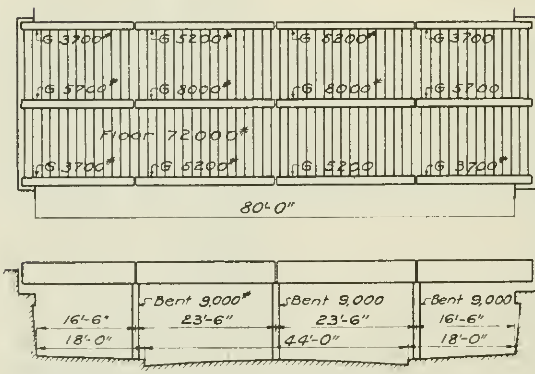
60'-0" Street

Estimate			
Material	Quantity	Unit Cost	Total
Struct. Steel	121900#	3¢	$3660
Conc. Floor	52 C.Y.	$18.00	930
Conc. Abut.	530 "	$7.00	3710
Exc. for Abut.	340 "	$1.00	340
Backfill for Abut.	120 "	25¢	30
Conc. in Pier Footgs.	45 "	$8.00	360
Exc. for Pier Footgs.	80 "	$1.00	80
Backfill for Pier Footgs.	40 "	25¢	10
Paving on R of W.	400 S.Y.	$3.25	1300
Sidewalk on R of W.	2400 S.F.	15¢	360
Waterproof'g	1725 "	20¢	340
Falsework	160 L.F.	$8.00	1280
Eng. & Cont.		20%	$2500
Total			$14900
Each add. Track costs			$5100



66'-0" Street

Estimate			
Material	Quantity	Unit Cost	Total
Struct Steel	136400#	3¢	$4090
Conc Floor	57 C.Y.	$18.00	1030
Conc Abut.	530 "	$7.00	3710
Exc for Abut.	340 "	$1.00	340
Backfill for Abut.	120 "	25¢	30
Conc in Pier Foot'gs	46 "	$8.00	370
Exc for Pier Foot'gs	80 "	$1.00	80
Backfill for Pier Foot'gs	40	25¢	10
Paving on R of W	490 S.Y.	$3.25	1590
Sidewalk on R of W	2200 S.F.	15¢	330
Waterproof'g	1900 "	20¢	380
Falsework	172 L.F.	$8.00	1380
Eng. & Cont		20%	2660
Total			$16,000
Each add. Track costs			5500

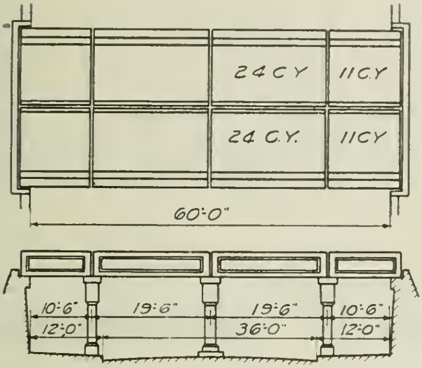


80'-0" Street

Estimate			
Material	Quantity	Unit Cost	Total
Struct. Steel	162000#	3¢	$4860
Conc. Floor	69 C.Y.	$18.00	1240
Conc. Abut.	530 "	$7.00	3710
Exc. for Abut.	340 "	$1.00	340
Backfill for Abut.	120 "	25¢	30
Conc. in Pier Footgs.	51 "	$8.00	410
Exc. for Pier Foot'gs	90 "	$1.00	90
Backfill for Pier Foot'gs.	40 "	25¢	10
Paving on R. of W	490 S.Y.	$3.25	1590
Sidewalk on R of W	3600 S.F.	15¢	540
Waterproof'g	2240 "	20¢	450
Falsework	200 L.F.	$8.00	1600
Eng. & Cont.		20%	2930
Total			$17,800
Each add. Track costs			$6300

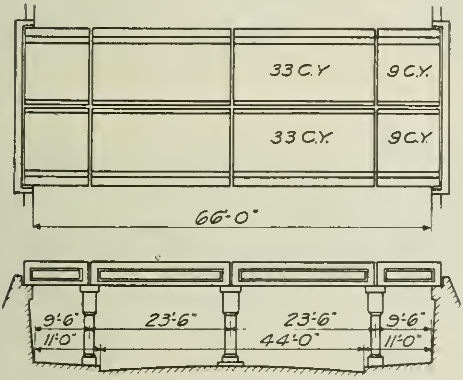
TYPE D Steel Structures Spanning full Width of Street with Four Spans

FIG. 12



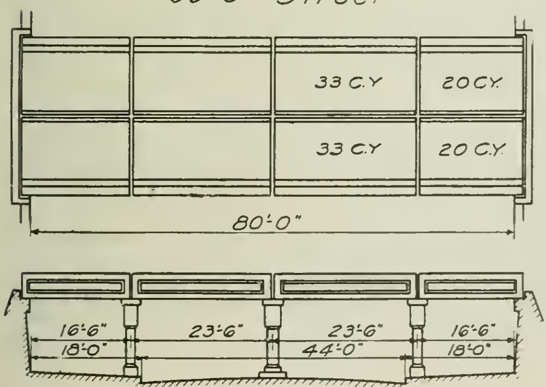
60'-0" Street

Estimate			
Material	Quantity	Unit Cost	Total
Conc. Slab	140 C.Y.	$14.00	$1960
Conc Columns	55 "	$21.00	1155
Col Footgs.	68 "	$8.00	545
Excavation for Col Footgs.	150 "	$1.00	150
Backfill for Col Footgs	60 "	25¢	15
Conc Abut.	420 "	$7.00	2940
Exc for Abut	325 "	$1.00	325
Backfill for Abut.	160 "	25¢	40
Paving on R. of W.	400 S.Y.	$3.25	1300
Sidewalk on R. of W.	2400 S.F.	15¢	360
Waterproofg	1725 "	20¢	340
Falsework	160 L.F.	$8.00	1280
Eng & Cont		20%	2090
Total			$12,500
Each add. Track costs			$4200



66'-0" Street

Estimate			
Material	Quantity	Unit Cost	Total
Conc Slab	168 C.Y.	$14.00	$2350
Conc Columns	55 "	$21.00	1155
Col. Footgs.	68 "	$8.00	545
Exc for Col Footgs.	150 "	$1.00	150
Backfill for Col Footgs.	60 "	25¢	15
Conc. Abut.	420 "	$7.00	2940
Exc for Abut	325 "	$1.00	325
Backfill for Abut.	160 "	25¢	40
Paving on R of W.	490 S.Y.	$3.25	1590
Sidewalk on R. of W.	2200 S.F.	15¢	330
Waterproofg	1900 "	20¢	380
Falsework	172 L.F.	$8.00	1380
Eng & Cont.		20%	2200
Total			$13,400
Each add Track costs			$4500

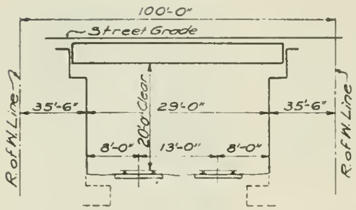


80'-0" Street

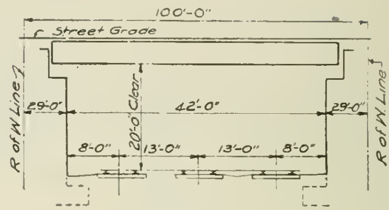
Estimate			
Material	Quantity	Unit Cost	Total
Conc Slab	212 C.Y.	$14.00	$2980
Conc Columns	59 "	$21.00	1240
Col. Foot'gs.	76 "	$8.00	610
Exc for Col Footgs.	170 "	$1.00	170
Backfill for Col. Foot'gs	65 "	25¢	15
Conc. Abut.	420 "	$7.00	2940
Exc. for Abut	325 "	$1.00	325
Backfill for Abut.	160 "	25¢	40
Paving on R. of W.	490 S.Y.	$3.25	1590
Sidewalk on R. of W.	3600 S.F.	15¢	540
Waterproofg	2240 "	20¢	450
Falsework	200 L.F.	$8.00	1600
Eng. & Cont.		20%	2500
Total			$15,000
Each add. Track costs			$5300

TYPE D Concrete Structures Spanning full Width of Street with Four Spans

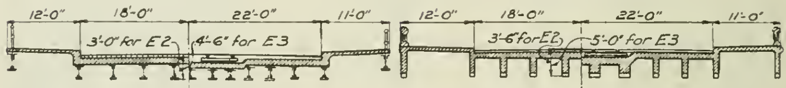
FIG. 13.



TYPE E2



TYPE E3



Half Section
Steel Structure
36'-0" Roadway
60'-0" Street
for Types E2 & E3

Half Section
Steel Structure
44'-0" Roadway
66'-0" Street
for Types E2 & E3

Half Section
Concrete Structure
36'-0" Roadway
60'-0" Street
for Types E2 & E3

Half Section
Concrete Structure
44'-0" Roadway
66'-0" Street
for Types E2 & E3

Estimates - Steel Bridges.

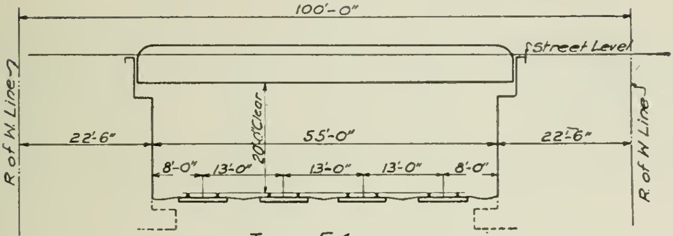
Material	Unit Cost	Type E2 60'-0" Street 36'-0" Roadway		Type E2 66'-0" Street 44'-0" Roadway		Type E3 60'-0" Street 36'-0" Roadway		Type E3 66'-0" Street 44'-0" Roadway	
		Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost
Structural Steel	$ .03¼	60,000#	$ 1950	90,000#	$ 2920	95,000#	$ 3090	130,000#	$ 4220
Conc Sidewalk on Br.	.40	864 S.F.	345	792 S.F.	320	1180 S.F.	470	1,078 S.F.	430
Conc. Slab on Br	20.00	36 C.Y.	720	44 C.Y.	880	49 C.Y.	980	60 C.Y.	1200
Reinf. Conc. Abut.	10.00	520 C.Y.	5200	560 C.Y.	5600	520 C.Y.	5200	560 C.Y.	5600
Exc. for Abut	1.00	600 C.Y.	600	660 C.Y.	660	600 C.Y.	600	660 C.Y.	660
Backfill	.60	720 C.Y.	430	800 C.Y.	480	720 C.Y.	430	800 C.Y.	480
Handrail	1.50	80 L.F.	120	80 L.F.	120	105 L.F.	160	105 L.F.	160
Paving on Br.	2.25	144 S.Y.	320	174 S.Y.	390	196 S.Y.	440	240 S.Y.	540
Paving on R. of W but off Bridge	3.25	254 S.Y.	825	312 S.Y.	1030	204 S.Y.	665	250 S.Y.	810
Sidewalk on R. of W but off Bridge	.15	1,536 S.F.	230	1408 S.F.	210	1220 S.F.	185	1,122 S.F.	170
Eng. & Cont	20%		2160		2490		2480		2,830
Totals			$12,900		$15,100		$14,700		$17,100

Estimates - Conc Bridges

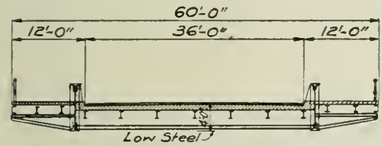
Conc. Floor	$ 22.00	100 C.Y.	$ 2200	130 C.Y.	2860	165 C.Y.	$ 3,630	190 C.Y.	$ 4180
Reinf. Conc. Abut.	10.00	475 C.Y.	4750	515 C.Y.	5150	475 C.Y.	4750	515 C.Y.	5150
Exc. for Abut.	1.00	600 C.Y.	600	660 C.Y.	660	600 C.Y.	600	660 C.Y.	660
Back fill	60	720 C.Y.	430	800 C.Y.	480	720 C.Y.	430	800 C.Y.	480
Paving on Br	2.25	144 S.Y.	325	174 S.Y.	350	180 S.Y.	405	220 S.Y.	500
Paving on R of W but off Bridge.	3.25	254 S.Y.	825	312 S.Y.	1,030	220 S.Y.	715	270 S.Y.	880
Sidewalk on R of W. but off Bridge	.15	1,536 S.F.	230	1,408 S.F.	210	1320 S.F.	200	1210 S.F.	180
Handrail	2.25	80 L.F.	180	80 L.F.	180	105 L.F.	230	105 L.F.	230
Eng. & Cont.	20%		1,860		2,240		2,240		2,440
Totals			$ 11,400		$ 13,200		$ 13200		$ 14,700

TYPE E2 - STRUCTURES SPANNING 2 TRACKS WITH SINGLE SPAN
TYPE E3 - STRUCTURES SPANNING 3 TRACKS WITH SINGLE SPAN

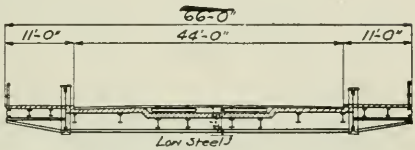
FIG. 14



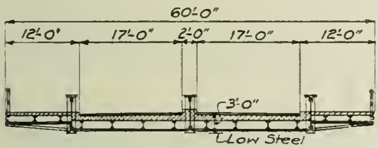
TYPE E4



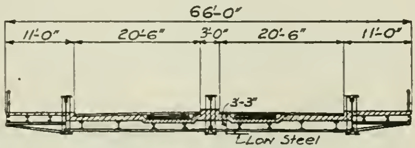
Section of Two Girder Bridge Spanning Four Tracks.
36'-0" Roadway & 60'-0" Street
Type E4



Section of Two Girder Bridge Spanning Four Tracks - 44'-0" Roadway & 66'-0" Street
Type E4



Section of Three Girder Bridge Spanning Four Tracks
36'-0" Roadway & 60'-0" Street
Type E4

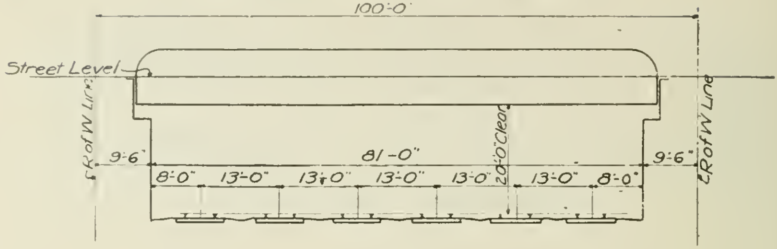


Section of Three Girder Bridge Spanning Four Tracks - 44'-0" Roadway & 66'-0" Street
Type E4

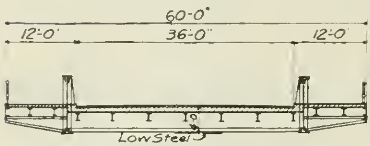
ESTIMATES										
Material	Unit Cost	Type E4-2 Girders 60'-0" Street 36'-0" Roadway		Type E4-3 Girders 60'-0" Street 36'-0" Roadway		Type E4-2 Girders 66'-0" Street 44'-0" Roadway		Type E4-3 Girders 66'-0" Street 44'-0" Roadway	
		Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost
Structural Steel	$ .03¼	166,000#	$ 5395	127,000#	$ 4,130	238,000#	$ 7735	180,000#	$ 5850
Concrete Sidewalk on Bridge	.40	1,200 S.F.	480	1200 S.F.	480	1080 S.F.	430	1080 S.F.	430
Conc Slabs on Br.	20.00	67 C.Y.	1,340	74 C.Y.	1,480	80 C.Y.	1,600	85 C.Y.	1,700
Reinf. Conc. Abut.	10.00	520 C.Y.	5,200	520 C.Y.	5200	560 C.Y.	5,600	560 C.Y.	5,600
Exc. for Abut.	1.	600 C.Y.	600	600 C.Y.	600	660 C.Y.	660	660 C.Y.	660
Backfill	.60	720 C.Y.	430	720 C.Y.	430	800 C.Y.	480	800 C.Y.	480
Handrail	1.50	130. L.F.	200	130 L.F.	200	130 L.F.	200	130 L.F.	200
Paving on Br.	2.25	240 S.Y.	540	220 S.Y.	495	295 S.Y.	665	275 S.Y.	620
Paving on R of W but off Bridge	3.25	160 S.Y.	520	160 S.Y.	520	195 S.Y.	630	195 S.Y.	630
Sidewalk on R of W. but off Br.	.15	960 S.F.	145	960 S.F.	145	880 S.F.	130	880 S.F.	130
Eng & Cont	20%		2,950		2,720		3,570		3,300
Totals			$17,800		$16,400		$21,700		$19,600

TYPE E4-STEEL STRUCTURES SPANNING FOUR TRACKS WITH SINGLE SPAN

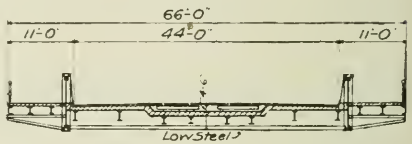
FIG. 15



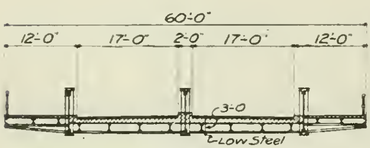
TYPE E6



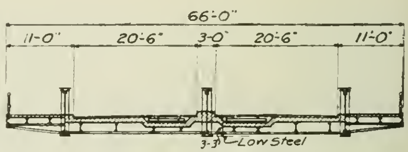
Section of Two Girder Bridge Spanning Six Tracks - 36'-0" Roadway - 60'-0" Street Type E6



Section of Two Girder Bridge Spanning Six Tracks - 44'-0" Roadway - 66'-0" Street Type E6



Section of Three Girder Bridge Spanning Six Tracks - 36'-0" Roadway - 60'-0" Street Type E6



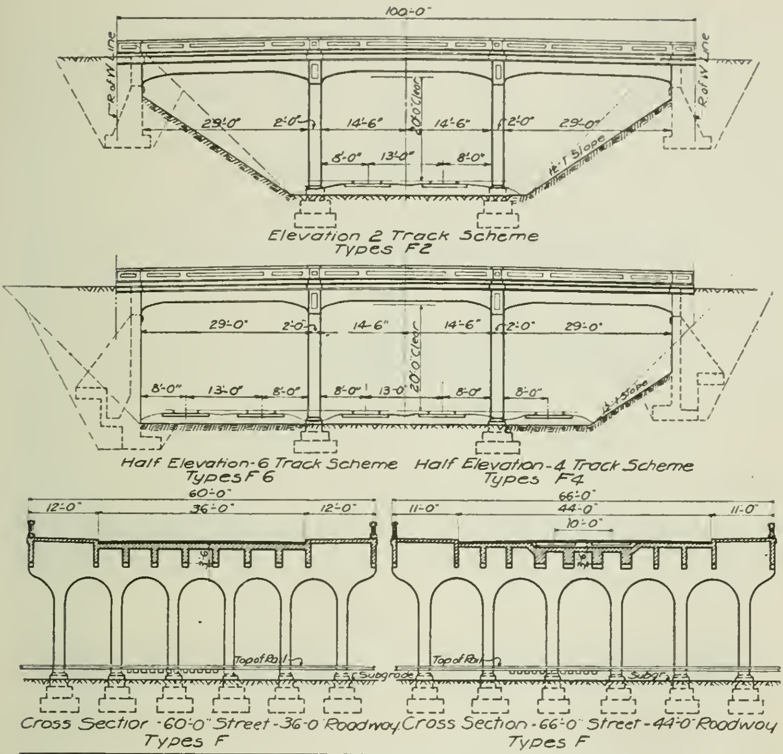
Section of Three Girder Bridge Spanning Six Tracks - 44'-0" Roadway - 66'-0" Street. Type E6

ESTIMATES

Material	Unit Cost	Type E6-2 Girders 60'-0" Street 36'-0" Roadway		Type E6-3 Girders 60'-0" Street 36'-0" Roadway		Type E6-2 Girders 66'-0" Street 44'-0" Roadway		Type E6-3 Girders 66'-0" Street 44'-0" Roadway	
		Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost
Structural Steel	$ 0.03¼	300,000#	$ 9,750	240,000#	$ 7,800	410,000#	$ 13320	324,000#	$ 10,530
Concrete Sidewalk on Bridge	0.40	1,800 sq ft	720	1,800 sq ft	720	1,584 sq ft	630	1,584 sq ft	630
Concrete Slabs	20.00	100 c.y.	2,000	110 cy	2,200	117 c.y.	2,340	124 cy	2,480
Reinforced Conc. Abutment	10.00	540 C.Y.	5,400	540 C.Y.	5,400	580 C.Y.	5,800	580 C.Y.	5,800
Exc for Abut.	1.00	620 cy	620	620 cy	620	680 cy	680	680 cy	680
Back Fill	.60	750 cy	450	750 cy	450	830 cy	500	830 cy	500
Handrail	1.50	200 lin ft	300	200 lin ft	300	200 lin ft	300	200 lin ft	300
Paving on Br	2.25	360 sq y	810	330 sq y	740	430 sq y	970	400 sq y	900
Paving on R of W. but off Bridge	3.25	14 "	45	14 "	45	59 "	191	59 "	191
Sidewalk on R of W, but off Br	.15	240 ft	35	240 ft	35	528 ft	79	528 ft	79
Eng & Cont	20%		4,070		3,690		4,990		4,410
Totals			$ 24200		$ 22000		$ 29800		$ 26500

TYPE E6-STEEL STRUCTURES SPANNING SIX TRACKS WITH SINGLE SPAN

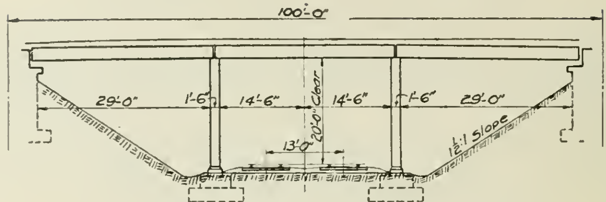
FIG 16



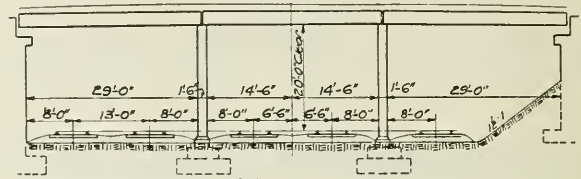
ESTIMATES													
MATERIAL	Unit Cost	Type F2 60'-0" Street 36'-0" Roadway		Type F2 66'-0" Street 44'-0" Roadway		Type F4 60'-0" Street 36'-0" Roadway		Type F4 66'-0" Street 44'-0" Roadway		Type F6 60'-0" Street 36'-0" Roadway		Type F6 66'-0" Street 44'-0" Roadway	
		Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost
Conc. Floor	$22.00	280 C.Y.	$ 6,160	360 C.Y.	$ 7,920	280 C.Y.	$ 6,160	360 C.Y.	$ 7,920	280 C.Y.	$ 6,160	360 C.Y.	$ 7,920
Conc. Cols. Neat work	23.00	34 " "	780	40 " "	920	34 " "	780	40 " "	920	34 " "	780	40 " "	920
" " Footings	8.00	60 " "	480	74 " "	590	60 " "	480	74 " "	590	60 " "	480	74 " "	590
Reinf. Conc. Abut.	10.00					330 " "	3,300	360 " "	3,600	474 " "	4,740	515 " "	5,150
Plain " "	7.00	210 C.Y.	1,410	230 C.Y.	1,610								
Exc. for Abut. & Col. Foot'gs.	1.00	1,200 " "	1,200	1,340 " "	1,340	1,480 C.Y.	1,480	1,640 C.Y.	1,640	830 C.Y.	830	940 C.Y.	940
Back Fill	.60	550 " "	330	600 " "	360	1,100 " "	660	1,200 " "	720	1,380 " "	830	1,500 " "	900
Paving on Br.	2.25	380 S.Y.	850	460 S.Y.	1,040	380 S.Y.	850	460 S.Y.	1,040	380 S.Y.	850	460 S.Y.	1,040
Paving on R. of W. but off Br.	3.25	20 " "	60	30 " "	100	20 " "	60	30 " "	100	20 " "	60	30 " "	100
Sidewalk on R. of W. but off Br.	.15	132 S.F.	20	120 S.F.	20	132 S.F.	20	120 S.F.	20	132 S.F.	20	120 S.F.	20
Handrail	2.25	200 L.F.	450	200 L.F.	450	200 L.F.	450	200 L.F.	450	200 L.F.	450	200 L.F.	450
Eng. & Cont.	20%		2,400		2,850		2,860		3,400		3,000		3,570
Totals			$14,200		$17,200		$17,100		$20,400		$18,200		$21,600

TYPE F - CONCRETE STRUCTURES SPANNING 2, 4 & 6 TRACKS WITH THREE SPANS

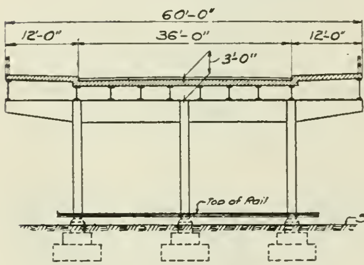
FIG. 17



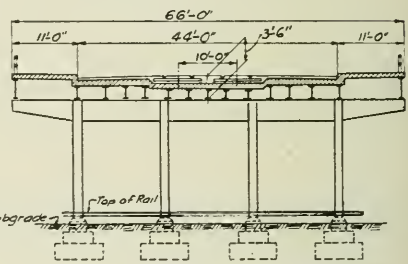
Types F2 Elevation-2 Track Scheme



Half Elevation-6 Track Scheme Half Elevation-4 Track Scheme
TYPES F6 TYPES F4



Cross-Section 60'-0" Street-36'-0" Roadway
TYPES F2 - F4



Cross-Section 66'-0" Street-44'-0" Roadway
TYPES F6

ESTIMATES

	Unit Cost	Type F2 60'-0" Street 36'-0" Roadway		Type F2 66'-0" Street 44'-0" Roadway		Type F4 60'-0" Street 36'-0" Roadway		Type F4 66'-0" Street 44'-0" Roadway		Type F6 60'-0" Street 36'-0" Roadway		Type F6 66'-0" Street 44'-0" Roadway	
		Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost
Struct. Steel	$.03¼	215000#	$6990	315,000#	$10,240	215,000#	$6,990	315,000#	$10,240	215,000#	$6990	315,000#	$10,240
Conc. Sidewalk on Br.	.40	2400 S.F.	960	2200 S.F.	880	2400 S.F.	960	2200 S.F.	880	2400 S.F.	960	2200 S.F.	880
Conc. Slab	22.	100 C.Y.	2200	165 C.Y.	3630	100 C.Y.	2200	165 C.Y.	3630	100 C.Y.	2200	165 C.Y.	3630
Conc. Col. Foot'gs	8	40 C.Y.	320	50 C.Y.	400	40 C.Y.	320	50 C.Y.	400	40 C.Y.	320	50 C.Y.	400
Reinf. Conc. Abut.	10.					330 C.Y.	3300	360 C.Y.	3600	474 C.Y.	4740	517 C.Y.	5170
Plain Conc. Abut.	7.	210 C.Y.	1470	230 C.Y.	1610								
Exc. for Abut. & Col. Foot'gs	1.	1100 C.Y.	1100	1240 C.Y.	1240	1380 C.Y.	1380	1540 C.Y.	1540	730 C.Y.	730	840 C.Y.	840
Backfill	.60	500 C.Y.	300	550 C.Y.	330	1100 C.Y.	660	1200 C.Y.	720	1380 C.Y.	830	1500 C.Y.	900
Paving on Br.	2.25	380 S.Y.	855	460 S.Y.	1030	380 S.Y.	855	460 S.Y.	1030	380 S.Y.	855	460 S.Y.	1030
Paving on R. of W. but off Br.	3.25	20 S.Y.	65	30 S.Y.	100	20 S.Y.	65	30 S.Y.	100	20 S.Y.	65	30 S.Y.	100
Sidewalk on R. of W. but off Br.	.15	132 S.F.	20	120 S.F.	20	132 S.F.	20	120 S.F.	20	132 S.F.	20	120 S.F.	20
Handrail	1.50	200 L.F.	300	200 L.F.	300	200 L.F.	300	200 L.F.	300	200 L.F.	300	200 L.F.	300
Eng. & Cont.	20%		2,920		3,920		3,450		4,540		3,590		4,690
Totals			$17,500		$23,700		$20,500		$27,000		$21,600		$28,200

TYPE F₅ - STEEL STRUCTURES SPANNING 2, 4 & 6 TRACKS WITH THREE SPANS

FIG. 18

The foregoing comparisons for track elevation bridges are on the basis of two track structures for Cooper's E-50 loading with track and girders 13 ft.-0 in. on centers. The depth of floor for the steel structures is 3 ft.-6 in., and for concrete structures 3 ft.-10 in. No account has been taken of the additional cost chargeable to the concrete structure due to the difference in thickness of floors. This would vary, depending on the distance between structures, and whether retaining walls were required to retain the fill between structures. On the other hand, no account has been taken of the additional cost to maintain the steel bridges; it being assumed that the additional cost of maintenance of the steel structure, if capitalized, would offset the cost of the additional fill and walls. Paving and sidewalks have been figured on the basis of the right of way being 100 ft. wide. This may be wider than the majority of right of way, but there will be few crossings where at least this amount of paving and sidewalk will not have to be restored. Abutments and pier footings have been figured on the basis that the foundation is good for a load of from 2 to 2.5 tons per sq. ft.

The estimates are intended to represent only the comparative cost of a structure as illustrated. Numerous items, such as rails, ties, ballast, and drainage of subways being common to all structures have not been included, it being assumed that they would vary with the location and conditions under which a structure is built, but that there would be little difference due to the type of structure built.

Bridges for track depression projects may be divided in two main types:

Type E. Bridges spanning the tracks with clear spans.
Type F. Bridges spanning the tracks with two or more spans with intermediate supports.

In bridges for track depression as well as for track elevation it is desirable to observe the same conditions, namely:

1st. Keep the floor of the bridges as thin as possible;
2nd. Avoid any obstructions between tracks;
3rd. Select a type of bridge which can readily be altered to provide for additional tracks.

Bridges of type "E" (bridges with clear spans) meet the first of these requirements, but in most cases not to as good advantage as structures of type "F" with supports between tracks. For streets with narrow roadways and short spans, not exceeding three tracks, a deck type structure of either concrete or steel can be adopted. For longer spans and wide roadways, however, the deck type must give way to the through type with girders projecting above the roadway, and reinforced concrete cannot be used to advantage; but a combination of structural steel and concrete may be used. For narrow roadways but two lines of girders need project above the roadway, one on either side at the curbs; but for wide roadways center girders are required. This is a disadvantage, the same as the center piers in bridges of type "D" (structure spanning the street in four spans with supports at the center of street and at the curbs) for track elevation, but is not serious. Structures of type "E" spanning the tracks with a single span do not lend themselves well to the third requirement, that of additional tracks. Either additional tracks must be provided for when the structure is built, or considerable expense must be incurred to lengthen the bridge to provide for them.

Bridges of type "F" (bridges spanning the track with two or more spans) meet the first requirement of thin floors and the third requirement of providing for additional tracks, but do not meet the second requirement of no obstructions between tracks. This can be overcome by spacing the tracks in pairs at 13 and 18 ft. centers respectively where more than two tracks are used, which will give the required clearances, but will add an item of expense for additional excavation, and, where the right of way is narrow, an item for additional right of way or higher walls. This type of bridge is also well adapted to the use of concrete.

The comparative economy of the various types to meet different conditions is shown in the foregoing estimates:

The foregoing comparisons for track depression bridges are on the basis of 20 ft.-0 in. clearance over tracks at 13 ft.-0 in. centers, except in bridges of type "F" (bridges of two or more spans with intermediate supports) where alternate tracks are widened to 18 ft.-0 in. centers to provide adequate side clearance. A 24 ton concentrated load on two axles 10 ft. centers and 5 ft. gauge and two 40 ton street cars were assumed as the bridge loads, with 150 lbs. per sq. ft. on the portion of the sidewalks and roadway not occupied by the concentrated load and street cars. As it is not a common practice to carry the full width of the street across the depression where the streets are 80 ft. wide, no estimates are shown for this width of street. It is usual for 80 ft. streets to carry only the roadway and two amply wide sidewalks across the depression, reducing the width of street by the amount otherwise occupied by parking. As in the case of the track elevation bridges, paving and sidewalks off the bridge have been figured on the basis of 100 ft. right of way. The estimates are intended to be comparative only, and the same items were omitted as in the case of track elevation bridges.

Ignoring property damages, and, in the case of track elevation, the excavation required for depressing the streets, and in the case of track depression the excavation required for depressing the tracks and the fill required for the street approaches, the cost of a particular type of structure across an assumed 100 ft. right of way remains practically constant, regardless of the elevation to which the tracks are elevated or depressed; i. e., structures of type "D" (bridge spanning the street in four spans) will cost practically the same, ignoring the above item, whether the tracks be elevated 2 ft. or 10 ft. The same is true for any of the other types.

From an examination of the estimates it can be seen that for a two or three track proposition there is little difference between the cost of bridges for elevation and those for track depression. Concrete bridges of type "D" (bridges with supports at curbs and at center of roadway) are the cheapest type for track elevation and concrete bridges of type "E" (bridges spanning tracks with clear spans) are the cheapest for track depression. As the number of tracks increase, however, bridges of type "F" (bridges spanning tracks with two or more spans with intermediate supports) for track depression show a saving over other types of bridges. If the distance between adjacent bridges be great, this may be more than offset by the cost of the additional excavation or higher walls required, by having the tracks spaced at 18 ft. centers to provide sufficient side clearance where supports are located between tracks. The estimates show further that the first cost of concrete bridges, although requiring a slightly deeper floor, are cheaper than steel spans with concrete slabs. It might be said here, that if timber floors were used in place of the concrete slabs for the depression bridges, the cost of such bridges would be reduced below those of reinforced concrete, but on the other hand, if the steel bridges are encased, the difference in cost between the two will be still greater in favor of the concrete bridges.

In track depression bridges of type "E" (bridge spanning tracks with clear span) there is a manifest saving, by using the center girder, of between $20 and $30 per linear foot of bridge besides the saving either in the cost of excavation in the cut and reduction in heights of walls where used, or in the amount of fill, paving, etc., on the approaches, depending on whether the tracks are depressed one foot less or the street raised one foot less, due to the decrease in the floor depth.

All of the foregoing figures for both track elevation and track depression bridges are applicable only when the tracks cross the streets at right angles, or when they cross at an angle which will not materially increase the span lengths.

For track elevation bridges, where the tracks cross the streets obliquely, or cross at the intersection of two streets, it is desirable, although in some instances difficult without resorting to unsymmetrical and complicated construction, to space the supports so that they line up in the direction of both streets.

Right of Way and Retaining Walls.

In general, for the same number of tracks in each case, track depression will require a greater width of right of way than track elevation, even where the tracks occupy the full width of right of way and where retaining walls are resorted to.

It is seen from Fig. 1 that the amount of additional right of way required for track depression over that required for track elevation, if no retaining walls are used, depends on the amount of elevation and depression of the tracks.

In cases where the entire right of way is occupied by tracks retaining walls would be required for both track elevation and track depression. In such cases it is seen from Fig. 19 that it is necessary to acquire additional right of way to accommodate the same number of tracks in depression as in elevation, or else eliminate one track to allow room for the retaining walls, which must be built on railroad property. The loss due to the elimination of one track to the railroad company is impossible to determine. An order of any city or commission calling for track depression under such circumstances, in the face of the railroad's opposition, amounts to confiscation of railroad property without compensation and without due process of law, and it is doubtful if it would be upheld in the courts.

Both of these conditions are serious handicaps for track de-

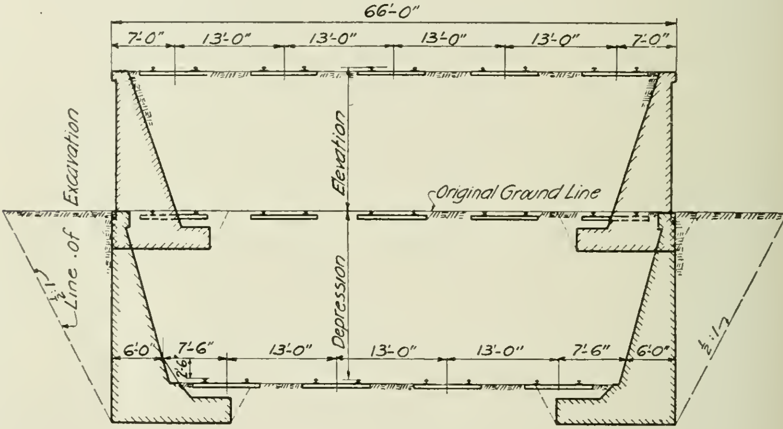


FIG. 19 - TYPICAL CROSS SECTIONS OF 66'-0" R OF W. FOR TRACK ELEVATION AND TRACK DEPRESSION WHERE FULL WIDTH OF R OF W IS UTILIZED

pression, for in the majority of cases the districts where grade separation is required are usually thickly settled and the tracks are lined with industries or other improvements, making the acquisition of additional right of way out of the question on account of the value of adjacent property, and leaves the building of retaining walls the only alternative. This would very often be the governing factor in the selection of a plan were the choice made entirely from the economic standpoint, unless the cost of walls be offset by the saving in the cost of track depression bridges over those for track elevation, and in some cases by the saving in the cost of excavating the material for the cut over the cost of filling the embankment.

There may, however, be instances where the tracks run through a strictly residence district, where land values would not be excessive and additional right of way could be acquired for a nominal figure, but this condition would be the exception rather than the rule.

Any one of numerous types of retaining walls may be adopted on any project, economy being the prime factor in the selection.

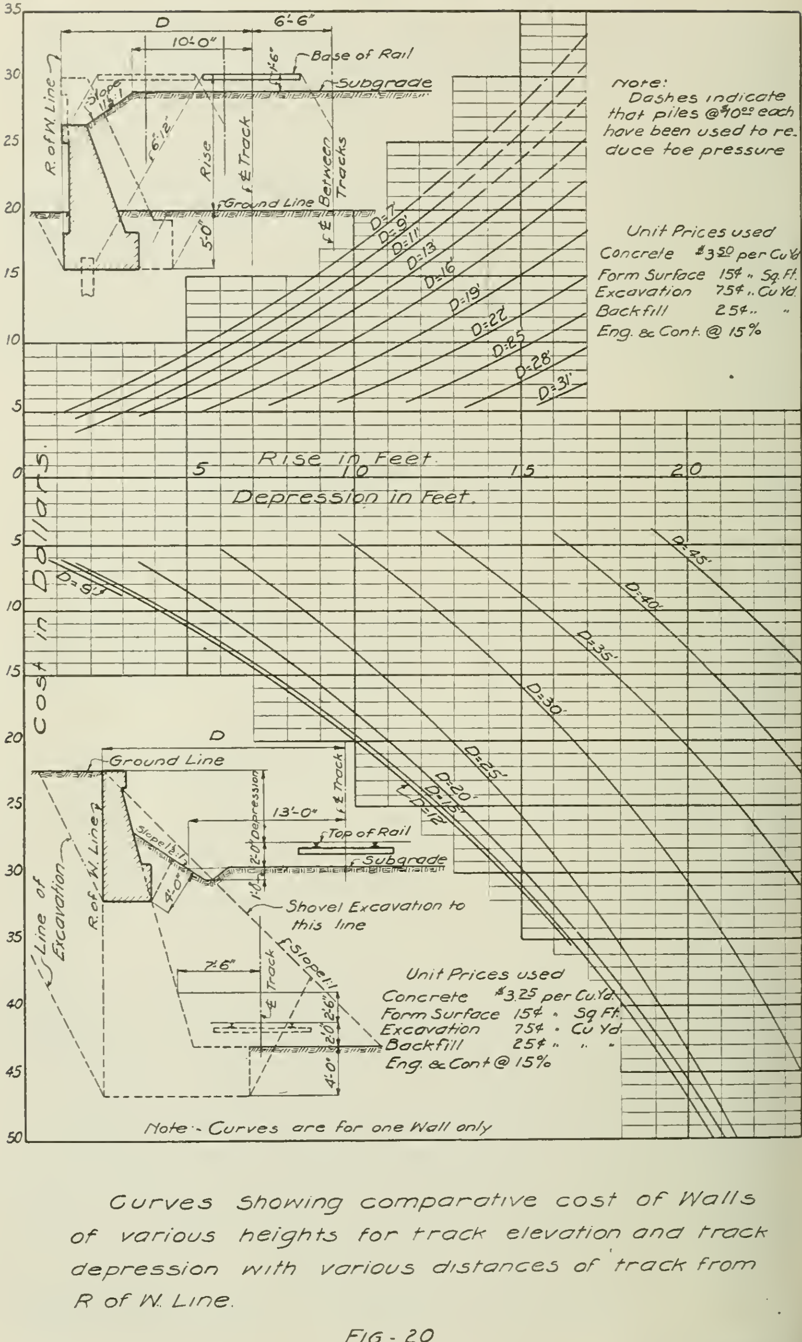
Much literature has been published regarding the economy of various types of walls, and this phase of the subject will not be discussed further than to state that for walls of the height required for track elevation and track depression a gravity wall will, under ordinary conditions, be cheaper than the reinforced concrete types. The following curves, Fig. 20, will serve to indicate the *comparative* costs per linear foot for various heights of wall for track elevation and track depression for various distances of track from right of way lines.

In compiling these curves, the most severe case has been assumed, in that all walls have been figured to be wholly within the right of way. Some economy can be gained, especially in the high wall where a toe is allowed to extend beyond the right of way, as is generally permitted where there is a street or alley parallel to and adjacent to the right of way. The unit prices assumed are indicated in the figure.

Fig. 21 will serve to indicate the *comparative* costs, per linear foot of right of way, of fill and walls for various heights of track elevation, and of excavation and walls for various depths of track depression, for one, two, three, and four tracks on 60, 66, and 100 ft. rights of way, under the following assumptions:

For track elevation it was assumed that fill would be made up to 9 ft. in height by raising the track by depositing material along either side of the track and jacking it a foot or so at a time and tamping the material under the tracks. For heights above 9 feet it was assumed that but one trestle would be built whether one or more tracks are elevated. The limit of 9 feet was obtained in the following manner: It was assumed that the ordinary city block is approximately 300 feet long; this would allow the tracks to be raised 9 feet, by using a 3% grade, without crossing any of the streets. At the streets it was assumed that trestles would be so built as to later permit the construction of bridges without blocking traffic. If the tracks were raised to heights above 9 feet in short blocks, it would mean that one or more streets would have to be blocked while the tracks were being raised, either by cribbing or filling, and then after the tracks were at the final elevation the fill or cribbing would be removed and a trestle built. This, however, would cause double work at each street, the expense of which would in all probability pay for the additional cost of building the trestle the entire length of the elevation.

For track depression it was assumed that the shovel would remove the earth within the dotted lines indicated on the figure



Curves showing comparative cost of Walls of various heights for track elevation and track depression with various distances of track from R of W. Line.

FIG-20

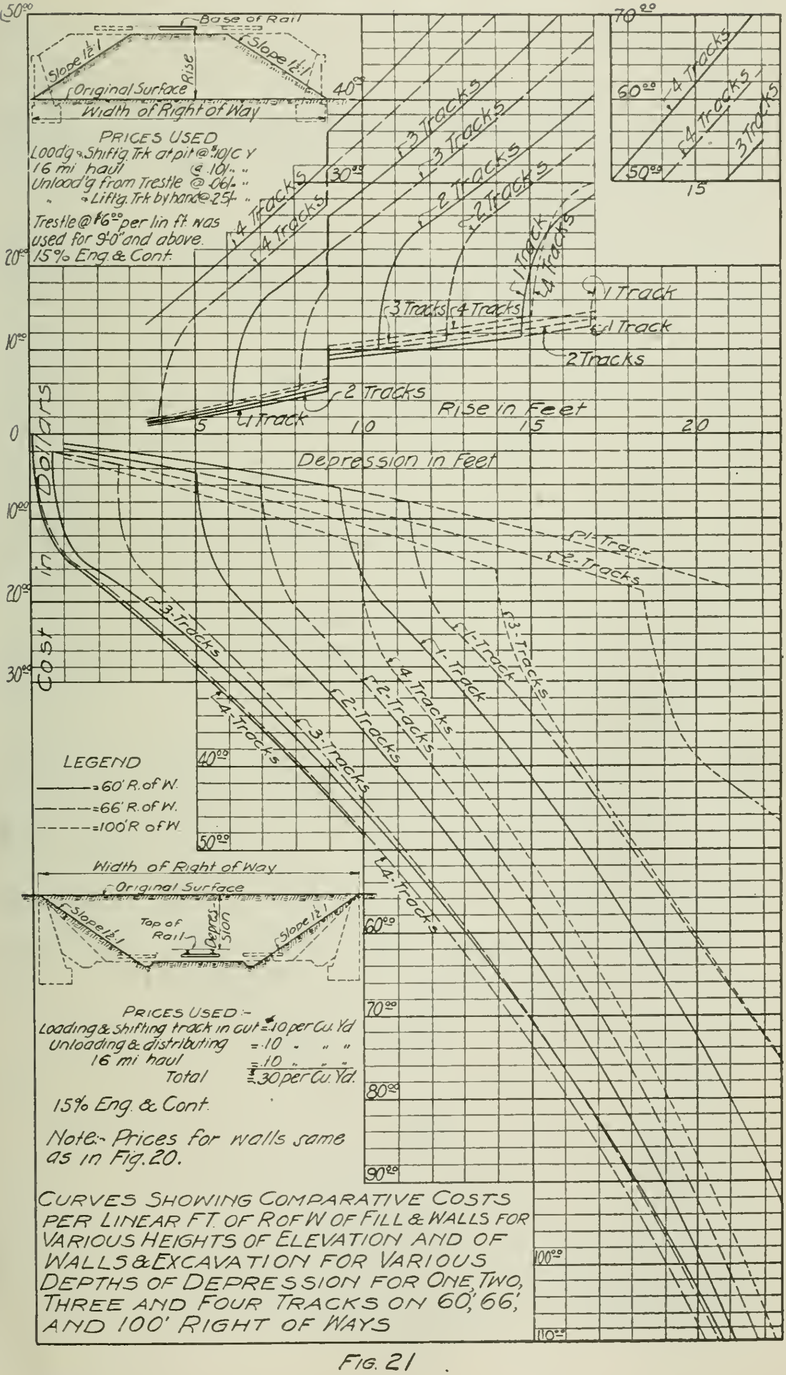

Base of Rail
Slope 1½:1
Slope 1½:1
Rise
Original Surface
Width of Right of Way
PRICES USED
Load'g & Shift'g Trk at pit @ $.10/C Y
16 mi haul @ .10
Unload'g from Trestle @ .06
" & Lift'g Trk by hand @ .25
Trestle @ $6.00 per lin ft was used for 9'-0" and above.
15% Eng. & Cont.
4 Tracks
3 Tracks
2 Tracks
1 Track
Rise in Feet
Depression in Feet
Cost in Dollars
LEGEND
60' R. of W.
66' R. of W.
100' R of W.
Width of Right of Way
Original Surface
Slope 1½:1
Top of Rail
Depression
PRICES USED:-
Loading & shifting track in cut = .10 per Cu. Yd
Unloading & distributing = .10
16 mi haul = .10
Total = .30 per Cu. Yd.
15% Eng. & Cont.
Note:- Prices for walls same as in Fig. 20.
CURVES SHOWING COMPARATIVE COSTS PER LINEAR FT. OF R OF W OF FILL & WALLS FOR VARIOUS HEIGHTS OF ELEVATION AND OF WALLS & EXCAVATION FOR VARIOUS DEPTHS OF DEPRESSION FOR ONE, TWO, THREE AND FOUR TRACKS ON 60', 66', AND 100' RIGHT OF WAYS

FIG. 21

and the remainder would be removed at the time, or after, the walls are built.

The unit prices used for excavation, fill and trestle are as indicated in the figure; the unit prices for walls are the same as those shown on Fig. 20 for comparative cost of walls. No item has been included to take care of the traffic, which would depend on the density and location.

Change in Grade of Streets.

So far only complete elevation and complete depression of the tracks have been considered, which require very little change in the grades of the streets. The question immediately arises as to whether or not a partial elevation of the tracks with a partial depression of the street, or a partial depression of the tracks with a partial elevation of the streets, would not be the plan to adopt. It might be said here that on practically all projects for complete track elevation or depression the plans usually provide for at least a slight change in grade of the street, varying from 1 ft. to 3 ft., which change can readily be made without incurring excessive expense or property damage. It may also be said that to change the grade of the street entirely without changing the railroad track, except in the case of isolated crossings or in country districts, is unusual.

To change the street grade any appreciable amount brings up a number of questions: namely, allowable grades on streets, economy, drainage and interference with sewers, gas and water mains, and property damages.

Considerable discussion always arises as to what maximum grades are allowable where the grade of the street is changed. Chicago, where probably more money has been expended for grade separation work than any other city in the country, has fixed by ordinance a maximum grade of 3%. To adopt this grade, however, in all cities would be unquestionably in error, especially so in a hilly city, where existing street grades of from 6 to 8 percent are not uncommon.

Although most cities try to limit the allowable grades to 3% or 4%, the following table gives some of the grades which have been used on work of this nature in various cities:

Location.	Maximum Grade.
Chicago	3½%, usual 3%
Buffalo	4%
Joliet, Ill.	3½%
Evanston	3½% or 3%
Milwaukee	4%
Minneapolis	5%, 4%, usual 3%
Cleveland	6%, usual 4%
Detroit	4%, usual 3%
Philadelphia	5½%, usual 3%
Indianapolis	4½%, usual 3%
Washington	9%, 8%, 6%, usual 3%, 4%
Newton, Mass.	9%, 8½%, 7½%, 6%, usual 3% and 5%
Lynn, Mass.	3%, 4%, and 5%
Brockton	9%, 5%

The most rational manner of determining grades to be used would be to take the maximum existing street grade of the thoroughfare of which the street to be changed is a part, or in the case of comparatively flat country, adopt a minimum grade of 3% to 4%, depending on the character of traffic frequenting the streets, and the length of approaches. In special cases exceptions could be made and a slightly steeper grade than ordinarily used could be permitted for a short distance, in order to avoid interfering with the grade of adjacent intersecting streets. This would often materially reduce the construction cost and obviate considerable property damages, and the slight increase in grade for the short distance would not seriously affect teaming.

The level portion of the street where carried under the tracks should extend far enough beyond the portal of the subway so that loads of maximum height will not encroach on the vertical clearances when starting up the approaches. Where the rate of change in grade exceeds 6 in. in 100 ft., vertical curves extending 15 or 20 ft. on each side of the intersection should be adopted.

Where the street is to be carried over the tracks, the sidewalk and roadway must be elevated the same amount, but where the street is carried under the tracks the roadway is sometimes depressed 4 or 5 feet further than the sidewalk at the deepest part. This has the disadvantage of having high curbs, but where wagons would back up to property adjacent to right of way for loading or unloading it would be an advantage. It also has the additional advantage of producing a smaller actual damage to property, as very often the sidewalks can be left at their original level and the streets depressed 4 or 5 feet and the tracks elevated the remainder. This method is illustrated in Fig. 22. If, however, this method is carried to extremes and the elevation of sidewalk and street differ to any great extent at the adjacent cross streets, steps are required to get from the street to the sidewalk, which is a decided disadvantage.

At first glance it would be natural in most projects to say that the less the grade of the tracks is changed the less the project will cost. This, however, is not always the case. Streets may occur with such frequency that the cost of excavation or filling streets, the cost of repaving streets and sidewalks, alterations to sewers and water pipes, and property damaged, will be equal to or greater than the cost of excavating or filling the embankment for track elevation or depression.

Wherever streets are depressed adequate provision should be made for drainage. In some cases where proper provision have not been made, the streets are flooded and traffic blocked. Catch basins with proper connections to sewers should be placed some distance outside of the portal of the bridge so that in winter or spring time, when the thaw starts, they will not be in the shadow of the bridge and remain frozen. Similar provision and precaution to provide for drainage should be exercised in the cut in the case of track depression.

In cases where the streets or tracks are depressed to such an extent as to interfere with sewers, the problem is much more complicated. Either new sewers must be constructed at a lower level or else the sewerage will have to be siphoned. Both of these schemes entail considerable expense and are serious handicaps to track depression.

Interference with the water and gas mains is a less serious objection, the question of gradients there being a secondary consideration. Although it adds quite an item to construction cost,

Fig. 22. 75th St. Subway under I. C. R. R. at Grand Crossing, Chicago.

provision can be made to carry them across the bridge floor, or depress them under the cut.

The question of property damage is one for which it is impossible to lay down any set rule. There are many things both imaginary and real for which property owners claim damages when a project of this nature is being executed. In making allowance for this phase of the question, each problem will have to be handled separately, the damages estimated and an amount allowed which would be sufficient to put the property back into as good a condition or perhaps better condition than previously existed. It will be found, in a good many cases where damages are settled out of court, that considerable saving can be effected by buying the property damaged and selling again after the work is completed.

Apportionment of Expense.

The question of apportioning the expense incident to the separation of grades is of great importance, and with the exception of a few States, where legislation divides the expense on a percentage basis, the question is far from settled, and arises whenever the problem of elimination of crossings is considered.

There are a few cities where the railroads are required to pay the entire cost of grade separation. The unfairness of such orders, however, needs little comment. Regardless of alleged charter right or restrictions, the lawmakers should recognize that in the early days grade crossings were an economic necessity and not especially dangerous or objectionable, and were built with the consent of the people; that changed conditions are the natural consequence of the growth of cities and the development of railroads; and that the railroads should not be forced to bear the entire cost of non-productive improvements, especially since they are restricted in the matter of rate making.

There have been cases also where the expense has been borne by the municipality, the steam railroad, the street railway, and the various other public utilities, each doing the work and bearing the expense incurred by the changes to the property controlled by it. Where this plan is followed there is controversy between the parties interested relative to procedure of the work, etc., after a plan has been adopted, and even before the final plan is decided upon, each interested party is working for its own financial interest, trying to throw the burden of expense on the other parties, and, as a consequence, the best plans are not always adopted. This method of apportioning the cost has consequently not proved entirely satisfactory and is giving way to the more reasonable and logical method of considering the work as a unit and dividing the total cost of the project among the parties interested on a percentage basis agreed upon by the interested parties before work is started.

Numerous reports on grade separation have been made by committees with unlimited authority to investigate and report, with recommendations, the most practical solution. An examination of the different State laws and city ordinances enforcing grade separation (Fig. 23) shows that the apportionment of cost on a percentage basis has been followed in the majority of cases. Legislatures and the people have come to realize that in the separation of grade crossings the interests of the railroads, the state, the municipalities and the public are a unit, and have therefore apportioned the cost of the work on a percentage basis. The consensus of opinion of those who have studied the problem of grade separation appears to advocate the apportionment of the cost on this basis.

DIVISION OF EXPENSE IN THE TEN STATES THAT HAVE FIXED THE PROPORTIONS.

From Engineering Record, March 13, 1915.

Percentage of Expense.

State.	Railroad.	Munici-pality.	State.	Remarks.
New Hampshire	100	0	0	
New Jersey	100	0	0	
Indiana	75	25	0	The county, city and street railway, if any, bears the 25%.
Maine	65	10	25	State limited to $15,-000 per year.
Vermont	65 or more	not over 10,	not over 25	Depending on priority of railroad or highway.
	60 or more	not over 15	not over 25	
Massachusetts	65	not over 10	Bal-ance	Street railways interested may be made to pay not over 15%.
Ohio	65	35	0	Street railways may be assessed, if present, for any part of city's share up to 50%.
New York	50	25	25	Special provision for Buffalo.
Connecticut	100	0	0	Depending on whether railroad municipality or State initiates the improvement.
	50	50	0	
	75	0	25	
Virginia	100	0	0	Depending on whether the change is to be made in the railroad or the highway.
	50	50	0	

DIVISION OF EXPENSE IN CITIES IN SPECIAL CASES.

Percentage of Expense.

	Railroad.	Municipality.	Remarks.
Buffalo	100	..	Within the right of way.
	65	35	Outside of right of way in streets.
	55	45	Lands purchased and property damages.
Atlanta, Ga.	All within R. of W.	Damages, cost outside of R. of W.	By agreement.
Newark, N. J.	....	....	$600,000 lump sum for work estimated at $2,-000,000 and 50% of damages.

Providence, R. I.	66 to 75	33 to 25	Varies according to circumstances.
Philadelphia	50	50	Amount varies according to particular circumstances.
Scranton, Pa.	100	....	
New York	50	50	N. Y. Central tracks south of Harlem River.
Detroit	100, less property damages	....	This amounts to about one-third of the work, as streets are depressed nearly one-half way and tracks raised slightly over one-half way.
Kansas City, Mo.	100	....	Street car company pays one-half of cost of bridges used by it.
Milwaukee	All within R. of W. less portion used by street car company.	Damages and costs outside R. of W. less portion used by street car company.	Two projects.
	70	25	5% to street car company. One project.
Minneapolis	100	....	
Washington, D.C.	All within R. of W.	Damages and all cost outside of R. of W.	By agreements.
Denver, Colo.	All within R. of W. less portion used by street car company.	Damages and all cost outside of R. of W. less portion used by street car company.	
Chicago	100, less property damages.	Property damages.	
Canada	66⅔	33⅓	

Fig. 23.

The following, as bearing on this proposition, is contained in a paper by H. F. Pfeiffer, presented before the St. Louis Engineers Club, May, 1909:

"I do not believe that this abstract proposition can well be controverted or denied, namely, that where an improvement is required that will benefit a number of interests jointly, equity requires that each pay in proportion to the benefit received by it. That being the case, it is unjust to force one of the parties benefited to pay the entire expense. I contend, therefore, that the city, or state and city, the railroad and street railroad, if any, using the crossing, should divide the expense on some equitable and just basis; what that is I am not prepared to say, except that it should be on the basis of percentages of the entire cost of the work and not along the line of land damages or special features of construction. The work is a unit and the expense entailed should be treated and divided as such."

Assuming that the cost of the project should be apportioned between the parties who have created its necessity, or by those benefited, the question then arises: what percentage should each party pay? So many elements must be considered in determining this question that it seems impracticable to lay down a fixed rule to apply to every case, though this has been done by some legislatures.

In arriving at proper conclusions in any particular case, there are two elements which stand out more prominently than others, namely:

I. Apportionment based on responsibility.
II. Apportionment based on benefits.

It is argued, in considering the first of the above mentioned elements, that the expense in eliminating crossings should be proportioned with respect to the relative responsibility of the parties in creating the need of the improvement. As an example, assume a railroad to be constructed at grade through undeveloped and unpopulated territory near a city. The construction and operation of the railroad materially assists in the city's development. The city develops and grows out along the railroad, streets are built across the railroad track, and street traffic, at first light, in the course of time becomes so heavy that public safety requires separation of grades. In the meantime railroad traffic, at this particular place, has not increased. The whole situation requiring separation of grade is created by the increase in street traffic. This is a condition for which the railroad is not responsible, and it is argued that it should not be required to pay any portion of the cost of grade separation.

On the other hand, a railroad may be constructed through a city in the very early days of railroad construction. At first the traffic over this road was light—one or two trains a day. The speed was slow, the trains short, and easily managed with little menace to life or property. Gradually the railroad traffic is increased; the number of trains instead of being one or two a day are fifteen and twenty; instead of one track there are two and four. In the meantime street traffic had increased very little. Under such circumstances it can well be said that the responsibility for the necessity for grade separation was brought about by the railroad, and it should stand all or the greater portion of the expense.

Ordinarily, however, the responsibility does not rest solely with either the municipality or the railroad. As a rule, street traffic and railroad traffic, being dependent to a certain extent on each other, have increased simultaneously; the property, growth, and development of the city have kept pace with the increased number of tracks and increased traffic of the railroad or vice versa. Other things being equal, it might therefore be said that the responsibility for the necessity of grade separation rests equally upon both the city and the railroad. In some places, however, priority of construction is a factor in discussing the question of responsibility. Some claim that if the highway was there prior to the coming of the railway, the railway is responsible for the crossing, and if the highway was opened across the railway the responsibility rests with the highway. This has been taken into consideration in the Connecticut grade crossing law and the laws of Canada.

A brief consideration of the second element above mentioned, namely, the apportionment based on benefits, is well set forth in "Report of Grade Crossing Elimination" by Robert H. Whitten, Librarian Statistician of New York, from which the following is taken in part:

"The benefits may be classified as follows:

1st: Benefits to the city.

(a) Public safety. By doing away with dangerous grade crossings the safety of vehicles and pedestrians using the crossing is assured, thus avoiding a large number of deaths and injuries, representing an enormous economic loss to the community in the conservation of human life.

(b) Removal of cause of delay to street traffic. Statistics have been compiled in various municipalities showing the enormous loss of time during the year caused by delay at crossings.

(c) Removal of a cause of delay to fire engines and trucks. We all realize the delay of fire engines and trucks at grade crossings, and that such delay is always at the expense of property. It has been realized that some delay is inevitable in a large city, and anything which minimizes this delay is of great value to the community.

(d) Rapid Transit. In a large and growing city facilities for rapid transit are most vital. With grade separation, track and station facilities are often added for urban or suburban rapid transit service; with numerous grade crossings any really adequate rapid transit service is impossible. Rapid transit increases real estate values, reduces rents, reduces congestion of population, facilitates business and adds to the comfort and convenience of the traveling public. It can be readily seen that all of the foregoing elements should be taken into consideration in realizing the benefit to the city and the proportion which each should stand of the cost.

2nd: Benefits to property owners in increased land values.

It is universally recognized by those who have given special attention to the elimination of grade crossings that the separation of grades always enhances the value of real estate, not only in the immediate vicinity but also in distant portions of the city by decreasing the time to and from the heart of the city. So universally has this been recognized that in a few cases a portion of the cost of grade separation has been assessed on property specially benefited. In a great city there is no more potent factor in increasing land values than improved rapid transit service. This fact is recognized by the State of New York in the New York City Rapid Transit Act as amended in 1809; which Act provides that rapid transit lines may be constructed by the State and the cost assessed in whole or in part on land specially benefited by the improvement. A grade separation improvement may render possible efficient urban or suburban rapid transit service, and by doing so will surely increase land values in the property served. The land so increased in value might in certain cases properly be assessed for a portion of the cost of the grade separation improvement.

The following case verifies the foregoing. The tracks of the New York Central Railroad in New York City were removed from the surface of the city and placed in a tunnel between 49th and 96th Streets on Park Avenue under an Act of 1872. The total cost was $6,400,000, of which amount the city paid one-half. The improvement was not completed until 1875, but a report of the Board of Engineers states that up to October, 1873, there had been an increase in the assessed value of real estate affected of $40,000.000, or more than six times the cost of the entire improvements. In 1909 a bill was prepared by the New York City administration and presented to the legislature applying the special assessment method to grade separation improvement. On account of the present New York Act, making an arbitrary, inflexible division of the apportionment, the measure did not pass.

No fixed rules, however, can be set to fix an area of assessment for all cases. It might be desirable to recognize the principle in any general grade crossing law and leave it to the discretion of the Commission, authorized to apportion the cost of any particular improvement, to apportion a part of the cost on any area specially benefited, if in its judgment the conditions warranted.

3rd: Benefits to street railway.

(a) Elimination of delays at crossings. The same service should be actually rendered with less cars and crews.

(b) There would be a saving in the installment of and in the maintenance of derailing devices and other safety appliances, as well as the expensive maintenance of track at crossings.

(c) There would be a saving on the wear and tear of motors and machinery due to imperfect crossings, and the stopping and starting.

(d) There would be saved to the Street Railway Company the danger of accidents at crossings, and the liability of the company for such, in a similar manner to the saving to steam railroad companies.

In a preliminary report on grade crossings made March 29th, 1910, T. B. Comstrock, Engineer of the Los Angeles Board of Public Utilities, includes an estimate of the cost of stopping cars of an important interurban railway at four steam railroad crossings as follows: 'General Manager McMillan, of the Pacific Electric Railway Company, estimates the present cost of stopping cars at the four crossings at $48.00 per day or $17,520 per annum, equal to interest at six per cent on $291,986.00. The saving in this and other ways with gains in time and economy of operation will amount to at least $500,000 annually for this division of the interurban traffic.

4th: Benefits to the railroad.

(a) Expense of crossing protection. This includes the maintenance of warning signs, bells, signals, gates, signal tower, and the employment of a flagman and gateman, and in some cases also of a towerman.

(b) Expense due to accidents.

From the reports of twenty-one roads to the Interstate Commerce Commission the Bureau of Railway News and Statistics had estimated that for the year ending June 30th, 1908, the railways of the United States paid $21,462,000 for injuries to persons. This item does not include legal expenses in connection with personal injury claims, which doubtless would be a very considerable amount. In 1908, 8% of the total number of persons killed and 1.6% of the number of persons injured were killed or injured at grade crossings.

(c) Relief from trespass nuisance.

A complete elevation or depression of the tracks makes it possible to deal effectively with the trespass nuisance.

With tracks on the level and public crossings but a few hundred feet apart, it is almost impossible to keep persons from using railroads as a thoroughfare, and it is much more difficult to prevent trespass by tramps and petty thieves. The presence of track walkers and trespassers leads to numerous accidents and deaths, resulting in delay to traffic, loss of time to employes in attending death inquests, and in some cases liabilities for damages.

(d) Increased speed and freedom of operation.

With crossings at grade, trains, both passenger and freight, are required to run very slowly through cities, nevertheless frequent accidents occur. With a separation of grade, trains may run with greater speed.

(e) Miscellaneous betterments.

A re-building of the road incident to track elevation or depression gives opportunity to carry out many needed improvements. Modern signal systems may be installed; stations reconstructed and modernized; subways and over crossings provided at important or exchange stations.

(f) Improvements in grade and alignment.

The elevation or depression of tracks usually tends to remove or at least diminish grade through municipalities.

(g) Increase in number and improvement in location of tracks.

Incident to grade separation the number of tracks is often increased and their arrangement improved so as to facilitate the separation of different kinds of service, such as through freight, switching, and making up of trains.

(h) Rapid Transit.

Many railroads in large cities having a heavy suburban traffic find grade separation helpful in the development of their business."

From the foregoing it is clearly demonstrated that the benefits derived from grade separation are shared by the municipality, the public, the steam railroads and the street railways, and that the apportionment of expense on the percentage basis is the wisest and most fair method to adopt.

There is considerable difference in opinion and in practice as to whether the apportionment should be in accordance with some fixed rule, as is the case in the New York State aid law, or whether it should be left to the discretion of a commission to be fixed according to the merits of each particular case, after a most thorough investigation and extended consideration of the project. The great weight of the majority who give the matter careful consideration will be of the opinion of Mr. Richard H. Phillips when he said in a discussion of the subject before the convention in St. Louis in 1909:

> "No rule as to division of cost stated in terms of exact percentage can be laid down if a proper division is to be made, inasmuch as the percentage of interest may vary in each case. * * * The question affecting, as it does, the city in general, the steam roads, the street railways, the manufactories, merchants, and owners of adjacent property, it would appear good policy, good business procedure, that each interest be consulted, the benefits and damages estimated and, finally, the cost divided in such manner as a thorough consideration should think best."

Advantages and Disadvantages.

The benefits derived from separation of grades have been considered in the discussion of the apportionment of expense. These, however, apply, in general, to the separation of grades either by depression or elevation. The advantages and disadvantages of track elevation and track depression on account of interference with sewers, effect on right of way, drainage and comparative cost of bridges and walls, etc., have already been discussed.

Some of the benefits or advantages and disadvantages applying especially to either track elevation or track depression may be summarized as follows:

1. For track elevation, the work of construction can be carried on with little or no interference to traffic, either in the streets or on the railroad. It is, however, exceedingly difficult to depress the tracks without stopping traffic on both streets and railroads, or building a detour around the entire project. All will agree that it is an easier matter to elevate the tracks by depositing material along either side of the track and then lifting the track a foot or so at a time, tamping the material under and allowing trains to run over the tracks so raised, than to depress a track by means other than taking it up and building a parallel track to handle traffic while excavation is being made. Where more than one track is to be raised, one or more trestles are sometimes built raising the tracks to their final position and the fill is dumped from the elevated track.

The question of time on construction is also an important factor. A project for track elevation can be accomplished in considerably less time than it would take to depress the same number of tracks, on account of being able to carry on the work at many different points simultaneously.

2. A distinct advantage of track elevation is the ease with which the industrial situation can be handled. Industries having

side track facilities can adapt themselves to take trackage from the elevated level by slight alterations to their buildings and doing their receiving and shipping from the second floor. For coal yards, trestles can be readily provided and are particularly advantageous. During construction also elevation has the advantage in that shipping facilities are disturbed very little, causing practically no interruption to business.

Where tracks are depressed, there is usually not sufficient distance between bridges, and the right of way is not wide enough to allow inclined tracks to bring the cars from the depressed tracks to the former ground level to serve the industries, and it is therefore necessary for the industries along the right of way to adjust themselves to take trackage from the lowered track level by altering buildings, and building basements and sub-basements. Even if there were sufficient distance between bridges to allow inclined tracks, such an arrangement is objectionable, as it requires the right of way to be encumbered with massive walls which after built tend to restrict the development of both the right of way and the industries. Much inconvenience and interruption to business must be contended with, while the tracks are being lowered and changes to buildings are being made.

The expense for making such changes, whether in the case of elevation or depression, represents a considerable sum. The industries have claimed that the railways were liable for, and should bear, the expense of changes to industries and industry tracks made necessary by the change in grade of the railway company's tracks, in order that service might be continued from the new level. The railway companies do not concur in this and the past practice has been for the industries to bear the expense, as the railway companies contend that the grade of the tracks are changed not on their initiative, or for their benefit, but by orders of the cities, or utilities commissions, as a measure of public safety, and therefore the industries should make, at their own expense, all adjustment and alterations required, including the cost of changing the tracks serving them.

3. The annoyance from noise, smoke and gases will be less from track elevation than track depression, although it is sometimes argued that these evils are less in depression. This argument, however, is not well taken. Little need be said to convince all that the smoke and gas nuisance will be less to those on the streets from tracks on a high level than from tracks on the lower level. The question of noise, however, is one on which there can be some difference of opinion.

Conclusions.

It has not been the writer's intention that this paper should represent a technical study of the grade separation question. Although portions of it may deal purely with the engineering side of the question, the primary object has been to set forth, in a general way, some of the questions which will arise in considering a problem of this nature. The question is of such magnitude that it is impossible in a paper of this length to cover fully and completely all the questions which arise; no two projects are alike; all have peculiarities of their own, and special features must be dealt with as they arise. From the foregoing considerations, however, it may be said in a general way that track elevation is more satisfactory than track depression, both to the railroads and to the industries having side track connections located along the right of way, and at the same time the former possesses many advantages to the city. With the possible exception of cases where the tracks pass through a high class residence district where the aesthetic appearance is of such importance as to outweigh the other factors, track elevation would appear to be the best solution of the problem.

DISCUSSION.

Walter S. Lacher, ASSOC.W.S.E: Mr. Bainbridge's paper will be very widely read, not only by the railroad engineer, but the men who are representing the city and the state, and who are, therefore, opposed to the railroads in negotiations for grade separation projects. I believe that with a general reading of papers such as this, a broader view of the situation will be taken and the railroads will not suffer as much from unfair ordinances or orders as they have in the past. There is no other place in the country where you have the same situation as you have here in Chicago; a city that is laid out as flat as this. Consequently an opinion on grade separation based on a knowledge of conditions in Chicago is not necessarily applicable elsewhere.

Each project has to be worked out independently, as each locality has its own problems. Not only must we consider the topographic situation and the layout of the streets, but we must also consider the plan to which the railroads and the community have already committed themselves. The result may be a solution entirely different from that which we would make if we were entering the city with an entirely new railroad.

It is so easy to get the wrong point of view and the incorrect interpretation of precedents. For instance, the usual way for the city fathers to take up the question of grade-crossing elimination is to find out what other people have done. That is the surest way to go astray. In going to Cleveland to see what the Lake Shore and Nickel Plate have done there, they would undoubtedly get an incorrect idea of the situation, as it is largely a case of separation of grades on a new line which the railroads were very anxious to build. In Kansas City, also, the railroads were taking the initiative in order to get certain improvements in grade, line, etc., and the city was in a position to require the railroads to make an unusual outlay.

I was riding on a train one day and got into conversation with a stranger in regard to his city where a railroad was depressing its tracks. He seemed to be very well informed on the situation and stated that the railroad had obtained permission to depress its tracks in order to make a new freight yard on low land beyond the city limits. It seemed that this man was in the business of selling construction material to the railroad company, yet even to him it seemed perfectly reasonable for a railroad to use its right of way in a large city as a borrow pit.

Elmer T. Howson, M.W.S.E.: I have been especially interested in the information Mr. Bainbridge has brought out regarding the question of track elevation. In going through his paper I was originally of the opinion that he was favoring track depression, but in reading the last two pages I now see he does not. There are many conditions as he has pointed out, which should be gone into very carefully to arrive at the most economical solution. Grade separation is becoming of increasing importance within the last few years, with the rapid increase in the number of automobile accidents on the main traveled highways. The traffic is increasing almost entirely on the part of the public and it is going to create considerable trouble for the railroads.

The Long Island Railway has gone to considerable expense to erect post barriers at their grade crossings to reduce the number of accidents, for the people persist in going through the gates.

There were one or two things in Mr. Bainbridge's paper that I would call attention to. One was on page 665, where he quotes from a report of Mr. Comstrock that one of the advantages of grade elimination is the relief from the trespass nuisance. Only to a limited extent is this true.

ENGINEERING IN WAR

W. V. Judson, Lt. Col., Corps of Engineers, U. S. Army.

Present April 5, 1915.

First I shall try to tell you as briefly as possible what is the nature of the duties of engineer officers and troops in war. And then I shall try to tell you something of the character of modern war, especially from an engineer standpoint, so that you may understand the conditions under which engineers work in war, and see the relation of that work to the work of other arms of the service.

The duties of engineers include the services of reconnaissance, castramentation, fortification, sieges, demolitions, general construction, roads and railroads, and such other special services of an engineering nature as may arise.

The service of reconnaissance includes tactical reconnaissance, surveying, mapping and sketching, photography, drafting and map reproduction.

The service of castramentation has to do with the selection of ground for camps, and the laying out and preparation of camps for occupancy.

The service of fortifications pertains both to the attack and the defense and includes the selection of defensive positions when out of the presence of the enemy; rectification of and assistance in the selection of such positions in the presence of the enemy; the location, design and construction of the more important field works; assistance in and supervision of the construction of the hasty defenses wherever possible; the supply of tools and materials; and the services of reconnaissance, demolitions, water supply and communications incident thereto.

The service of sieges pertains both to the attack and defense and includes selection and location of defensive lines, lines of investment and siege works; the construction of saps, mines, countermines, and defensive works; the operation of searchlights; preparation for and assistance in attacks, counter-attacks and sorties; organization of captured points; the supply of tools and materials; and the services of reconnaissance, demolitions, castramentation, water supply and communications incident thereto.

The service of demolitions includes the carrying out of all work of this nature authorized by the commander.

The service of battle-field illumination includes the supply and operation of searchlights and other means of battle-field illumination.

The service of general construction includes the location, design and construction of wharves, piers, landings, storehouses, hospitals and other structures of general interest in the theater of operations.

The service of communications includes the construction, maintenance and repair of roads, ferries, bridges and incidental structures; the selection and preparation of fords; the construction, maintenance and operation of railways under military control, and the construction and operation of armored trains.

The special services include all deliberate surveying and mapping; and all municipal, sanitary and other public work of an engineering nature which may be required in territory under military control.

The services given in the above list are executed under the supervision of engineer officers, by engineer troops, by details from other arms, by civilian labor, or by any combination of these means, as the particular circumstances may require.

Time is usually all important and labor is plentiful, and whereever the labor of other troops can be profitably employed, such troops should be provided promptly and used freely, the tools of the engineer train being brought up for this purpose.

In war our mobile troops would, for the most part, be organized into field armies, and each field army into divisions.

The engineer troops and equipment of a division consist of a battalion of four companies, an engineer train, and such proportion of the ponton battalion as may be assigned to the division.

All engineer companies are trained and equipped alike, although individuals within the companies are assigned to and trained in special functions, and certain companies, at times, may be assigned to special duties only.

An engineer company consists of four officers, mounted, and 164 enlisted men of whom 26 are mounted.

Only a small number from each company are trained for certain special classes of work, such as sketching, map reproduction, photography, surveying, drafting, demolitions, operation of engines, etc.; but practically all of the company are trained for all such kinds of work as roads, fortifications, bridges and mining.

Each company has a combat train consisting of 2 wagons and 8 pack-mules containing instruments, tools, tackle, explosives and supplies.

There is also a divisional battalion combat train consisting of 2 wagons containing equipment for surveying and map reproduction and for blacksmith work; and finally there is a divisional engineer train of 9 wagons containing reserve entrenching tools for infantry, including axes, shovels, picks, saws, sandbags, wire and the like.

The engineer troops in a field army consist, in addition to the divisional troops, of a battalion with the following ponton equipage:

6 divisions of heavy equipage, 1,350 feet
3 divisions of light equipage, 552 feet.

This battalion is organized and equipped as all other engineer battalions.

In the ordinary case certain parts of the equipage will be assigned to the divisions of the field army and when so assigned the use and disposition on the march, in camp and in battle will devolve upon the division commanders.

On the Line of Communications are a regular divisional engineer organization and a body of railway troops. These latter pertain to the service of railways and are subject to the orders and instructions of the director of railways. They are primarily for the construction and reconstruction of the railways, and secondarily for the operation and maintenance of the same when the conditions of safety are such that civilian operators or maintenance-of-way men are difficult to obtain or keep.

In addition to the engineer units above described, there are various purchasing agents, depots, parks and the like.

To each field army there is attached a chief engineer, with such military and civilian assistants as he may require.

The commanding officer of the divisional engineer troops acts as the chief engineer of a division.

In the line of communications service there is a director of railways, an engineer officer who builds, repairs and operates railways not left in civil control.

Civil engineering is the youngest of the learned professions. There were no technical schools in this country seventy years ago, except at West Point, at which a very fair engineering education for those days was to be had as early as 1810, and Troy Polytechnic, which was instituted about 1824, but which did not become a full-fledged technical school until eight or ten years later.

The first trained engineers were military engineers, for the most elaborate and important structures built in great numbers during the middle ages were fortresses; and the most important events in those days were the attack and defense of fortresses, largely under the direction of engineers.

The work of the military engineer in general differs from the work of the civil engineer in that the former must provide not only against attack by the forces of nature, but also against attack directed by all the arts of man. Often speed of execution is the first essential in his work, but on the other hand many of his constructions are not expected to be permanent. The principal work of the military engineer in the past has had to do with the construction, attack and defense of fortifications.

I shall now try to tell you something of the development and present state of the art of fortification.

Originally land fortifications had only to oppose the passage of individual soldiers carrying swords, crossbows or the like. An effective fortification was a wall, and the alignment of the wall was straight or curvilinear, depending upon its function. If it was to protect a town it surrounded that town and was called an enceinte. All developments from this simple enceinte have been forced by the invention and improvement of artillery and of explosives. To prolong the time it would require to breach a simple wall by primitive artillery fire or by mining operations, the wall soon came to be reinforced by close-lying outworks known as redans, demi-lunes and the like; and to bring more fire upon attacking parties an alignment of the wall was adopted so that bastians resulted, and the fire from one part of the wall might sweep the ground in front of another part.

The further development of artillery subjected the protected area to destructive fire, but it was impracticable to remove the enceinte far out to the front, by reason of the number of men that would be required to man the longer front. Furthermore, the defense was also provided with superior weapons so that it seemed (and was) an effective defense to build detached forts at intervals, surrounding the protected area at a suitable distance with a line of them. This was the approved fashion of land fortification some 25 to 50 years ago and toward the end of that period were built by the great engineer Brialmont the defenses of Liege, Namur and Antwerp. Brialmont was somewhat of an extremist. He made his forts very strong, with concrete and iron, and he armed them with artillery in cupolas, but he neglected the intervals between the forts. Even while he built, most engineers were coming to believe that the artillery should be mobile; moving where needed in the intervals and provided there with emplacements, concealed as far as practicable. They believed that the detached forts should be largely of earth, simplified and manned almost wholly by infantry.

Fifteen or twenty years ago, noting the progress in ordinance, some saw that if the defense were congested in such units as detached forts, excellent targets for artillery fire would be afforded. They did not advocate an abandonment of intervals but a relief from congestion in the defensive units, making of the latter groups of small redoubts and trenches, each group covering a considerable area and called a fortified pivot. Such was the most approved theory of land defense some ten years ago, when the Russo-Japanese war began. During that war there was developed in the hard school of experience the system that is in present use on the battlefields of France and Poland. Further improvements in artillery, as demonstrated in the war in Manchuria, forbade even such congestion as existed in the fortified pivots. Intervals became dangerous by reason of the increasing employment of the night attack. The development of the telephone and the multiplication of its use in war removed objection to the scattering of the troops which formerly would have led to loss of control.

Much the same tactical considerations that led to the employment of successive skirmish lines in the infantry attack led to the present system of fortification upon the field of battle. The crowning principle of the present system is dispersal, but concealment is of almost equal importance.

A fortified line today consists of a zone, perhaps half a mile or more in depth, with many scattered pieces of trench work; some long and some short, in some sort of defensive relations one with another insofar as the ground permits; many provided with overhead cover of timber or boughs and earth to afford protection from shrapnel; where practicable connected with the rear by deep traversed or zigzag trenches; amply provided with telephone service, and the ground of near approach covered with wire entanglements and other obstructions. Toward the rear of the zone are the artillery positions, behind crests, forests or villages, the guns employing indirect fire, guns and detachments protected by earth cover and the projectiles passing over a portion of the infantry. Such a line, on ground fairly favorable to defense, and with some 4,000 to 6,000 good troops to the mile, is almost impregnable to frontal attack.

Where the defensive lines or zones are occupied, then there is a sort of equilibrium, the local defensive possessing great advantage. In places the hostile zones will approach each other within a few yards. Elsewhere they may be a mile or more apart. Spaces between the zones will be swept by the fire of both sides. Siege operations will be in progress where the trenches are close together and here there will be sapping and mining and the use of hand grenades. During the night there will be occasional attacks, in efforts to make local adjustments of the zones, and for the same reason there will occasionally be furious bombardments, accompanied or followed by infantry attacks, in special localities.

When hostile armies meet there is a tendency for each quickly to occupy such a line along its entire front. Ordinarily an army thus intrenched cannot be driven from its position except by flank attack. Even a flank attack in these days of great numbers and long battle lines does not commonly produce disaster and thus lead to a decision. As a general rule there will be ample time for new dispositions to be made before a flank attack can either disorganize any considerable portion of an army so extended or threaten its communications.

When equilibrium has been established along a front, assuming that the flanks have been extended to neutral frontiers or other impassable obstacles, the life of the troops is not as difficult as might be imagined. A brigade of 4,000 men, for example, would be dispersed over an area extending perhaps a mile along the front and two miles from front to rear. But a small proportion at any one time would be on outpost duty or in the more advanced trenches as trench guards. These trenches would be fully manned only during infantry attacks upon them. Behind the trenches the supports would be fairly comfortable and protected from hostile fire, where possible, by over-head cover and by folds of the ground. Behind the supports again would be the reserves, who would soon provide ample shelter for themselves. There would not be much marching; and marching, with great loads upon each soldier, is probably the greatest hardship of war. Moreover, where there is not much movement the problem of supply is vastly simplified, and in trench warfare the troops are for the most part well and regularly fed.

In time of war the government would need a vast number of volunteer engineer officers and troops. The best officers would be those practicing civil engineering in time of peace. It is earnestly to be wished that opportunity and inducement could be offered for a limited amount of work on the part of many civil engineers to qualify them for such service.

Due to the changed character of modern war then, the occupation of military engineers in times of peace in constructing great land fortresses of stone and iron is gone. The only permanent works of this character remaining are for coast defense. Inasmuch as in war some of you might be called upon to serve at or near coast works, a few words descriptive of them may not be out of place.

What is known as a fort, at the entrance to a harbor, is simply a group of dispersed and concealed gun and mortar batteries, comparatively defenseless, without mobile troops, from land attack. A heavy gun battery ordinarily contains but 2 or 4 guns, placed behind a parapet of concrete with earth or preferably sand in front of it, the latter sodded and the concrete painted green so that the battery may be as nearly invisible as possible from points upon the water. Under the concrete parapet, and upon the flanks of it, are the magazines. The guns are upon disappearing carriages and are thus withdrawn behind the parapet except when being fired. The great mortars upon which great reliance is placed, are in deep pits. The personnel is almost completely protected from hostile fire directed from the sea, and the invisibility and dispersal of the batteries make the latter very poor targets indeed. It is the office of coast works to deter an enemy from navigating the waters covered by their guns, and it is probable that our own coast works will thoroughly perform that function. An enemy contemplating invasion from across the sea would probably seek to land in some fairly protected waters, devoid of coast works, and near enough to some great centers of population or industry to give his landing some strategic importance. It would be his object, after so landing, to seize by land attack the coast works protecting the harbor and city which might be his objective, so that his ships could enter and a proper base be established.

In case of such an invasion it would be the purpose of an American army to interpose itself between the enemy's landing place and his objective, and if possible, to bottle up the enemy at the former.

Calculations as to the size of army needed by the United States must be largely based upon consideration of the forces required to perform this bottling up operation.

In order to give you a general idea of the distribution of the troops of an army when in contact with an opposing force, and of some of the physical conditions of a typical position, I shall recall to my mind the situation of the Russian army confronting the Japanese upon the line of the Sha in Manchuria in 1904 and 1905, where I had the good fortune to be present as military attaché, but in what I shall say I shall not confine myself to any conditions then existing where they departed from the normal.

As we approach the position from the rear, let us say by a single track railroad with its numerous sidings, the density of traffic apprises us of the fact that the limiting force which can be gathered and maintained at the railhead has been reached, and we know that that force comprises about 400,000 men of all arms. Moving in the same direction as ourselves, toward the front, are some fifteen trains per day. Besides foodstuffs, ammunition, clothing, medical supplies and the like, these trains bear many recruits to take the places of those killed, wounded, captured, or sick; guns, rifles and special equipment of all kinds to replace articles lost or become unserviceable; animals for the artillery, cavalry and transport; food for the animals; materials for the construction of bridges and buildings, for the revetment of trenches and the construction of bomb-proofs, barbed wire, fuel, and finally the materials necessary for railway maintenance, construction and repair.

In the opposite directions come many empty trains; trains loaded with sick and wounded and with prisoners; and trains carrying materials sent to the rear for repairs.

Upon the successful conduct of this great transportation business depends in large degree the success of the army.

At each town along the railroad we notice great hospitals, among which the sick and wounded are distributed as soon as they can be brought back from the front. Such base hospital accommodations must be provided for some 80,000 men.

At each bridge and at each town we notice troops guarding the line of communication. Each body of such troops will have constructed trenches and placed obstructions to enable it to defend its position as long as possible. Far out upon the flanks are troops in observation. On each side of the track a wagon road will be noticed. In the case of a raid against the line of communication, the news of it will have been transmitted by the troops in observation, and the railway guards will be concentrated upon the threatened points. The cutting of the railroad, for the army at the front, would be like the cutting of the main artery of an individual.

A few miles in rear of the front of the army great railroad yards have been constructed. Here are established depots and parks of equipment, animals, supplies and munitions of all kinds for issue to the various units of the army. From this base standard gauge or industrial tracks radiate toward the front and flanks, for the army covers a front of perhaps 80 miles, perpendicular to the railroad. These radiating tracks are duplicated by wagon roads, and there is never a time when there is not a vast amount of work in progress, adjusting rail and wagon roads to the movements of the army.

Near the base we notice that perhaps 50,000 to 100,000 men are encamped. This is the strategic reserve of the whole army, placed where in emergency it can be moved rapidly in any direction. Here also, or perhaps further in rear, is the headquarters of the army. It is noticeable that the base is strongly entrenched, and the railroad as well, on both sides for some distance from the base. Thus in case of defeat it will be possible to operate the railroad till the last, and remove wounded, guns and much of the equipment and supplies.

In front of the base and several miles toward the front, is the headquarters of the First Field Army which constitutes the center. Here may be also the reserve for the center, perhaps a division. Further to the front are the various division headquarters, and further still the brigade headquarters, the latter for the most part just in rear or in the rear edge of the defensive zone occupied by the troops at the front which I have previously described.

In rear of the defensive zone, concealed from the enemy as far as possible, is a great road or several parallel roads, upon which troops can be moved from one part of the line to another. From this road other roads proceed toward the front, losing themselves gradually in the covered ways and zigzags of the trenches; and toward the rear from this road other roads converge toward the main rail-end, where are the depots, the headquarters and the principal reserves.

A brigade of let us say 4,000 men is assigned to perhaps a mile of front. It furnishes its own outposts, trench guards, first line, supports and local reserves.

To the right and left, respectively, of the First Field Army are the Second and Third Field Armies, constituting the wings of the grand army, each organized as is the first army for defense and communication. Upon each flank is a large body of cavalry to observe and to retard efforts to turn the position. All parts of this great organism are in communication with each other, through the headquarters of the various units, by telephone or telegraph or by wireless.

Let us see what the engineers are doing within the area that I have described.

The director of railways, an engineer officer, is operating and maintaining the railroad over which we have approached the front. Under his direction the yards at the advanced base and the spurs radiating out from it have been built and are being operated.

Under the chief engineer of the army the great main system of wagon roads has been constructed. The engineer depot and parks at the advanced base are under his control. Under his supervision have been built the works for the defense of the advanced base and the rail-end. His advice has been available to the commanding general in the selection of the position and the location and character of the defensive zone. He sees that the field armies are properly supplied with engineer personnel and material. He is charged with the public works of the towns and cities occupied near the front, and with what may be called the public works of the army itself. The construction and reconstruction of main bridges fall to him, and the demolition of such bridges if the army retreat. He is the topographical authority, and furnishes all information of this character to his chief, preparing general maps for the use of the army. He may establish factories for the fabrication of hand grenades, portable wire entanglements and the like, and saw-mills to cut up lumber into convenient form for trench cover and many other operations. He employs civilians wherever he can to relieve the troops.

The chief engineers of field armies perform similar functions, each for his own unit; it being the duty of the chief engineer of the army to see that there is proper co-operation and no duplication of work.

Each chief engineer of a field army has at his disposal a ponton battalion, the companies of which are trained as pioneers as well, although the care of their animals and equipage will take most of their time.

The divisional engineers are building or supervising the construction of trenches, bomb-proofs and communications near the front; fabricating and placing obstructions in front of the trenches; where the lines are close together, constructing subterraneous passages known as mine galleries, projecting under the trenches of the enemy, and exploding mines therein; acting as pioneers when an advance is made, destroying the obstacles constructed by the enemy; mapping the position and front of the division, and in so far as is practicable the enemy position opposite it, and performing or furnishing superintendence for all kinds of skilled labor as emergencies arise.

I will conclude by the following quotation from my report on the Russo-Japanese war:

"On the whole, there was little development of novelties in the recent war. Indeed, we must resurrect the distant past for examples of some of the implements and methods used. The bayonet is not obsolete, nor is the officer's sword a mere badge of authority. In the close fighting many men are wounded by brickbats; and hand grenades are most useful weapons. The methods of siege laid down in the books are now known to be not much altered. What counted most were not new-fangled devices and surprising methods, but the preliminary training of the troops, the right tactical use of all arms, and the proper administration of the great military business of supply and transportation.

"Finally it may be said that when, under present conditions, two countries reasonably well prepared make war, the result is apt to be so near a draw that even victory is extremely unprofitable. This is a splendid fact, as it makes for peace, and may eventually lead to partial disarmament by international convention. But countries which will not prepare for war, while others insist on preparation, are the countries who are so acting as to retain war in the scheme of civilization."

October, 1915

IN MEMORIAM

WILLIAM MacKENZIE HUGHES, M. W. S. E.

Died June 25, 1915.

The Western Society of Engineers must transfer the name of William MacKenzie Hughes from its list of living members to the roster of the honored dead. He died on the 25th day of June.

Mr. Hughes was a native of Utica, New York, where he was born June 5th, 1848. We are told that he began his business career as a machinist's apprentice. Later he took a four-year course at Cornell University, graduating in 1874.

Thus equipped with both practical and scientific knowledge, he entered upon his chosen specialty of bridge and structural steel work in a position of grave responsibility, that of bridge engineer for the city of Cincinnati, which position he held from 1874 (the year of his graduation) until 1881, when he entered the service of the New York, Chicago & St. Louis Railway Company. In 1883 he became bridge engineer of the city of Cleveland, serving that city in that capacity until 1888. During 1889 and 1890 he was engineer and assistant general manager of the Keystone Bridge Co. From that position he went with Mr. Gottlieb into the service of the Columbian Exposition as engineer of construction, February, 1891. He resigned that position in August of the same year. During the years 1893-4 he served the city of Chicago as bridge engineer. Mr. Hughes was consulting engineer for the Metropolitan (West Side) Elevated R. R. during its construction period, from 1892 to 1896. In 1896 he became bridge engineer of the Sanitary District of Chicago, resigning May 1st, 1898. After that, however, he did special work for the District, taking it into his private practice. On May 3rd, 1899, he re-entered the service of the District with the title of engineer of bridges and bridge construction, which position he held until Dec. 31, 1900. In 1904-5 he designed the structural work of the Kenwood and Stock Yards branch of the South Side Elevated Ry. and all of the steel work on the Chicago Junction Railroad track elevation.

We, who knew Mr. Hughes, prized his friendship and appreciated the force of character back of the man's quiet unobstrusive manner, and we know that the profession which he adorned has lost a useful member and that we, his associates, have parted with a valued friend. Our sympathy goes out to his wife and daughter.

Memoir prepared by J. J. Reynolds, Albert Reichmann, Isham Randolph, Committee.

ARTHUR MARSHALL MORGAN, M. W. S. E.

Died June 26th, 1915.

Arthur Marshall Morgan, born at Odell, Livingston County, Illinois, April 10, 1862, died at his home in Evanston, June 26, 1915. Mr. Morgan was a son of Sidney S. Morgan of Hartford, Connecticut. His mother was Anconetta Marshall of Connecticut. He was a grandson of Richard P. Morgan, Sr., a civil engineer, who made the first surveys of the Hudson River Railroad. He was a nephew of the late Col. Richard Price Morgan, a civil engineer of prominence in railroad and financial circles, and also of George Cadogan Morgan, an hydraulic engineer of wide practice and high reputation, and it was with the latter that Arthur Marshall Morgan received the training which fitted him so well for his life work. In 1881, at the age of nineteen, he entered the office of his uncle, where he remained for over thirty years, working up from office boy to general manager, a position which he occupied for many years, and upon the death of his uncle in 1913, he assumed control and continued a large business until his death.

Few engineers have enjoyed a wider and happier acquaintance among their clients. He had a faculty of winning and holding the confidences of those whom he served. He was a servant to many and gave of his life unsparingly to his clients, his family and his church, where he worked as elder, superintendent of his Sunday school and teacher of a large class of young men.

Monuments of his thought and planning may be found in scores of villages, towns and cities throughout the Middle States, while as widely scattered may be found a large number of young men, holding places of trust in the business world, who also testify to helpful thoughts and plans from the same broad mind.

On September 22, 1886, Mr. Morgan married Miss Myrtie Guild of Clinton, Wisconsin, who, with the two sons, Merritt Sidney and Arthur Marshall, Jr., and a daughter, Ruth, survive him.

Memoir prepared by W. S. Shields, W. G. Potter, Dwight C. Morgan, Committee.

Editor's Note.—Since the publication of the memoir of the late William Dana Taylor, M. W. S. E., in the June, 1914, Journal, we have been advised by Lt. Col. Edgar Jadwin, Corps of Engineers, U. S. Army, that, at the time of the Spanish War, Mr. Taylor accepted a commission as Captain in the Third U. S. Volunteer Engineers. Colonel Jadwin says: "His service for the regiment was short, being only during the period of its organization and early training. He was, however, universally liked, highly respected, and recognized as a man and engineer of parts. It was with regret that his resignation was accepted in order that he might re-enter the railroad service mentioned in your obituary notice."

PROCEEDINGS OF THE SOCIETY

MINUTES OF THE MEETINGS

Regular Meeting, October 4th, 1915

The regular meeting (No. 912) held Monday evening, October 4th, 1915, was devoted to a "Ladies Night." The meeting was called to order by President Jackson at 8:15 p. m., with one hundred and eighty members and guests in attendance.

President Jackson opened the meeting with a few remarks, after which the conduct of the meeting was transferred to Mr. D. A. Tomlinson, assistant general chairman of the Entertainment Committee.

Several vocal solos were rendered by Mrs. E. N. Layfield accompanied by Miss Whitmore on the piano, after which Mr. Ernest S. Rice and Miss Mildred Rice were presented to give an illustrated lecture on the "Indians of the Southwest." Many beautifully colored lantern slides, descriptive of the life, customs and environments of the Indians, were shown.

After a few humorous stories by Mr. Tomlinson, Mrs. Layfield again sang. The meeting adjourned for refreshments at 10:20 p. m.

Extra Meeting, October 11, 1915

An extra meeting (No. 913), in the interests of the Hydraulic, Sanitary and Municipal Section, was held on Monday evening, October 11th, 1915.

The meeting was called to order by Mr. L. K. Sherman, Past Chairman of the Section, at 8 p. m., with about seventy-five members and guests in attendance.

The chairman of the meeting introduced the speaker of the evening, Col. C. McD. Townsend, Corps of Engineers, U. S. Army, who presented his paper on "The Currents of Lake Michigan and Their Influence on the Climate of the Neighboring States." A very interesting discussion followed from Messrs. G. M. Ilg, H. J. Fixmer, W. E. Williams, D. W. Roper, Prof. John F. Hayford and L. K. Sherman.

The meeting adjourned at 9:30 p. m., after which refreshments were served.

Extra Meeting, October 18, 1915

An extra meeting (No. 914), in the interests of the Hydraulic, Sanitary and Municipal Section, was held on Monday evening, October 18th, 1915.

The meeting was called to order by Mr. G. C. D. Lenth, Chairman of the Section, at 8 p. m., with about seventy members and guests in attendance.

There being no business to bring before the Section, Mr. E. N. Layfield, acting secretary, read the paper of the evening on "A Short Description of Some of the Construction Features of the Greater Winnipeg Water Supply," as the author of the paper, Mr. James H. Fuertes, could not be present. Lantern slides were shown illustrating some features of the construction. Discussion followed from Messrs. Lyman E. Cooley, W. W. DeBerard, B. E. Grant, John W. Lowell, Jr., W. A. Hoyt and E. N. Layfield. Mr. Layfield at the close of the meeting announced that the Board of Examiners of Structural Engineers for the State of Illinois were ready to consider applications for licenses and wished the members present to spread the information to persons who were interested. The meeting adjourned at 9:15 p. m., after which refreshments were served.

Extra Meeting, October 26, 1915

An extra meeting (No. 915), a joint meeting of the Electrical Section, Western Society of Engineers and the Chicago Section, American Institute of Electrical Engineers, was held Tuesday evening, October 26th, 1915, convening at 8 p. m., at Fullerton Hall, in the Art Institute, with W. J. Norton, chairman, Chicago Section, A. I. E. E., presiding and about 475 members and guests in attendance.

There being no business to be brought before the meeting, Mr. Norton introduced the speaker of the evening, Dr. C. P. Steinmetz, who addressed the meeting on the subject of "Illumination." Discussion followed by Mr. W. E. Williams and Dr. Steinmetz.

At the conclusion of the meeting, Chairman Norton called attention to the next meeting of the joint societies to be held on November 22nd, and thanked Dr. Steinmetz on behalf of the two societies for his address. The meeting adjourned at 9:45 p. m.

E. N. Layfield, *Acting Secretary.*

BOOK REVIEWS

The Books Reviewed Are in the Library of This Society.

Railway Maintenance Engineering. By William H. Sellew. D. Van Nostrand Company, New York. Cloth; 5 by 7½ in., 350 pp., 1915. Price, $2.50.

The author, who has had a long experience in maintenance work on a railroad which has a very high standard of maintenance, is a non-resident lecturer on railroad engineering at the University of Michigan, and he states in his preface that the book has been prepared from notes used in his classes and that while written to present the subject from the viewpoint of the student, an endeavor has been made to introduce matter of a sufficiently advanced character to make the book of value outside the classroom. The author has succeeded in doing this and has produced a book well worth reading and studying. As the title indicates, the book is devoted primarily to railroad maintenance work, but as maintenance men have more or less to do with the correction of old lines and the projection of branches, and as they also need to consider the principles of location and construction, in handling many of their maintenance problems, these subjects have been treated to some extent. The arrangement of chapters in the book follows the classification of investment accounts of the Interstate Commerce Commission, for which arrangement the author is to be commended. Much of the material of a book of this kind is necessarily taken from standards that have been adopted by railroads and the author freely quotes from the proceedings of the American Railway Engineering Association and elsewhere, giving proper credit to the source. The book contains a good bibliography at the end of each chapter and also a good index which adds greatly to the value of the book, as a work of reference. From the standpoint of style in technical writing, some improvements might be made, but these are not serious enough to quarrel about in the case of good book.

The book contains fifteen chapters, as follows: Engineering; Land; Grading; Bridges, Trestles and Culverts; Ties; Rails; Other Track Material; Ballast; Maintaining Track and Right of Way; Station and Roadway Buildings; Water Stations; Fuel Stations; Shops and Engine Houses; Icing Stations; Signals and Interlockers. The book is well illustrated, has a number of useful tables, and is brought to date in such matters as the use of the modern ditching machine, the standard gauge dump car, and other such features.

Materials of Construction, Their Manufacture, Properties and Uses. By Adelbert P. Mills. John Wiley & Sons, New York. Cloth; 6 by 9 in.; pp. 658. Price, $4.50.

This book is in three parts:

Part I.—"The Materials of Masonry Construction" covers gypsum plasters, quicklime, hydrated lime, hydraulic limes and grappier cements, puzzolan and slag cements, natural cements, Portland cements, concrete materials and properties, building stone and stone masonry and brick and other clay products, in ten chapters covering 256 pages with 142 figures and diagrams.

Part II.—"The Ferrous Materials" is covered by the chapter headings Pig Iron, Cast Iron, Malleable Cast Iron, Wrought Iron, Steel and Special Alloy Steels, in 283 pages and 163 figures.

Part III.—"The Non-Ferrous Materials and Alloys and Timber" is covered in two chapters of 118 pages and 41 figures.

The book admirably fulfills the author's purpose in endeavoring to supply a text book and reference work covering the manufacture, properties and use of the common materials used in engineering structures.

The book is well balanced, diagrams and illustrations carefully selected and unusually well designated. The material is well chosen with enough historic matter and scientific discussion to make it interesting without being burdensome.

There are, however, many minor adaptations and compounds of various materials with which the practicing engineer is often confronted that are not mentioned.

Asphalt and allied materials not usually treated in books of this character, are common materials, and why should they not be mentioned?

The decay and durability, also treatment of timber could have been given a little more space to advantage. Dry rot is not mentioned. The comparative durability of different species of wood exposed to the weather is not given, and many other points of practical consideration are omitted. This is true of other parts of the book. While it is not intended as an inspector's hand-book, yet many little practical suggestions would have made the book more useful.

The book is a well balanced treatment, bringing up to date a constantly increasing and diversified subject. W. A. H.

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THE DEVELOPMENT AND IMPORTANCE OF AN ADEQUATE ENGINEERING DEPARTMENT FOR A PUBLIC SERVICE COMMISSION

WALTER A. SHAW, M. W. S. E.

Presented May 3, 1915.

Some months ago our President asked me to give an informal talk before the Western Society of Engineers dealing particularly with the development and importance of an adequate engineering department for a public service commission.

It is not my purpose to discuss any of the many theories involved in the making of a valuation for rate-making purposes or to treat of such topics as depreciation or the question as to whether investment cost or reproduction cost should have the greater weight in determining a value for rate-making purposes.

In hearings that I have held for the purpose of taking testimony to establish fair values for the purpose of determining a just and adequate rate, there have appeared before me and testified a number of well-known experts, and I find that upon some of the cardinal principles involved none of them agree, and they differ widely in the principles advanced in their view of the subject. At some future date I may venture to express an opinion upon the theories and principles advanced upon the troublesome subject of a valuation of properties for the purpose of rate making.

In my talk tonight, which is informal, I trust you will pardon me if the subject is not strictly followed.

The Legislature of the State of Illinois, which assembled January 1, 1913, appointed a committee to make a thorough investigation of the laws which had been passed by several states creating public utilities commissions and the work of these various commissions. The committee, after a thorough investigation, reported in detail on the subject and recommended the passage of a law creating a State Public Utilities Commission. This recommendation was concurred in and such a law placed upon the statute books of the State of Illinois. The law, as passed, provided that it should go into effect January 1, 1914, and that the commission should be composed of five members to be named by the Governor with the consent and advice of the State Senate. The law provides that the Governor shall designate one of the five commissioners so appointed as chairman.

A few days prior to the day the law went into effect the present State Public Utilities Commission was appointed, and on January 2, 1914, it assembled at Springfield and proceeded to organize for business and to carry out the duties imposed upon it. One of its first duties was to establish the nucleus of a working organization to put into effect the provisions of the law, the organization to be sufficient in size to take care of the immediate work, and, at the same time, be capable of expansion as the demands made upon the commission increased.

The law creating the State Public Utilities Commission provided that it should assume all of the duties of the old Railroad and Warehouse Commission, which had, as far as the engineering department was concerned, three employes, namely, a consulting engineer, an assistant engineer and one investigator.

At the beginning the commission adopted the following tentative organization:

An Executive Department, in charge of the secretary of the commission. This department has charge of all files, correspondence, records, and it transmits and carries out all orders of the commission.

A Legal Department, consisting of a chief counsel in charge, and the necessary assistants. This department has charge of all legal matters which may come before the commission in the course of its work.

An Accounting and Statistical Department, with a chief accountant and statistician in charge, with the necessary assistants, clerks and stenographers. This department has charge of and supervision of all accounts in connection with all utilities operating in the State and collecting and filing of all tariffs and rates in effect, together with all statistics that may be gathered and compiled for the use of the commission.

A Railroad Rate Department, with a chief in charge, together with the necessary assistants. This department has charge of all matters in connection with railroad rates.

An Engineering Department, with a chief engineer in charge, together with the necessary division heads, assistants, clerks and stenographers.

The above tentative organization was approved temporarily and later on, after the commission had made a further study of the duties imposed upon it, and after having several months' actual experience, the commission permanently approved and adopted the above organization as outlined with the exception of a few minor changes and a further subdivision in the departments themselves.

The department heads report directly to and are responsible to the commission and in turn each department head is held directly responsible for the efficiency and conduct of all employes directly under him and the taking up and proper disposal of all work of the commission that should be handled by his particular department.

In commenting further upon the accounting and statistical division, it might be said that one of the most essential parts of the work in connection with the making of a valuation in order to determine a fair and equitable rate by allowing a fair return upon a fair value of the property used and useful, is to require each and every utility to accurately keep their books and accounts in accordance with forms as outlined and prescribed by the commission. It is most important that the books correctly show proper capital charges, operating charges, maintenance charges, retirements, and so forth. This portion of the work is now well under way and will soon be completed and when so completed each utility in the State will be required to keep its accounts and records in accordance therewith. In working out these forms in such a manner that the Engineering Department and Accounting Department may work in harmony, many conferences are held between the two departments. It is further necessary that the two departments work in harmony for the reason that the commission, in determining the fair value, should consider all data that may be obtained from the records and accounts of the company, and also for the reason that the commission deems it proper to consider all historical facts in connection with each case.

The work of making investigations in connection with the valuation of property and gathering data to be used by the commission for passing upon applications for issuing securities, both stocks and bonds, is placed upon the accounting division.

In some cases the commission finds that in order to pass intelligently upon an application for issuing securities it is necessary to have a valuation made by the Engineering Department. In such instances the data gathered by both the Accounting Department and the Engineering Department is considered in making a finding: in fact the commission finds that in order to obtain the best results there must be close co-operation between the engineering and the accounting departments.

In the first days of the commission, the engineers who had been in the employ of the old Railroad and Warehouse Commission were made the nucleus of a working organization for the Engineering Department: but after a further and more extensive study, the following organization was adopted:

A chief engineer, responsible directly to the commission for all subjects pertaining to his department. An assistant chief engineer to be assigned such duties from time to time as may best serve the interests of the Engineering Department.

A railway division with a chief in charge. This division has charge of all work in connection with railroads, such as block signal systems, grade crossings, condition of railroad tracks, investigation of accidents, and so forth.

An electrical division with a chief in charge. This division has charge of valuations of all electrical properties when required; to investigate the more important complaints made regarding service; the preparation of rules and regulations; special reports; investigations, and so forth.

A gas division, with a chief in charge. This division has charge of all valuations where necessary to be made in connection with gas properties, preparation of rules and regulations governing service and making special reports and investigations; in fact, all matters requiring the services of an expert in connection with gas properties.

A telephone division, with a chief in charge. This division takes up and makes investigations and reports of the more important complaints as to service, the making of all valuations where necessary, the preparation of rules and regulations governing the operation of telephones and considers all other matters of an engineering nature that may come before the commission in connection with the various telephone systems in the state.

A mechanical and water-works division, with a chief in charge. This division has charge of all valuations which may be required for any purpose whatsoever in connection, more particularly, with water-works and steam heating plants; investigations of more important complaints; the preparation of rules and regulations governing water-works and steam heating plants, and so forth.

A service division, with a chief in charge. This division has charge of and makes investigations of all informal complaints made to the commission of any nature whatsoever; the making of special investigations and reports as may be required, dealing more particularly with services rendered by the utilities and their compliance with rules and regulations adopted and approved by the commission. The head of this division comes in direct contact with the public perhaps more than any other of the division heads. He should be a man of wide experience and have a good general knowledge of the practical operation of all utilities, and last but not least, a good diplomat.

The success of this division depends in a large measure upon the impression made upon the public. Perhaps, also, the impression the public may form of the practical operations through the Public Utilities Commission, may, in a large measure, depend upon the services rendered to the public by this service division.

At the time this division was created it was thought that the State should be divided into about six districts with a service engineer in charge of each district, each district engineer to handle all complaints of any nature coming directly to his knowledge or such complaints as might be referred to him; also to ascertain as far as practical whether the rules and regulations adopted by the commission are being complied with by the various utilities operating in the state. This division is also required to make such recommendations from time to time as might be beneficial to the public in general and not create a hardship upon the companies or conflict with the rules and practices of the company or rules and practices adopted by the commission. This division will give particular attention to such portions of the rules and regulations pertaining to gas and electricity as has to do with pressure, heat units, voltage, proper registering of all types of meters, line troubles and what is known as free extensions.

Up to the present, the commission has adopted standards of service covering electrical plants, gas plants, water plants and telephone systems.

During the preparation of the standard rules and in making investigation of standards of service required by franchise ordinance in the State, the commission ascertained that there were various and conflicting standards required in the various municipalities of the State. Some were exceedingly high and practically impossible for the companies to fulfill; others were exceedingly low and poor service being rendered.

The commission, by the adoption of standards, has put into effect a standard of service required of all companies over the entire State, and the standards required are such as to render good and efficient service to the consumers and not create a hardship upon the companies.

However, in all the standards adopted the commission insists that in all cases where there is now in effect franchise ordinances setting forth standards of service that are higher than the standards adopted by the commission the companies must continue to fulfill the standards of service as required by the franchise ordinances until such time as there is an adjustment of the rates. This may be done by making a valuation of the property or such other investigations as may be found necessary.

Good results have already been obtained on account of the adoption of standards and much better results are expected for the future.

On the establishment of the permanent organization a competent chief engineer and a limited number of division heads and assistants were selected. In selecting the chief engineer and division heads the commission selected, as far as possible, men who were experts in their particular line of work and by selecting and appointing such men it was possible for the commission to handle a large amount of technical work with a small number of assistants, and as time progressed those selected became trained and schooled in the work of the commission; and as the work increased, the ground work of the organization was so laid out that the increased demands made upon the commission could be taken care of by employing additional assistants.

I believe that the organization as above outlined and as now in effect will properly take care of all the work of an engineering nature that may come before the commission for years to come, and whether or not the Engineering Department performs its full duties and successfully conducts its work depends, first, upon the personality and executive ability of the chief engineer; second, upon the executive ability and personnel of the division heads and, perhaps, third, but not so important, the personnel of the assistants.

In the selection of a chief engineer and division heads, the test applied was executive ability, technical training and practical experience in the character of work that would likely come before the commission and also the capacity to perform the duties imposed. Politics was entirely lost sight of and members of the engineering staff were selected for merit only.

In all formal complaints filed with the commission, it is necessary, in order to properly dispose of the complaint, to have a hearing and evidence is introduced. The law requires that all reports of investigations and recommendations that may be made, or valuations of property made by the Engineering Department in rate cases in connection with all matters, must be based on evidence brought before the commission and made a part of the record. In the light of this requirement of the law one of the most important qualifications of the chief engineer or division heads is to have the ability to properly present a case by oral testimony or exhibits. This requirement, perhaps, is somewhat foreign to the practice and experience of the average engineer. It, nevertheless, is an essential qualification for commission work. The same thing may be said as to the qualifications in this particular line of other members of the engineering staff.

The law contemplates that all employes other than the secretary, chief engineer, chief accountant and statistician, chief counsel and all assistant counsels, and experts temporarily employed, shall be certified from the civil service list when such a list has been prepared by the State Civil Service Commission. There having been no list from which to certify, practically the entire force in the engineering department at the present time are temporary appointees. The commission hopes that when examinations are held and certifications made that there will be no radical changes in the present personnel.

On account of the wide variation of work to be performed and the fact that besides being an engineer of technical training and practical experience, he should have executive ability and experience in court work, it is somewhat doubtful as to the practicability of selecting division heads by holding competitive examinations.

To give you an idea of the financial difficulties under which the commission has labored, I want to call your attention to the fact that for the first eighteen months of its existence the commission had an appropriation of only $180,000 to meet all expenses, except the salaries of commissioners, secretary and chief counsel.

The commission, by paying fair salaries to chiefs of departments and by making a proper division of the work among themselves, each commissioner making a specialty of the work for which he is best qualified by technical training and experience, has been able, although handicapped by insufficiency of funds, to keep up with its work and no decisions have been unnecessarily delayed.

During the first year there were seventeen appeals taken from orders of the commission to the Circuit Court of Sangamon County. All of the cases that have been passed upon by the Circuit Court have been affirmed and those which were appealed from the Circuit Court to the Supreme Court have all been affirmed by the Supreme Court, with one exception, which was reversed on account of a technical error in the record.

In connection with the issuance of securities, attention to which has been heretofore called, the law provides that for all securities issued there shall be a fee paid into the State Treasury of $1.00 for each $1,000.00 issued. From this source there has been paid into the State Treasury about $670,000.00, a sum considerably in excess of all expenses of the Commission, including salaries of the Commissioners themselves, their secretary and chief counsel.

In all valuation work and rate adjustment it is generally considered good practice for the Commission to ascertain all facts, as far as it is possible to do so, from the records of the company or otherwise as to the original investment, this data being considered by the Commission in connection with any other theories of valuation which may be advanced, whether it be what is known as "Cost of Reproduction New, Less Depreciation" or otherwise.

This evidence may be brought before the Commission by its own employes, either of the Engineering Department or Accounting Department, or both, working in conjunction, or by experts appearing before the Commission and testifying, either for the petitioners or the respondent companies. It is equally important that a complete and thorough analysis be made of the records of the books of the company as to operating charges, maintenance and any other items of expense in connection with the operation of the utility. A complete analysis should also be made of all sources of income. In general this latter data is obtained by accountants. However, it has been found that all accounts should be closely scrutinized by an engineer who has a knowledge of accounts. Any engineer having this knowledge can use the data so obtained more intelligently and can better determine in a valuation and rate making case the data that should appear in the testimony and he is also, in general, in a better position to indicate or prescribe the form in which the exhibit should be presented. In many cases the engineer, if he has some knowledge of book accounts, can obtain valuable information by personally going through and scrutinizing the books and records.

In Illinois, as in all other states where the keeping of a uniform system of accounts has not been compulsory, it is found that the accounts or records have been kept in all kinds of forms, and in many instances after going back a few years no accounts or records can be found either as to the investment of the plant or as to the income, or operating, or maintenance expenses. In some instances the records indicate that cost of operation has been charged to capital account and vice-versa. In such cases the items appearing on the books must be interpreted and this interpretation usually falls to the lot of the engineer, or at least our experience to the present has been such.

We find further that in working out proper methods as to forms of accounts to be kept and as to how charges should be made the engineer must keep in close touch with the accountant and, in general, his advice should be largely followed. Some experts engaged in valuation and rate making give more weight and attach more importance to book values, when it is possible to obtain investment costs from the books; other experts or engineers depend largely upon results obtained by applying what is called the reproduction method new less depreciation. Without going into the merits of either theory or method I believe that due weight and consideration should be given to all data obtained from the books as to investment cost, etc. It is also essential that proper analysis be made of all operating costs, income, etc. But granting all claims that may be made as to the weight that should be given investment costs in arriving at a fair value, I believe, taking all things into consideration, particularly the haphazard way in which the books of many companies have been kept, that the Engineering Department is the most important department of any state commission and in saying this I do not mean to belittle any accountant or his work. And I further believe that the success made by any commission in valuation and rate making depends largely upon an efficient and competent engineering department.

On account of the large amount of work coming before state commissions, which requires the skill of a trained engineer to solve, should not more engineers be appointed on state commissions? Does not the technical training and practical experience of the engineer in such matters better qualify him to grasp the situation and render a just and equitable decision than the man that has had no training in the subject he is handling?

It is argued on the part of some that a commissioner to be successful should have judicial experience and training. Does not the practicing engineer obtain judicial experience and training, especially the engineer that deals with construction work? The very nature of an engineer's work, in charge of construction, makes him an arbitrator between the party having the work performed and the party actually doing the work.

His success largely depends upon his being able when a contention arises as to the execution of the work, to consider both sides of the question and after giving all facts due consideration to render a decision which will be just and equitable to all parties involved.

Does not this experience give the engineer judicial training and experience?

I believe when the public becomes more familiar with the duties imposed upon a state regulatory body and becomes better informed as to the technical problems involved, we will see more engineers appointed upon state utilities commissions, and if so the profession will not be found wanting and the public will be the gainer.

Discussion.

O. P. Chamberlain, M. W. S. E.: I had occasion to have several cases before the Railroad and Warehouse Commission. I met Mr. Shaw shortly after the present Commission was organized, and while talking with him several matters came up which had been referred to them, and I came to the conclusion after seeing how the work was handled that a great many matters were coming before the Commission besides engineering matters, and I wish to say that the Commission, and particularly Mr. Shaw, are to be congratulated for the work they have done in a short space of time and with the very limited amount of money with which the Commission was compelled to work.

One thing that has interested me more than anything else, not purely an engineering matter, although such to a certain extent, is rate making. We all know that from ten to twelve years ago and for a long period before that time, railroad freight rates were in the hands of the traffic manager, who was the sales manager of the railroad. He sold freight as a salesman sells commodities. The attitude of the railroads has changed entirely in the last five or six years. They have come to recognize the right of the State and the National Government to regulate rates. But the methods do not differ greatly from those of former years except that the approval of a commission must be obtained before publication.

There must be some principle by which a fair freight rate can be made. One of the important things in business today is to route material to take advantage of the lowest freight rates. By routing over two lines instead of one, I found in one case I could save more than 20 per cent on freight rates, and sometimes by taking a longer way around I could save expense. I do not know what has been done by the Commission in this State or in other states to correct this matter.

I know of another case in which material was hauled double the distance necessary, for which I was compelled to pay. Now it seems to me that these matters, that have been talked over so many times, ought to be so impressed upon our commissions as to result in rates, for a given commodity, based primarily on mileage of haul and secondarily on the number of transfers to be made. This matter should be taken up scientifically by the Interstate Commerce Commission and the different state commissions, as the freight rates are now in a demoralized condition.

Robert M. Feustel: The difficulties which beset the regulating body have been impressed upon me more forcibly the last six weeks than ever before. I had always understood that some of the New England States had been subjected to public utility regulation for many years and that regulation in these states was far advanced over that of our middle Western States. I have appeared recently in some cases before the New Hampshire and Massachusetts Commissions, and I find that, while regulation of securities has been more or less in effect in these states for a good many years, actual regulation of rates and service has not been attempted to anyways near the extent as has been the case with our Western Commissions.

The question of an adequate rate of return, an adequate allowance for depreciation, what should be considered as a fair rate making value, and many more allied questions are just beginning to be studied thoroughly by these commissions. The testimony given by engineers in cases in other parts of the country has been studied by eastern commissions. They have come to realize that regulation is not a cut and dried method and that the same method of handling is not possible for even apparently similar cases in different sections of the country.

I have listened to testimony given by various engineers and have come to the same conclusion as have some of the members of the regulating bodies. The expert witness of today has become the advocate of his client rather than the searcher of facts and an interpreter of these facts. Most of the commissions are earnestly trying to handle the various problems fairly. It must be appreciated that to a single regulating body are presented cases which have had thought and study by many civic bodies, many city councils, and competent experts. The regulating body is expected to solve promptly complex problems which have been in controversy for many years. Needless to say, it is highly important that the facts be put before this body as simply and as clearly as possible. It strikes me, therefore, that a problem which should have the earnest attention of all engineers at the present time is that of clearly presenting facts in all cases and refraining from indulgence in complex theories which really muddy the waters for the regulating bodies.

S. T. Smetters, M. W. S. E.: What guarantee have we that the Public Utilities Commission rulings will be on the books four years from now. Their decisions may be reversed inside of a year.

Mr. Shaw: Public hearings will be held as to whether it should be reversed or modified on the evidence presented, and you have the right to appeal from the Commission's decision to the Court.

W. E. Symons, M. W. S. E.: While Mr. Shaw's paper deals principally with public utilities, and the transportation features are largely those of interurban service, yet the broad question of transportation and its cost is involved. The underlying principles, or fundamentals, are in many cases common to both interurban or electric lines and steam railways.

I noticed one particular point brought out in the discussion, and that is with reference to the long and short haul of freight, and in this particular feature there seems to be a lack of information that would be helpful to all those interested in questions of this kind.

One of the most important features to be considered in connection with the so-called long and short haul is the cost of terminal service. In some recent studies which I have made in connection with steam railway lines I have found in one State in the southwest that the terminal cost per ton for handling freight was 40 cents, therefore, on an interstate shipment there would be a terminal cost of 80 cents, which must be met out of the rate provided on the shipment before any revenue is derived for transporting the commodity, or what may be commonly termed the haulage charge. In another State the cost per ton was about 30 cents, so that in each of these States a terminal charge of twice the amount per ton should be provided for on all intrastate shipments, while on interstate shipments there would be only one terminal charge, and the rates should be predicated upon the amount necessary to allow the carrier such profit from transportation as will properly maintain the property and yield a fair return to shareholders. This, of course, means that the intra- or State rates, must of necessity be much higher than the interstate or through rates.

In Japan and New South Wales the question of terminal charge is recognized by the authorities in permitting the carriers to make a separate charge for terminal service, aside from the transportation or haulage charge. In Japan the freight rate per ton mile is 8.3 mills, while the terminal charge is 11 cents per ton. In New South Wales the freight rate is 1.76 cents and the terminal charge is 23 cents per ton. In each country the freight rate is in excess of the average freight rate in the United States; in fact, in New South Wales it is more than double, and in addition to this there is a terminal charge for handling all freight received or delivered.

As an illustration of the use of the carriers' equipment without compensation, we may take freight cars handled at one of the large commercial centers. In the year 1912 there were in revenue freight service in this country about 2,215,000 freight cars. The average miles *per day* made by these cars was less than 25, although as a matter of fact, while under way in freight trains (which is the only time they are producing revenue for their owners), they were probably moved at an average rate of speed of 25 miles per hour, so that on this basis they were only bringing a return to their owners during a very short period of time. In the city of Chicago alone, during that year, there were over 7,000,000 freight cars received, taken to freight yards, thence to team tracks and warehouses, after which a corresponding number of freight cars were delivered and sent forward from Chicago, making a total of about 15,000,000 freight cars handled at this terminal in one year, while there were only about two and a quarter million freight cars in the entire United States. From this it can be plainly seen that the carriers' property is being largely used for the benefit of the shipper, for purposes aside from actual transportation.

The foregoing features are not as a rule generally understood by the public, and in many cases are not understood by the shippers, and if this matter were properly explained, doubtless all of those interested, particularly the authorities who have to do with rate making, would feel more liberally inclined toward the carriers, particularly so in making rates to govern local or intrastate shipments.

As a general fundamental principle I hold that no rate should be in effect that does not yield sufficient revenue to maintain the property in a high state of physical condition and yield a good, fair return to the shareholders.

THE RELATIONS OF THE RAILWAYS AND THE PUBLIC

By L. E. Johnson.*

Presented Nov. 2, 1915.

I have accepted your invitation to address you in the belief that it indicates your interest in the railway problem of the United States. That there is such a problem all agree, however much they may differ as to its true nature and proper solution; and it is a problem in which it is very desirable that the more intelligent and public-spirited of our citizens, such as those composing this society, shall actively interest themselves. Not only is it desirable that they should do this, but it is their positive duty. On the way the railway question is finally settled will greatly depend the welfare of the nation. Public opinion will determine whether it will be settled right. In order that public opinion may cause it to be settled right the public must have good leadership; and that leadership should be furnished by men such as you, whose education, training and position in life fit them to study important public questions intelligently, to consider them rationally, to decide about them without selfish prejudice and to secure a respectful hearing for their views.

We hear much complaint from educated and well-to-do people because public opinion allows, and even causes, much of our administration of public affairs to be wasteful and inefficient. While these complaints are well founded, the conditions which justify them usually are largely due to the derelictions of those who make the complaints. If the railway question is not settled right, or if it and the unsatisfactory railway situation out of which it grows continue to be disturbing and harmful elements in our public and business affairs, the responsibility will rest mainly on the shoulders of that more intelligent and capable class of our citizens who can, if they will, guide public sentiment into right channels.

Our railway problem exists, first, because certain conditions under which our railways are conducted are unsatisfactory and, second, because certain features of their management and operation are not what they should be on some railroads. It is generally recognized that to solve the problem presented there should be changes made in the relations existing between the people and the governments of the states and the nation, on the one hand, and the managements and owners of the railways on the other hand. Some people believe these changes should be effected by the adoption of government ownership and management of the railways. Others believe the needed changes should be accomplished by modifications in the present policy of regulation, in which latter class I place myself.

*President Norfolk & Western Railway Company.

OBJECTIONS TO GOVERNMENT OWNERSHIP.

I believe a majority of the people think at present that the adoption of government ownership would not promote the public welfare but would have the opposite result. If we consider the effects of this policy in other countries, and the conditions under which it would be tried here, we must concur in this view. There are a very few countries, Prussia affording the best example, where state railways have been managed with a considerable degree of success, but in most countries both the economic and political results of government management have been bad. Forty years ago an Italian commission which had thoroughly studied the subject expressed the opinion that under government ownership politics would corrupt the railroads and the railroads would corrupt politics. This view has been supported by the experience of Italy itself and by that of France, of Australia, of Canada, and of every other country where the conditions have been such as to make it possible for politics to affect government management. Nowhere else, perhaps, has the deplorable influence which politics is almost certain in a democratic country to exert on government railway management been more strikingly illustrated than in our next-door neighbor, Canada.

Since 1867 the Dominion has owned and operated the Intercolonial Railway, and since 1873 the Prince Edward Island Railway. These lines now have a mileage of 1,734 miles. Never in a single year since the government acquired it has the Prince Edward Island Railway earned even its operating expenses, to say nothing of interest on the investment in it. The Intercolonial in the 47 years it has been under government management has failed by $8,500,000 to earn its operating expenses, to say nothing of interest on the large investment which the people of Canada have made in it. If you add to the operating deficits which these railways have incurred the interest on the investment which they have failed to earn, and which has, therefore, had to be paid from taxes, the total losses they have inflicted on the tax-paying public of Canada run into hundreds of millions of dollars. Other railways in eastern Canada owned by private companies have charged practically the same rates as these government railways and have been operated at a profit. The reason for the enormous losses incurred by the government railways is that they have been run largely on political instead of business principles.

This is not all the experience Canada has had with public ownership. In 1904 the government began the construction of the National Transcontinental Railway from Moncton to Winnipeg. The official estimate of its cost was $61,415,000, or $34,083 a mile. At the end of 1914 the line had not been provided with equipment or adequate terminals, and yet up to that time there had been spent on it $173,000,000, or about $99,000 per mile. A government commission appointed to investigate its construction denounced it as enormously wasteful, and the Grand Trunk Pacific, to which it had been intended to lease the line for operation, refused to take it over because it could not afford to pay three per cent interest on the excessive expenditure which had been made.

The explanation of the wasteful construction of the National Transcontinental is the same as the explanation of the wasteful operation of the Intercolonial. The work was done on political rather than business lines. The principle of the "pork barrel" had dominated the management and construction of government railways in Canada as it has the development of waterways, the erection of public buildings and a good many other matters in this country.

The experience of other countries and the conditions in our own warn us that we cannot afford to try the experiment of government ownership of railways here; at least, not until our government management would not be rendered impossible by politics of the "pork barrel" variety.

THE ALTERNATIVE.

There is only one alternative to government ownership. This is a system of wise and fair regulation. Railway managers are often accused of not recognizing this fact. They are often charged with being opposed not merely to effective regulation, but to any regulation. I deny this. I know the consensus of opinion of our railway managers, and I assert emphatically that they are not opposed to any regulation or to effective regulation, but that they appreciate the need of it and are as strongly and sincerely in favor of it as any other class of our citizens. They are in favor of effective regulation because they know that this is the only alternative to government ownership, and as patriotic citizens they are opposed to government ownership. They would be in favor of it even in the absence of the danger of government ownership, because they recognize the fact that effective regulation, if it be also wise and fair, will promote the interests and protect the rights not only of the general public but also of the owners, the officers and the employes of the railways themselves.

It is, therefore, not just to assume when railway men criticize the present system of regulation that they are objecting to any and all regulation. It is not any and all regulation they oppose, but certain kinds of regulation which they regard as unwise and unfair, and as, therefore, not only unjust and harmful to the railways, but prejudicial to the welfare of the public.

All intelligent railway men recognize the fact that there have been in the past shortcomings and abuses in the management of some, if not all, of our railways and that government regulation has helped to correct some of these. They concede that there are still such shortcomings and abuses and that government regulation can, and ought to, help to correct them. But they also believe that there are some very serious shortcomings and abuses in the present system of regulation; that in consequence it is doing harm as well as good; and that unless it is radically changed and raised to a higher plane of efficiency and fairness, it will fail in the long run to do much of the good that the public desires and will do much harm, which the public does not intend.

In order that we may better understand the situation, let us first consider what are the purposes which government regulation ought to seek to accomplish. Let us, then, briefly review the means which it is using to attain these ends and the effects which they are producing; and let us finally consider some of the steps which should be taken to better adapt our system of regulation to the accomplishment of its proper objects.

MAIN PURPOSES OF REGULATION.

The three main purposes of government regulation should be to further the economy, efficiency and safety of railway operation; to cause rates to be reasonable and non-discriminatory; and to make investment in railway securities safe and attractive.

It is generally recognized that regulation should seek to improve railway service and to make rates fair and reasonable. It is not so generally recognized that it should aim to improve railway securities as investments, but there are some very good reasons why it should do this. In the first place, if either railway management or government regulation is such as to make investors in general afraid to buy railway bonds and stocks, the companies will be unable to get enough capital to make their service good and adequate. In the second place, not only is the railway business a very large industry, but it is also one which can be put on such a basis as to make it both feasible and desirable for large numbers of people of small means to invest in it. Now, since this can be done, it becomes a thing that ought to be done. Nothing better promotes the prosperity and welfare of a country than the practice of thrift on the part of its people. The degree to which they will be thrifty is likely to depend largely on the opportunities open to them for the safe and profitable investment of any amounts, however small, which they may save. But the trend of our economic and industrial affairs for some years has been such as to reduce rather than to increase the number of the kinds of openings which formerly existed for the class of small investors. Corporate organizations have been growing in size and number and driving out the small concerns in which the small investor used to put his capital. If new opportunities for the investment of small savings are not opened up the number of people who have no direct ownership of property will continue to increase. This will be a bad thing for the individuals who own no property and a bad thing for the nation. A savings bank account is a good thing; but it is not a satisfactory substitute for the actual ownership of property. The best substitute we can offer for the opportunity to invest in small properties is the opportunity to acquire with reasonable safety small interests in large concerns, such as our railways and industrial corporations. This opportunity can be afforded only by having these concerns both managed and regulated honestly and wisely and in the interest of those who invest in their securities as well as in the interest of those who buy their goods and services or who are employed by them. There is just as much reason, from the standpoint of the general welfare, why our government should seek to make small investments in our industrial and railway corporations profitable and safe as why they should try to make small investments in our farms attractive and safe. We need to secure the widest possible diffusion of the direct ownership of property. The more widely the ownership of property in a country is diffused the more stable will be its institutions and the more certain its prosperity.

METHODS OF REGULATION.

Railways may be regulated either by law-making bodies or by commissions created especially for that purpose. If regulation is to be wise it must be done by bodies having some expert knowledge of railway matters. A commission may have such knowledge, but a legislative body cannot have it. If regulation is to be fair it must be free from political and other influences that will tend to divert it from its proper purposes. A commission may be comparatively free from political influence, but a legislative body cannot be. For these and other reasons the function of regulation should be delegated chiefly to commissions.

A commission whose members are appointed for long terms is less likely to be influenced by political and other influences tending to impair its fairness and efficiency than one whose members are elected for short terms. Therefore, members of commissions should be appointed and their terms of office should be long. Indeed, I am inclined to believe that it would be conducive to their greatest fairness and efficiency if their members, like our federal judges, were appointed for life.

In most important respects, from the standpoint of the public, our railways constitute a single transportation system extending into every part of the country. Regulation should, therefore, be directed toward promoting the interests of the nation as a whole. Local and sectional conditions and needs should be considered both in their management and in their regulation. But clearly, regulation should not be allowed to further the interests of some classes of the people at the expense of the people as a whole, or to promote the interests of some localities and sections at the expense of the country as a whole. Therefore, regulation should be made as consistent and uniform as is practicable, and regulation by communities and states should be subordinated to that of the nation.

Regulation should not be such as to make railways unprofitable, because this would hamper their development and thereby hamper the development and impair the prosperity of the entire nation.

These principles all seem obvious and fundamental. Are they observed as well as they should be?

INCONSISTENCIES OF PRESENT REGULATION.

There is not one of them which is not violated. The nation has created the Interstate Commerce Commission and 45 states have created railroad or public service commissions. Nominally, these are all expert bodies, and theoretically, the legislatures and Congress have delegated to them the function of regulation. In practice the legislatures and Congress at almost every session, without investigation, impose on the railways burdens and requirements affecting operation and rates, the desirability and reasonableness of which ought to be left to be determined by the commissions after investigation. Within the last four years there have been 3,016 bills introduced in the state legislatures for the regulation of operation alone, of which 436 have been passed. The members of many state railroad commissions are elected and, of course, in their election political considerations and not their special fitness for their duties govern. Even when they are appointed they often are selected, not because of their special fitness, but for political reasons. It is inevitable that bodies thus constituted should not be expert and impartial to the degree that they ought to be. The want of impartiality of some of them is illustrated by the facts that seven state commissions appeared as parties against the railways in the five per cent rate case and that sixteen state commissions have appeared as parties against the railways in the cases involving advances in freight and passenger rates in western territory.

Furthermore, state regulation is usually controlled largely by local considerations and directed to the furtherance of the supposed interests of the people of the state at the expense of the interests of the people of the nation.

Finally, almost all of our regulation is directed toward restricting the net earnings of the railways within the narrowest limits that the courts will permit, whereas, as I have already stated, the governments should seek to promote the prosperity of the railways for much the same reasons and to the same extent that they do the prosperity of other lines of business in which the people invest their capital.

As much of the legislation passed is enacted without sufficiently thorough previous investigation, it is necessarily arbitrary and not adapted to promote any of the purposes of sound regulation. As there is almost no co-operation between the various state commissions, or between them and the Interstate Commerce Commission, and almost no co-ordination of their activities, it naturally results that the requirements imposed on the railways are often inconsistent and even conflicting. As the legislation passed, and even the orders sometimes issued by the commissions, often are secured almost entirely at the instance of and under pressure from certain well-organized classes of persons, it is not surprising that their intent and effect often is to promote the interests of these classes at the expense of the railways and the rest of the public.

REGULATION IN FAVOR OF SPECIAL INTERESTS.

For example, under the head of regulations affecting operation, we have in a number of states laws requiring the railways to man their trains with so-called "full crews." These laws purport to have been passed in the interest of public safety. They have been secured by the agitation and pressure of railway labor organizations and their real purpose is to force the railways to employ men they do not need. The railways succeeded in getting a referendum vote of the people on it in Missouri, and after hearing the question fully discussed the people repealed a full-crew law by a vote of more than two to one. They succeeded in getting a full discussion before the people and the legislature in Pennsylvania, and the legislature passed a bill to repeal a full-crew law by a large majority and to delegate to the public service commission the authority to require railways to "employ a sufficient and adequate number of men" on their trains, although the repeal bill was subsequently vetoed by the governor on entirely insufficient grounds. The railways succeeded in Connecticut in getting the excess crew question referred by the legislature to the state public service commission for investigation, and the commission reported that such regulation was not only unnecessary, but contrary to the public interest. The true nature of the so-called "full crew" laws having now become generally understood, attempts are being widely made to get passed bills to limit the length of trains, which would be even more unjustifiable and the effects of which would be more harmful.

Again, a number of states have passed laws requiring the railways to use high power headlights. But when this question was referred to the Wisconsin railroad commission—one of the ablest bodies of its kind in the country—and subjected to thorough investigation, a report adverse to the proposed regulation was made.

The inconsistencies between the regulation of the states themselves and between that of the states and the national government, is illustrated by the fact that while numerous states have adopted legislation regarding train crews or headlights, the federal government has not done so, and that there are wide variations between the provisions of the laws of the states and of the nation regarding the hours of service of railway employees.

DISCRIMINATIONS PRODUCED BY PRESENT REGULATION.

The regulation of rates by the various states and by the federal government originally was intended largely, and in the case of the federal government, mainly, to correct unfair discrimination.

It has produced a good effect by correcting many such discriminations; but it is now producing bad effects by actually creating other and equally unfair discriminations. For example, at a time when the interstate passenger rates of the railways in most parts of the country were 3 cents a mile, numerous states passed laws reducing state rates to 2 cents a mile. In some states railways got these laws set aside as confiscatory. In others, in order to avoid discrimination between state and interstate rates, they reduced the interstate rates also to 2 cents. In the five per cent rate case the Interstate Commerce Commission indicated that it believed that these low passenger rates were not yielding enough revenue to cover the part of railway expenses properly chargeable to passenger service and that the railways should raise them. The railways in eastern territory did raise the interstate passenger fares to 2½ cents a mile and tried to get the state legislatures to increase the state rates. This the legislatures did not do and, in consequence, there has resulted an unjust discrimination between state and interstate travel brought about by the inconsistent policies of the regulating authorities representing the public itself.

There are likewise unfair discriminations in freight rates due to the same causes. In the Shreveport case the Interstate Commerce Commission called attention to the fact that an unfair discrimination had been effected between certain state rates between certain points in Texas and certain interstate rates between Shreveport, La., and the same points in Texas, by the rate-making policy of the Texas railroad commission. Again, in the western freight rate case, it refused to allow certain advances in rates on live stock because certain of the interstate rates involved were already higher than corresponding rates fixed by legislative enactments or by the orders of state commissions. Here, again, were unfair discriminations established by the very policy of regulation entered on to stop unfair discriminations.

If you turn to the field of regulation of the financial management of the railways you find somewhat similar conditions. Practically all of our railway corporations have been chartered by the states which have created them. Some states have been lax in creating and regulating railway corporations. This laxity has left the door wide open for corporations created by these states to go forth into other states and handle their financial affairs in ways perhaps condemned by the public opinion of the country. On the other hand, other states, such as Texas, have imposed such stringent regulations on the financial management of railways within their borders as seriously to hamper their development and even to make them heavy burdens on the parts of the same railway systems in other states.

INCREASED COSTS OF OPERATION AND DECREASED EARNINGS.

The period during which the present system of regulation has been applied dates from about ten years ago. This period has been, as you know, one of steadily and rapidly increasing costs of operation. This has been partly due to our policy of regulation but mainly to the higher standards of service which the public has expected, to increases in taxes and to advances in wages which railway labor has demanded and which boards of arbitration organized under federal law have granted. I do not believe that even as yet the public has anywhere near an adequate knowledge and appreciation of the effect on the railway industry in general which has been produced by these various influences and which must continue to be produced if they continue to be exerted.

The eight or ten years prior to 1906 and 1907 were years of steadily and even rapidly increasing railway net earnings. Those since have been years of just as steadily and rapidly declining net earnings. This is not true of every individual road. There are a number of individual railways which, because of exceptionally good management or unusually fortunate situations, have continued to prosper, and some of them are even more prosperous than they were ten years ago. But these roads are no more typical than are certain roads at the other extreme which, because of bad management or unfortunate situations, have declined into the depths of adversity. It is the situation of the railways as a whole, not that of individual lines, which it is important for us to consider. Taking them as a whole, we find that in the seven years before 1906 their net return on their investment in property substantially increased, whereas in 1913 it was less than it was in 1906, in spite of the fact that they had meantime made many improvements and many economies in operating methods and that they had the largest gross earnings per mile in 1913 that they ever enjoyed. If you compare the trend of their expenses and earnings between the eight years, 1898 and 1906, and between the eight years, 1906 and 1914, in the latter of which there was a decline in total earnings, you will find ample evidence that their condition in the latter period was much less healthy and promising than in the former. Statistics compiled by the Bureau of Railway Economics from reports made by the railways to the Interstate Commerce Commission show that in the eight years before 1906 the density of passenger traffic increased 58.05 per cent, while in the eight years following it increased less than 25.98 per cent. In the former period the density of freight traffic increased 59.01 per cent, while in the latter it increased only 19.8 per cent. There were reductions in both the average passenger and the average freight rates during the later period, and, in consequence, while total earnings per mile increased 54.85 per cent during the earlier period, they increased only 21.1 per cent during the later period.

Let us now turn from the figures regarding traffic and earnings to those regarding expenses. In the eight years before 1906 the average annual wage per railway employe increased only 7.95 per cent, while in the eight years after 1906 it increased 32.57 per cent. In the earlier period taxes per mile increased only 41.77 per cent, while in the later period they increased 69.05 per cent. Operating income is what the railways have left after paying all their expenses and taxes. Because of the differences in the tendencies of earnings and expenses before and after 1906, in the earlier period of eight years average operating income per mile *increased* 53.83 per cent, while in the period between 1906 and 1914 it *decreased* 10.55 per cent; and this in spite of the fact that in the earlier period of eight years the investment in road and equipment per mile of line increased only 3.88 per cent, while in the later period it increased 20 per cent.

The fiscal year ended June 30th, 1914, ended before the war in Europe began, and the results of it were affected only by the business and transportation conditions existing in our own country; and yet the results in it were discouraging. In the fiscal year ended June 30, 1915, the total earnings of the railways were $163,000,000 less than they were in 1914. The net earnings were slightly larger than in 1914, but much smaller than in 1913; and the slight increase in them over 1914 was attained by drastic economies which included sharp reductions in expenditures for both the maintenance of equipment and maintenance of way. It is needless to tell members of the engineering profession that these reductions in maintenance expenses probably in most cases were more nominal than real and resulted from deferring work which was really needed to keep the properties in good condition.

The net return on the investment in road and equipment of our railways in 1898, when they were just beginning to emerge from a period of profound business depression, in which companies with a large mileage had become bankrupt, was 3.64 per cent. This had increased in 1906 to the very moderate figure of 5.39 per cent. Then began the period in which railway outgo was to increase faster than railway income, and in 1914 the net return on property investment had declined to 3.99 per cent. When complete figures are available they probably will show that the percentage of net return in 1915 was still lower. In other words, although the railways are paying higher wages to their labor and larger taxes than they were in 1898, or even in 1906; although they are rendering a larger quantity and a much better quality of service to the public, the percentage of net return on the investment in their properties is now practically down to where it was 17 years ago.

One result is that many railways have become bankrupt. According to the latest available statistics there are now 82 railways in the hands of receivers, having a mileage of 41,988 miles and a capitalization of $2,264,000,000. This is the greatest mileage ever in the hands of receivers in this country. It is a significant fact that the mileage of bankrupt roads is larger in proportion in the southwest, where the policy of regulation has been the most repressive, than in any other section. Furthermore, the construction of new mileage and the improvement of the facilities of that already existing have been seriously curtailed. The new mileage built has shown a downward tendency since 1906 and was smaller in 1914 than in any year since 1895. There have been heavy reductions in the purchases of equipment and supplies; and, in consequence, many thousands of men have been thrown out of work in both the railway and the railway supply businesses and every line of commerce and industry has been adversely affected.

Now, I would not be understood as attributing the unsatisfactory conditions which have been prevailing in the railway industry, and the resulting effects on business in general, entirely to regulation. They have been due to a combination of causes. There would no doubt have been large increases in the operating expenses and taxes of the railways if the policy of regulation had never been begun. The great faults of regulation have been that, first, in many ways it has unwisely and unnecessarily enhanced the increases in expenses, and that, second, it has at the same time prevented most of the increases in rates which these increases in expenses made desirable, and, indeed, in the face of these increases in expenses, has actually compelled many reductions in rates. The average annual wage of railway employees was 43 per cent higher in 1914 than in 1898 and average taxes per mile were 140 per cent greater; yet the average passenger rate and the average freight rate were actually lower after these increases in wages and taxes had occurred than before. Under an entirely intelligent and fair policy of regulation the public authorities would have co-operated with the managements of the railways in their efforts to solve the problems presented by the great and rapid increases in their expenses and taxes. Under the policy actually followed regulation has made their problem more difficult and complicated, with the results just mentioned.

Now it may be said that the railways have brought upon themselves much of the trouble from which they are suffering. I admit that. On the whole, the managements of our railways have been as able, as honest and as efficient as those of any other railways or other large corporate business in the world. But, as I have already conceded, many mistakes have been made and many offenses have been committed by them. It is because of these things that, as railway men now admit, regulation became desirable for the protection and benefit of the public and even of the railways themselves. But is the fact that the managements of the railways have not always been wise and fair any reason for adopting and persisting in a policy of unwise and unfair regulation? Clearly not. Is it not evident that the policy of regulation which has been followed has not established, and is not adapted to establish, satisfactory relations between the railways and the public? Is it not evident that it has not been promoting, and is not adapted to promote, the purposes which regulation ought to promote? It is not making the operation of railways more economical and efficient. It is substituting new forms or unfair discrimination in rates for those which have been abolished. It is preventing rates from being so adjusted as to meet the increasing demands on railway revenues. It is helping to make railway securities unattractive rather than attractive both to the large investor and the small investor, and is forcing the railways to sell bonds to raise capital when they ought to be selling stock and to sell short time notes when they ought to be selling bonds, thereby rendering them financially top-heavy and incapable of weathering the financial storms which are sure to break over us in the future as in the past. In order to establish satisfactory and beneficent relations between the railways and the public, our regulation of railways as well as our management of them, must be put on a sound basis.

REGULATION SHOULD BE IN HANDS OF EXPERTS.

The remedy for the defects in our policy of regulation seems to me obvious. It should not be destroyed, but it should be made less rigid and more flexible, less restrictive and more constructive, less the work of amateurs and more the work of experts. The legislatures should cease passing without investigation arbitrary laws for the regulation of features of the railway business with which their members, from lack of time and want of special knowledge, cannot possibly become competent to deal, and leave the performance of the function of regulation almost entirely to commissions. The commissions should be made in fact as well as in theory impartial bodies of experts. The state commissions should be restricted to the regulation of purely local and state matters and the Interstate Commerce Commission should be expressly authorized and required by law to overrule the state authorities when they adopt regulations the effect of which is to interfere with and burden the commerce of other states and the commerce of the nation as a whole. As I have already said, in all important respects the railways of this country constitute a single system and, therefore, the kind of regulation that should be applied to their operation, their rates and their financial affairs should not be determined by imaginary lines which separate the states from each other, but should be national, consistent and as uniform as the more or less varying conditions in the country as a whole may justify. There may be reasons for applying some different rules in states in which the conditions differ as widely as they do in Massachusetts and Arizona; but there cannot be any good reason for applying widely different and wholly inconsistent requirements in states adjacent to each other, such as Nebraska and Kansas, or Massachusetts and Connecticut; and there certainly cannot be any good reason why a state government should apply one rule in a state and the federal government should apply an entirely different rule in the same state. Both these things are done now. There can be no good reason why a state passenger should be allowed to travel for two cents a mile in a state when the Interstate Commerce Commission has held that 2½ cents is a reasonable rate for interstate travel in that same state, which is what is being done now. There can be no good reason why a state law in Texas, for example, should prescribe certain hours of work for railway employes engaged in state commerce when a federal law prescribes different hours for all railway employes engaged in interstate commerce, which is what is being done now. There can be no good reason why the Interstate Commerce Commission should hold that the earnings of the railways in eastern territory are not as large as they should be in the interest of the public, and that at the same time the states should be allowed to prevent the increases in earnings which the Interstate Commerce Commission holds should be permitted in the interests of the public. Yet this is being done now.

At the same time that state regulation is being improved and brought into a proper relationship of subordination to and co-ordination with federal regulation, there ought to be changes made in the organization of the Interstate Commerce Commission which will better fit it for the performance of its added duties. I personally would favor increasing the salaries of its members and having them appointed for life. Their duties are as important as those of any other officers of the government, and their positions should be made such that they will be attractive to the ablest men in the country and that the incumbents will be immune from political and all other improper influences. When these and other changes have been made which will strengthen the commission and increase its independence, I believe it would be both safe and desirable to increase its powers in several directions. If there is to be regulation of operation this should be done by the Interstate Commerce Commission. If there is to be regulation of the issuance of railway securities, as there already is in some of the states, the necessary authority, with proper restrictions, should be delegated to the Interstate Commerce Commission.

INTERSTATE COMMERCE COMMISSION SHOULD HAVE POWER TO RAISE AS WELL AS LOWER RATES.

At the same time the Commission should be empowered to raise rates which it regards as too low, as well as to reduce rates which it thinks are too high; and this power should apply to state rates when the Commission regards them either as unremunerative or as working an unfair discrimination against interstate commerce. The Commission is now greatly hampered in its regulation of rates by the fact that the law authorizes it to fix maximum rates but gives it no power to fix minimum rates. The law requires it to make rates reasonable, but gives it no power to make them reasonable if the defect in them happens to be that they are unreasonably low. The Commission should be given a clear mandate to make rates reasonable in the sense that they will not only never be excessive to the shipper or traveler, but will always also be fairly remunerative to the railway.

Our policy of regulation has thus far been one-sided. It has been tacitly predicated upon the assumption that its sole purpose should be to protect the rights and promote the interests of those who use the service of railways and who work for them. It has too often ignored the fact that those who invest in railway securities are also a class of our citizens possessing exactly an equal claim to have their rights protected and their interests promoted by the government. What is even more serious and important, those who have been responsible for our policy of regulation too often have not recognized the fact that the interests of the patrons of the railways and their employes will suffer if the rights and interests of the investors in them are not protected and promoted. It is only by the investment of adequate additional capital in railways that their facilities may be sufficiently improved and expanded. Furthermore, it is only by the investment of additional capital in the railways that there will be created an increased demand for labor on them; and the increase in the employment they afford will be in proportion to the increase in the investment in them. Therefore the only policy of regulation of railways which will confer the maximum benefits practicable on each class that is directly interested and on the public as a whole will be one which will equally consider the rights and interests of the traveler, the shipper, the employe and the investor.

In conclusion, if I have succeeded in lodging in the minds of any of you gentlemen any particular point regarding the relations of the railways and the public that will induce you to use your influence for improvements in these relations, I am well repaid for presenting this matter to you as I have.

DISCUSSION.

Willard A. Smith, M. W. S. E.: I am glad that Mr. Johnson has brought before you a subject which is not technically engineering, but in which engineers like all other intelligent citizens should be interested and informed. One phase of it he has not touched upon and it is important. The states nearly all have their own laws for regulating railways and the advocates of state rights claim that the individual state has full right and power to regulate all railway rates within its borders. The conflict between state and national legislation now makes a very complicated situation, as Mr. Johnson has shown. This, of course, is annoying and expensive to the railways and burdensome to the public. There should be only one regulating power, at least as far as rates are concerned. When the Union was planned and the Constitution was being formed, the varying laws of the different states had greatly hampered commercial intercourse. Railways did not exist and were not even dreamed of. But the wisdom of the fathers made the Constitution broad enough to cover all possible developments. They gave to the Federal Government the "power to regulate commerce between the states." This is exceedingly broad; but it was only at a comparatively recent date that Congress exercised this power by enacting the interstate commerce law, and establishing the Interstate Commerce Commission. In exercising the powers thus conferred, the Commission finds that it is greatly hampered by the regulation of intrastate rates by the various state commissions. Congress should and must extend the power of the Interstate Commerce Commission over all rates of all roads engaged in interstate commerce, whether those rates are interstate or intrastate. The Supreme Court of the United States will undoubtedly sustain such a law as constitutional, notwithstanding the protests of state right advocates. The power of Congress to regulate cannot be limited, or in any way interfered with by state legislation; it must be supreme. The Supreme Court has upheld this in a decision on the Safety Appliance law, which now applies to all equipment of roads engaged in interstate commerce, even though it may be used and kept in one state only. In the Minnesota rate case, the Supreme Court held that Congress had reserve power over rates which it had not yet exercised. No constitutional amendment is needed and Congress should be urged to extend the powers of the Interstate Commerce Commission so as to end this conflict. You like all other intelligent citizens, can do much to create sentiment which will lead to such legislation.

Lyman E. Cooley, M. W. S. E.: This paper is an admirable discussion of the principles underlying the relations of railway utilities to the general public. There is a gratifying disposition on the part of utility managers to take the public into their confidence and in this they are right, because I am satisfied that the people wish to be just, and it has been my experience, both at Springfield and in Washington, that legislators wish to be well informed in order that they may also be just. It is gratifying also that the engineering societies are recognized as the proper forum in which to present and discuss these issues, for such bodies bring together the men who can best interpret the economic bearing on matters which are technical in their essence, and I am glad to note in the forty years since I became a member of this society a growing realization by the engineer of his duties to the public and as a citizen.

Mr. Johnson has laid down three primary propositions but it seems to me that the most important and fundamental is the question of what constitutes a proper investment value in a public utility. This is a subject about which courts and legislatures are hazy, and financiers have failed to give us a clear definition. We are approaching it through the method of appraisement of physical values. I am impressed with the idea that, when this is determined, we will be in a position to also determine what constitutes the proper earnings, considering the risk of the business, and can then base thereon a rational schedule of rates. These determinations involve both technical and economic questions and some elements of public policy, but until we have resolved them, there will be many differences of opinion and much beating of the air.

This is the principal thought which Mr. Johnson's paper has suggested to me. The public utility relation must reach a sound economic basis in the early future if we are to avoid arrested development. The question is before you, and I have arrived at a stage where I prefer to hear what other students think about it.

E. H. Lee, M. W. S. E.: One particular point among many especially appeals to me, that is to say, the effect of leadership in the creation of public sentiment. A proper public sentiment is vital to the right handling of any great public question, and next to national defense the railroad question is doubtless more intimately connected with the public welfare and prosperity of this country than any other. The railroads of the country form one of its most important industries. They touch every man's business and pocketbook, whether he is a professional man or a laborer, whether he works with his hands or with his head. One of our prominent Chicago men and an Ex-Secretary of War, in a recent address on the subject of national defense, concluded by pointing out that this question, of paramount importance to the country, was one in which every man should be interested, and to which every man should give proper time and attention, and he asked the question of his hearers, "What are you men going to do personally and individually in assisting to create a proper public sentiment regarding this great question?"

The same question relating to the railroad situation may be asked of those present here tonight. Engineering work is influenced more quickly and profoundly by fluctuations in the prosperity of the country than almost any other professional work. A fair and reasonable share of prosperity for the railroads lies at the root of prosperity for the country generally. As engineers, what are we going to do about it? In the past, engineers have been too much inclined to become absorbed in the activities of their own little corner, to the exclusion of some of the larger questions which vitally affect them. It certainly should be our part as engineers to give this question sufficient thought to permit the forming of a definite opinion, and to then come out of our shells and advocate our opinions among friends and neighbors.

George H. Bremner, M. W. S. E.: I have made no preparation for a discussion of this question. Mr. Johnson's paper is one of great interest and the conclusions he has reached from his studies follow closely those which I have arrived at concerning the various aspects of the railroad question.

The various men connected with the Interstate Commerce Commission are all seeking light and desire to arrive at an honest, fair and just decision in every question arising concerning the regulation of railways.

The original Interstate Commerce laws were passed to promote competition between the railroads and eliminate rebates. Competition instead of being promoted has been reduced by the operation of the national and state laws, so that now it becomes necessary to provide some substitute for competition, for raising and lowering of rates and for allowing an equitable distribution of traffic among the railroads.

The Valuation Department of the Interstate Commerce Commission is trying to make a fair and equitable valuation of all railroads, which, when finished, should form a stable foundation for consideration of all matters pertaining to railroads.

This paper which Mr. Johnson has read tonight is convincing evidence that when the thinking men of the railroads, of the shippers, of the state and national governing bodies have fully considered all the different features of the relation of the railroads and the public, they will reach approximately the same general conclusion.

John F. Hayford, M. W. S. E.: I would like to add as much emphasis as I can to the idea that it is important that engineers should perform their part in helping to guide public opinion in this matter. Engineers have the proper training and the proper knowledge of the facts to make their guidance valuable. Engineers are losing an opportunity for service when they do not inform the public in this matter.

The Interstate Commerce Commission handed down an opinion about four years ago, in a case in which the railroads asked for a horizontal increase in freight rates.* While Mr. Johnson was giving his address, I was running a mental parallel with that opinion. If you put his statement and that opinion together, I think you will find that the railroads and the Interstate Commerce Commission are now headed in the same direction. There is agreement in so many ways, between the opinion referred to and Mr. Johnson's address, as to what considerations should be taken into account in order to reach just conclusions, and as to what should be done, that one must be optimistic in thinking that just conclusions will be reached and just readjustments made.

W. E. Symons, M. W. S. E.: In speaking on this subject, I feel somewhat like the old darkey who, after listening to several speakers at a religious gathering, was called upon to address the meeting, and said he thought the plan of salvation had been pretty well exhausted, by those who had already spoken, and that about all there was left for him to do in that direction was to say Amen and call for the Benediction.

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*See Engineering News, March 2, 1911, pp. 274-276, and March 9, 1911, pp. 293-296.

The author of the paper of the evening has treated this matter in such a thorough and exhaustive manner that there is little room left to add anything to the features brought out in the paper. Other speakers have also amplified the author's remarks, so that I find little opportunity to add anything except possibly some thoughts which may have occurred to me with respect to the subject in general.

The Western Society is very fortunate in having been favored by Mr. Johnson's presence here this evening and the points brought out in his very able paper should be given the widest of publicity among all classes of citizens, and particularly among those who either hold or aspire to public office.

As the author has well said, the carriers are not or have not, in the past, been entirely free from fault in matters resulting in controversies between public officials and railroad officers. Doubtless many mistakes were made by them, but it should be borne in mind that, while admitting the carriers were at fault, that the number of mistakes made by them was very small compared to similar errors in other lines of business or human activity. In other words, railroad officers should not all be condemned because an occasional one has made a mistake. We would not listen to the abolishment of all our banks because an occasional banker went astray. The custom is to punish the individual banker, but not to persecute bankers as a class. The same is true with respect to religious matters. An occasional minister goes astray, and he should pay the penalty for wrongdoing. We do not condemn the entire plan of salvation and proceed to put all our churches under suspicion because an occasional gentleman of the cloth makes a mistake.

For many years, however, it has been almost common practice for those seeking political preferment to be loud in their condemnation of corporate interests with particular reference to railways. This seems to have been a most inviting road to political preferment, and as the result of this, the public mind has been systematically and thoroughly poisoned to a degree that most of the legislatures and other law-making or regulatory bodies who have to do with public utilities, seem to enter upon their duties with a feeling that they must attack the railways, and this has resulted in the oppressive burdens outlined in the author's paper this evening.

I am very glad indeed that the author has mentioned the result of the referendum vote of the state of Missouri, with respect to the "Full Crew Bill," and on this particular point I would like to add a few remarks.

A few weeks after the election in Missouri, at which the "Full Crew" Law was repealed, I was employed as an expert witness in that state for the railways interested in the rate case, at that time pending before the Public Utilities Commission. I was introduced and offered as an expert witness for all carriers interested in the hearing. To appear in court as an expert witness for corporate interests, particularly for railway companies, usually serves as a signal to the opposition to concentrate their forces on the enemy. In other words, they assume battle formation and get their heavy artillery in line and the range finder of the 42-centimeter guns are expected to get the range. In appearing in this case which was of vital importance, I fully expected a rather strenuous siege on cross-examination. The direct examination was of the usual order following which, much to my surprise, the cross-examination was very much like a continuation of the direct examination. Three out of fivè members of the Commission cross-examined in turn, but there was not a question asked or an attitude assumed by any member of the Commission or its Chairman, that in any manner implied a doubt as to my honesty or sincerity, or the correctness of my conclusions, either with respect to cause or effect in the matter of the respective uses of the rolling stock and motive power of railways as subdivided by lines and terminal use and expressed in percentages.

A question would naturally arise, why were they so courteous and considerate in their dealings with an expert witness for the carriers. I am free to disclaim any credit for this myself. It was not because I was any better witness than others who had appeared before them; I might not have been as capable as some; it was almost entirely, if not wholly, due to the effect of the referendum vote on the "Full Crew Bill." This bill was passed against the opposition of the carriers who opposed it in every way they could under the circumstances. The Governor and members of both houses said they passed the "Full Crew Bill" in obedience to the expressed wish of their constituency. To this the carriers demurred, and said, we take issue with you and accept your guage of battle, to your constituency we will go, and the result was about 150,000 in favor of the "Full Crew" law and about 380,000 against it.

"Pork barrel" politics received a justly merited rebuke at the bar of public opinion, which is the court of last resort, and is about the only clean method by which the average politician can be reached.

The attitude of the Commission immediately following the verdict of the people in favor of fair treatment of corporate interests was, in my opinion, due largely to the salutary effect of a changed public sentiment.

I think the message Mr. Johnson brings to us this evening should be thoroughly disseminated, not only among the engineering profession, but in all other lines of human activity and domestic intercourse, to the end that it will be impressed on the mind of every public servant that unless they can show a clean slate in the matter of fair dealing with corporate interests, particularly public utilities, that the public will arise in its wrath, and through their right of suffrage, relegate all politicians of the "pork barrel" variety to permanent obscurity.

Another point, although apparently a slight digression from the subject matter, yet it has to do with the author, our guest of the evening. Mr. Johnson needs no endorsement from this or any similar body, the results of his wise and able management of a great railway property has established for him a leading place among captains of the transportation industry; owing to his characteristic modesty he has said little or nothing to us of the property in his charge, and it is on this point I wish to add a few words.

In all lines of business endeavor we are accustomed to judge the management by results obtained, having due consideration for the facilities provided, standard of physical condition and efficiency maintained, credit established, etc., and by any one or all of these, the Norfolk & Western will not suffer in comparison with other properties.

In some expert work, I recently had occasion to make up a tabulated statement of investment in material and supplies, and cash on hand, and the relation these bear to certain other items.

Ten (10) trunk lines were selected with a capitalization of over $8,000,000,000 (eight billion dollars), or about 54 per cent, and a mileage of about 83,000 miles, or about 34 per cent of the mileage in this country. The geographical distribution being fairly representative of different conditions, one trunk line, each in Canada and Mexico being included. An average of the items in question on these lines, with a comparasion of Norfolk & Western's figures is as follows:

Item	Average of ten (10) trunk lines	Norfolk and Western	N. & W. percent over other lines
Ratio Material and Supply investment to total assets............	01.73%	01.54%	10%
Ratio Material and Supply investment to operating expenses....	17.76%	14.33%	19.37%
Amount Material & Supply investment to each unit, all cars and engines	$169.00	$85.00	50%
Ratio Material & Supply investment to value each unit all cars and engines	11.63%	7.22%	37.91%
Average Operating Ratio	69.02%	67.32%	2.59%
Ratio of cash on hand to total operating expenses	21.33%	26.7%	23.10%

For the Norfolk & Western Railway the foregoing comparisons indicate clearly:

(a) That is is economically operated.

(b) That amount of capital invested in material and supplies is conservative.

(c) That the amount of capital invested in material is sufficient to meet any ordinary emergency, thus insuring good credit.

(d) That the operating ratio for a mountainous line is low, thus reflecting a high standard of physical condition of the property and a splendid organization.

In addition to the foregoing, I also find in looking over annual reports, that during the past 18 or 19 years, almost one hundred and forty million dollars ($140,000,000) of earnings has been put back into the property which is equal to that much new money being provided from capital account. Certainly such a record as this is a high tribute to the author's ability as a railway executive, and a certificate of authority on the questions treated upon in his message to us tonight.

Elmer T. Howson, M. W. S. E.: I think everyone present has been fully impressed with the importance of the subject of the regulation of railways as presented by Mr. Johnson. There is only one alternative to regulation and that is government ownership. It is not necessary for us to go to Europe to see the failure of government ownership. We need only go a short distance north into Canada to observe its results. Government ownership has been tried there and has proved a failure when compared with the results secured in the United States, as can be demonstrated by a study of the operating results on the Intercolonial Railroad and more recently by the construction of the National Trans-continental Railroad by government forces. Even before it was placed in operation, this latter road was the subject of an extended investigation because of the excessive sums spent for it, far exceeding the original estimates.

The only alternative to government ownership is regulation and the sooner we come to a fair and equitable policy of regulation which will insure to the public the rights to which they are entitled, while at the same time leaving to the railroads their fullest opportunity for development, the quicker will this problem cease to be a pressing one.

There is a third party to this controversy who is vitally interested in the relations between the public and the railways. I refer to the investor. The number of people composing this class is increasing, which fact is a very hopeful indication of the successful solution of the problem, for when a man is financially interested in a property, he becomes more vitally concerned with its affairs.

I think the Western Society of Engineers is fortunate in that this paper has been presented by a man connected with a railroad which has been operated successfully for many years. The speaker, therefore, does not take a pessimistic view because the road with which he is connected has not been able to weather the numerous attacks of recent years, but he speaks from the point of view of one of the most favored railroads in the country. His message, therefore, has all the more significance when he sees the dangers confronting our railways. If from his position, the present chaotic status of regulation appears serious, it must necessarily be far more so for those roads not so fortunately placed.

O. P. Chamberlain, M. W. S. E.: Mr. Johnson has so thoroughly covered his topic of the relations of the railroads to the public, and it has already been so ably discussed by the previous speakers, that there is little that I can add of interest Mr. Smith's plan of having the entire supervision of all railroad lines under the Government or Interstate Commerce Commission and his argument that this can legally be done on the ground that while certain freight movements may be intrastate, the lines themselves are directly or indirectly engaged in interstate traffic, would seem to one not versed in corporation law to be perfectly feasible. It is for the interest of the public as well as of the railroads that this plan be ultimately adopted. The trend of sentiment among railroad men is in this direction, and if no legal obstacles are found to such a method of handling the supervision of our railroads, it will undoubtedly be adopted in the not distant future.

Undoubtedly many shippers, patrons of our railroads, have suffered from the defect in the law noted by Mr. Johnson, viz:—that while it requires the Commission to reduce rates which it regards as too high, it gives the Commission no power to raise rates which are in its judgment too low. An unfairly low and unremunerative rate enjoyed by a competitor is just as unfairly discriminatory against a shipper as though he himself was charged an excessively high rate. Our laws seem to have overlooked this fact and consequently at the present time it is impracticable if not impossible to induce either a state commission or the Interstate Commerce Commission to raise a single rate bringing it to a level with competitive rates on other roads. Some one at some time must take this matter in hand and revise our laws so that discriminations of this character shall be done away with.

Samuel O. Dunn: There are three features of the present policy of regulation of railways to which I wish briefly to refer.

First: From the standpoint of the public as well as of the railways, there is too much duplication and conflict between the functions and activities of the state and Federal authorities. The fundamental principle of our constitutional system is that matters which are of local concern shall be dealt with by the states, while those which are of national concern shall be dealt with by the nation. When railways were local concerns engaged almost exclusively in handling business within the individual states it would have been proper and desirable for them to have been regulated by the governments of the states. The way in which they were regulated then would have affected only the people of the particular states which regulated them. But most railways long since outgrew state boundaries and any railway whose lines are now confined to a single state is usually engaged in connection with other roads in handling much more interstate than state traffic. Therefore, under present conditions no state can regulate the railways independently of the Federal Government without affecting not only interstate commerce but even the intrastate commerce of other states. The ability of a railroad to handle the intrastate commerce of Illinois may depend largely on how the intrastate rates of the same road are regulated in Indiana.

Under these conditions it is not only desirable from an economic standpoint, but in entire harmony with the principles of our constitutional form of government, for all regulation of railways to be delegated to some body or bodies representing the Federal Government, or at least placed under the control of Federal authorities. This would not deprive the states of the opportunity to deal with their local affairs. They would still, for example, have the right and duty of regulating all the numerous public utilities doing a local business, such as electric light and power plants, gas plants, street railways, interurban railways, etc. The present system of having the railways regulated by the state and Federal authorities largely independently of each other needlessly increases the costs of both regulation and railway operation, causes discriminations in the rates, especially as between state and interstate traffic, and is a practically insuperable obstacle to intelligent and salutary control of the issuance of railway securities. I am in favor of Federal regulation of the issuance of railway securities, but unless Federal regulation is to be made exclusive it would be far better to leave the exercise of this kind of authority entirely in the hands of the states. State regulation is in many cases bad enough, but exclusive state regulation of the issuance of securities would be better than regulation of their issuance by both the state and Federal governments.

Second: Thomas A. Edison recently made the wise remark that the time has come for us to begin to try to make democracy efficient. One of the worst faults of our present regulation is the inexpertness and consequent inefficiency of most of the regulating authorities. It has been extremely exceptional for any member of a state commission, or even of the Interstate Commerce Commission, to be appointed solely or even chiefly because of his special equipment for the performance of his duties. Most of the appointees have known no more about the railway business than the average citizen. In what other business except that of government would men be intrusted with such important duties and responsibilities without any special training or experience and without having demonstrated their special fitness? Suppose that the railways made a practice of selecting their superintendents, traffic managers, general managers and presidents from among the farmers, merchants, lawyers and politicians of the country. Do you think that they would then be efficiently operated and well managed? And yet you had just as well expect the railways to be well managed by men without experience in railway affairs as to expect them to be well regulated by men without experience in railway affairs. There could be no better place to begin the experiment of making democracy efficient than in connection with the regulation of the railways, and we will never make the regulation of railroads efficient until we stop proceeding on the assumption that men chosen at random, absolutely regardless of their fitness, will make good railway commissioners. I know of one case where a man was elected a railway commissioner for no reason whatever except that as a railway brakeman he had lost a leg in an accident. That may be democracy, but it is not the way to make a democracy efficient. There is no more distressing record of inefficiency and stupidity than the record thus far made, especially in many of our states, in the regulation of railroads, and this is mainly due to our failure to recognize the fact that in order to regulate railroads a man ought to know something about railroads.

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Third: All of our regulatory laws have been framed with the object of preventing railroads from earning too much money. It has almost escaped the attention of the lawmakers that public harm may result from having railways earn too little as well as from having them earn too much. There is a notion prevalent that in spite of all the unfair regulation the roads have been subjected to most of them are still making large profits. Within recent months their net earnings have heavily increased owing to a sudden expansion of business. But, as Mr. Johnson has pointed out, for nine years the tendency of railway net earnings has been downward. On October 1st, there were more miles of railway in the hands of receivers than ever before in the history of the country. In the year 1915 there probably has been less activity in the construction of new railways than in any year for fifty years. These railways would not have become bankrupt at this particular time if they and other roads had been earning large profits. The construction of new lines would not have practically ceased if the possibility of making money by building new lines had not been practically abolished. The all too exclusive devotion of regulation to the cause of preventing railways from earning too much is the main explanation of these conditions. Let us not be deceived if there is a general revival of business and if railway net earnings as a result show large increases. The one-sided policy of regulation which has been followed in recent years will, if persisted in, produce the same effects in future that it has produced up to the present time.

E. N. Lake, M. W. S. E.: Along the lines suggested by the remarks of the preceding speakers, I might add that not very long ago I heard a senior senator from the State of Illinois make an earnest public appeal for some arrangement by which technical advice would be available promptly to legislators, who are frequently asked to consider and pass upon legislation involving a wide range of technical subjects. This appeal is reasonable, and is to my mind a very hopeful sign.

Tonight we have heard from railroad sources a similar plea for more light upon technical matters. Certainly, if the legislators, the railroads and the public are agreed, we may hope for early results along these lines.

Another point the speaker referred to is the safety of railroad securities. There is at least one European country in which railroad securities are so nearly staple articles that one can buy them at a window in the large railway terminals, with about the same ease that you would purchase your railroad ticket. These securities may be had in denominations of as small value as $20.00. This indicates a degree of public confidence that we may well look forward to in this country.

INVESTIGATION OF THE INTERNATIONAL JOINT COMMISSION UPON THE POLLUTION OF BOUNDARY WATERS

Earle B. Phelps.*

Presented Sept. 27, 1915.

The Treaty of 1909 between the United States and Great Britain provides for the reference of certain questions arising between the United States and Canada concerning the International Boundary to a joint commission to be known as the International Joint Commission. This Commission as constituted is essentially judicial in character since it establishes facts by ordinary judicial procedure. It is also quasi-executive to the extent that it may undertake its own investigations and thereby obtain information upon which to base its recommendations to the two Governments. The present membership of the Commission comprises the Hon. Charles A. Magrath, Chairman of the Canadian Section, Hon. Henry A. Powell, Hon. P. B. Mignault, Hon. Obadiah Gardner, Chairman of the American Section, Hon. James A. Tawney, and Hon. R. B. Glenn.

Under date of August 1, 1912 the two Governments referred to the Commission "for examination and report upon the facts and circumstances of the particular questions and matters referred, together with such conclusions and recommendations as may be appropriate," the following questions:

1. To what extent and by what causes and in what localities have the boundary waters between the United States and Canada been polluted so as to be injurious to the public health and unfit for domestic use or other uses?

2. In what way or manner, whether by the construction and operation of suitable drainage canals or plants at convenient points or otherwise, is it possible and advisable to remedy or prevent the pollution of these waters, and by what means or arrangement can the proper construction or operation of remedial or preventive works, or a system or method of rendering these waters sanitary and suitable for domestic and other uses, be best secured and maintained in order to insure the adequate protection and development of all interests involved on both sides of the boundary, and to fulfill the obligations undertaken in Article IV of the waterways treaty of January 11, 1909, between the United States and Great Britain, in which it is agreed that the waters therein defined as boundary waters and waters flowing across the boundary shall not be polluted on either side to the injury of health or property on the other?

Immediately thereafter these questions were taken up for consideration by the Commission and Surgeon Allan J. McLaughlin, U. S. Public Health Service and Dr. T. A. Starkey of McGill Uni-

*United States Public Health Service, Consulting Sanitary Engineer.

versity, were requested to prepare a detailed plan for the conduct of the necessary investigations including the organization of field laboratories and methods to be followed. A question as to the intended scope of the inquiry having arisen and having been referred by the Commission to the two Governments, the terms of the inquiry were later modified and restricted by agreement between the Governments "to cases of pollution of boundary waters on one side of the boundary which extend to and affect the boundary waters on the other side." As thus restricted the investigation has not concerned itself with those cases of pollution arising in the broader lake waters which do not materially affect the waters upon the other side of the boundary line, but is practically limited to pollution of boundary rivers and the immediate effect of the discharge of polluted river water into the lakes.

A preliminary special session of the Commission was held at Washington, November 21, 1912, for the consideration of methods to be pursued in the investigation and a conference was held at Buffalo during the following month to which were invited the various public health and other officials of the two Federal Governments and various Provinces and States directly interested. At this conference it was decided that the investigation of international boundary waters should be confined to the following waters: The Rainy River, St. Marys River, St. Clair Lake and River, Detroit River, Niagara River and St. Lawrence River, together with certain special investigations of the waters in the vicinity of Port Arthur, Fort William and Duluth on Lake Superior; Saginaw Bay, on Lake Huron; in the vicinity of Sarnia and Port Huron; Port Stanley, Cleveland and the bay at the western end of Lake Erie; Rochester, Toronto and the eastern and western ends of Lake Ontario.

Dr. McLaughlin was employed by the Commission as Chief Sanitary Expert and Director of Field Work and Drs. J. W. S. McCullough, Chief Health Officer of the Province of Ontario and John Amyot, Professor of Hygiene, University of Toronto and Mr. F. A. Dallyn, Sanitary Engineer, Provincial Board of Health of Toronto were associated with Dr. McLaughlin in the prosecution of the work. Sixteen field laboratories were equipped for bacteriological investigations with the assistance of the Provincial Board of Health of Toronto, the U. S. Public Health Service, the Michigan State Board of Health and the New York State Department of Health. The U. S. Revenue Cutter Morrow was also equipped and utilized for this purpose and the laboratory of the Provincial Board of Health of Quebec at Montreal served as a field station for the St. Lawrence River.

During the summer of 1913, samples to the number of 17,784 were collected from 1,444 sampling points and were examined bacteriologically. The scope of the examination was designed to furnish the maximum information with a minimum of expenditure of effort and included the determination of total bacteria on agar at 20 deg. and 37 deg. C. and the quantitative estimation of B. *coli* by the lactose bile method, using a series of dilutions. The results of these examinations were tabulated and averaged by localities and seasons and were also shown in detail upon a series of 33 maps and 2 charts prepared by Mr. Dallyn. This information was reported in detail and submitted with a report of the Commission dated January 16, 1914, entitled, "Progress Report of the International Joint Commission on the Reference by the United States and Canada in re Pollution of Boundary Waters." It was shown that the majority of the waters of the Great Lakes are totally or essentially free from any evidence of pollution. In certain localities, however, on the lakes themselves and in all the connecting-water-ways dangerous sewage pollution was found. The major proportion of this pollution is directly traceable to the discharge of sewage from the cities and a series of 18 maps showing the sewer layouts of the more important communities along the boundary rivers indicates the general practice of these communities to dispose of their sewage by direct discharge into these boundary waters. The pollution of the waters by vessels was also investigated and attention was directed to the obvious pollution in certain portions of the lakes themselves, especially along the lanes of steamboat travel, which could only be attributed to this source.

Pending this investigation the Commission held hearings at various points along the International Boundary for the purpose of establishing certain facts and determining the state of public sentiment and other matters.

The entire cost of this branch of the investigation was somewhat over $42,000. and was borne equally by the two Governments. A summary of the conclusions of the first branch of the investigation is found upon page 13 of the Progress Report and shows that: "avoidable pollution exists in contravention of the treaty" in the Rainy, St. Clair, St. Marys, Detroit, Niagara, St. Lawrence and St. John Rivers, in Lake St. Clair, the western end of Lake Erie and the eastern end of Lake Ontario.

Investigation of public water supplies and typhoid fever statistics led to the conclusion: "That there is not a municipality using lake water that can be said to possess a safe water supply without treatment." In some cases the pollution was believed to be of such a character that it would not impose an unreasonable burden on water purification works of modern type, but in many localities the pollution was found to be sufficiently serious as to impose such an unreasonable burden. The first branch of the reference, therefore, namely, "to what extent and by what causes and in what localities have the boundary waters between the United States and Canada been polluted so as to be injurious to the public health and unfit for domestic and other uses," was answered in a most comprehensive, definite and satisfactory manner in the First Progress Report of the Commission dealing with this subject.

There remained for the consideration of the Commission the second branch of the reference dealing with: "Possible and advisable remedies for the prevention of this pollution." At a conference held at New York City, May 26th and 27th, 1914, there appeared by invitation of the Commission the following named sanitary engineers who answered and discussed with the Commission a set of formal questions which had been previously prepared for their guidance: Messrs. George W. Fuller, Earle B. Phelps, George C. Whipple, W. S. Lea, T. J. Lafreniere and F. A. Dallyn. The opinion of these gentlemen was sought especially upon the following points:

The extent of inevitable natural pollution of surface waters draining a populous area and the suitability of such naturally polluted waters as sources of public water supply with and without purification.

The suitability for domestic water supply after purification of such bodies of water receiving in addition the direct sewage and drainage of cities and towns.

The determination of a definite limit of safe loading of a water purification plant expressed in terms of sewage pollution beyond which an undue burden and responsibility would be placed upon such plant.

The propriety of utilizing natural water courses for the disposal of sewage and waste and the extent to which such use is economically justified.

The extent and character of sewage purification necessary and advisable for the protection of the International Boundary waters.

The effect of pollution from steamboats and the advisability of its limitation or control.

The Progress Report of the Commission was available at this conference and furnished the basis for the discussion. The opinions of the Consulting Sanitary Engineers were later summarized in the following resume:

1. Speaking generally, water supplies taken from streams and lakes which receive the drainage of agricultural and grazing lands, rural communities, and unsewered towns, are unsafe for use without purification, but are safe for use if purified.

2. Water supplies taken from streams and lakes into which the sewage of cities and towns is directly discharged are only safe for use after most careful purification and provided that the load upon the purifying mechanism is not too great and that a sufficient factor of safety is maintained, and, further, provided that the plant is properly operated.

3. As, in general, the boundary waters in their natural state are relatively clear and contain but little organic matter, the best index of pollution now available for public-health purposes of ascertaining whether a water purification plant is overloaded is the number of *B. coli* per 100 cubic centimeters of water expressed as an annual average and determined from a considerable number of confirmatory tests regularly made throughout that period.

4. While present information does not permit a definite limit of safe loading of a water-purification plant to be established, it is our

judgment that this limit is exceeded if the annual average number of *B. coli* in the water delivered to the plant is higher than about 500 per 100 cubic centimeters, or if in 0.1 cubic centimeter samples of the water *B. coli* is found 50 per cent of the time. With such a limit the number of *B. coli* would be less than the figure given during a part of the year and would be exceeded during some periods.

5. In waterways where some pollution is inevitable and where the ratio of the volume of water to the volume of sewage is so large that no local nuisance can result, it is our judgment that the method of sewage disposal by dilution represents a natural resource and that the utilization of this resource is justifiable for economic reasons, provided that an unreasonable burden or responsibility is not placed upon any water-purification plant and that no menace to the public health is occasioned thereby.

6. While realizing that in certain cases the discharge of crude sewage into the boundary waters may be without danger, it is our judgment that effective sanitary administration requires the adoption of the general policy that no untreated sewage from cities or towns shall be discharged into the boundary waters.

7. The nature of the sewage treatment required should vary according to the local conditions, each community being permitted to take advantage of its situation with respect to local conditions and its remoteness from other communities, with the intent that the cost of sewage treatment may be kept reasonably low.

8. In general, the simplest allowable method of sewage treatment, such as would be suitable for small communities remote from other communities, should be the removal of the larger suspended solids by screening through a one-fourth inch mesh or by sedimentation.

9. In general, no more elaborate method of sewage treatment should be required than the removal of the suspended solids by fine screening or by sedimentation, or both, followed by chemical disinfection or sterilization of the clarified sewage. Except in the case of some of the smaller streams on the boundary, it is our judgment that such oxidizing processes as intermittent sand filtration, and treatment by sprinkling filters, contact beds, and the like, are unnecessary, inasmuch as ample dilution in the lakes and large streams will provide sufficient oxygen for the ultimate destruction of the organic matter.

10. Disinfection or sterilization of the sewage of a community should be required wherever there is danger of the boundary waters being so polluted that the load on any water-purification plant becomes greater than the limit above mentioned.

11. It is our opinion that, in general, protection of public water supplies is more economically secured by water purification at the intake than by sewage purification at the sewer outlet, but that under some conditions both water purification and sewage treatment may be necessary.

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12. The bacteriological tests which have been made in large numbers under the direction of the International Joint Commission indicate that in most places the pollution of the boundary waters is such as to be a general menace to the public health should the waters be used without purification as sources of public water supply or should they be used for drinking purposes by people traveling in boats.

13. It is our judgment that the drinking water used on vessels traversing boundary waters should not be taken indiscriminately by travelers unless subjected to adequate purification.

14. While recognizing that the direct discharge of fecal matter from boats into boundary waters may often be without danger, yet in the interest of effective sanitary administration it is our judgment that the indiscriminate discharge of unsterilized fecal matter into boundary waters should not be permitted.

During September and October, 1914, the Commission held public hearings at all the more important centers upon the Niagara and Detroit Rivers to which were invited the various State and City officials interested. Copies of the Progress Report and recommendations of the Consulting Engineers had previously been furnished to these officials. During the course of these hearings it became evident that the interested communities were, for the most part, ready and willing to participate in a general program looking toward the correction of existing conditions. It became apparent also that the problem, especially in the larger centers of population, was one requiring serious study and that the cities were not at that time in possession of the necessary information upon which to base an opinion as to the feasibility or extent of remedial measures. The present writer was, therefore, invited by the Commission to prepare a detailed plan for the gathering of this information by the Commission preparatory to the recommendation of a general remedial policy. The plan which was presented was accepted by the Commission and the writer placed in charge of the work as Consulting Engineer and given authority to organize field offices and prosecute the investigation. In view of the special importance of the St. Clair, Detroit and Niagara Rivers and the desirability of arriving at definite conclusions in as brief a time as possible it was decided to confine the investigation to these particular rivers. It is obvious that any solution which may be found advisable and feasible at these points will, as a matter of general policy, be applicable to all the boundary waters in question.

District offices were therefore established at Detroit and at Buffalo and placed in charge of Mr. Henry C. McRae and Mr. Frank C. Tolles, respectively, with a designation of District Engineer. The personnel of each office includes, in addition, an Assistant Engineer, two draughtsmen and a clerk. At each of these offices comprehensive studies are being made of the existing sewerage system of main drainage systems and of disposal. The Detroit office is investigating all the communities on both sides of the St. Clair and

Detroit Rivers and the Buffalo office those upon the Niagara River. This work was inaugurated and has been continued throughout with the most intimate and hearty coöperation on the part of the cities and towns interested. Assuming at the outset the willingness of these communities to undertake that which is economically advantageous and desirable, it was believed that only through the development of such a policy of coöperation could results of value be obtained. Especially in the case of the larger cities was it essential that the studies and final recommendations should harmonize with the general policy and drainage plans for future development. The opinion of the Consulting Engineers has in general been adopted as the guiding principle in this investigation, but will of necessity be modified and adapted to the local situation. It is estimated that this investigation will be completed and in condition for final report at the end of the current year. The estimated cost of this branch of the work is $20,000.

As a result of the present studies the Commission will be in possession of complete facts as to the feasibility and cost of measures designed to protect the purity of the International Boundary waters against gross and detrimental pollution. There will remain the formulation of definite recommendations involving the future policy of the two Governments in this matter. Such a policy must be expressed in such broad general terms as to be applicable to all existing and future conditions and yet with such special reference to local situations as to leave no doubt of the requirements in any particular case. The formulation of such a policy will demand the most mature deliberation, the broadest legal knowledge and experience and the wisest statesmanship, qualities with which the International Joint Commission as at present constituted is abundantly supplied.

Discussion.

Dr. W. A. Evans: The technical points of this paper have had very careful consideration, and need no discussion at this time or under these circumstances. The same is true of the recommendations of the commission as to what type of community should purify its sewage by one method and what type should make use of another.

I may be of service by drawing attention to the application of these conclusions to communities not located on International Boundary Waters. It is probable that the scientists attached to the commission have in reality had this larger field in mind. Comparatively few people live on the banks of boundary waters. Comparatively few communities empty their sewage into, or take their drinking water from, such waters. But many millions live in places where the practices recommended in this report need to be applied.

About 1908 the city government of Chicago stimulated the formation of the Lake Michigan Water Commission. This commission was founded on the theory that the typhoid problem of the cities in the four states bordering Lake Michigan was a common problem. In the first place, one investigation and one conclusion would answer for the cities of the four states. What was found out at Chicago, Illinois, would apply at Milwaukee, Wisconsin, and Whiting, Indiana. There was no need of duplicating and reduplicating the work.

In the second place, polluted water does not respect state boundaries. The sewage from the Indiana towns at the foot of the lake is thrown into the Calumet River. That river flows from Indiana into Illinois and discharges the collected sewage into Lake Michigan, a few hundred feet from the Indiana line. The discharged sewage is blown to the Indiana cities' intakes or to the Chicago intakes, according to the direction of the wind.

The Great Lakes Water Commission was a natural outgrowth of the Michigan Water Commission and the report on the Pollution of Boundary Waters made by the International Joint Commission is a natural outgrowth of the influence of the Great Lakes Water Commission.

The conclusions of this commission run directly to the methods of sewage disposal and water purification of the communities located on certain of the boundary waters. But they must not stop there. They must be applied everywhere throughout the country. You note that certain of the recommendations apply to communities where the population is not great and the water is not grossly polluted. Our large cities have solved or are solving their typhoid problems. Many cities now have a typhoid rate under ten and some have a rate under five. They are in a class with the best of European cities. The great city hotbeds of typhoid of ten years ago—Pittsburgh, Cincinnati and Niagara Falls, no longer feed typhoid into other cities. Now the smaller cities and the rural communities are the typhoid feeders for the cities. If it were not for these feeders, the cities could easily attain a typhoid rate well below five.

I understand that Dr. Drake of the Illinois State Board of Health is alarmed because of the typhoid he is finding in the state. He need not be. The amount of typhoid is not unusual. The only difference is that he is learning about it, whereas his predecessor did not.

The smaller places are the reservoirs from which typhoid is being fed into the larger places. This is the condition because of two factors. In the first place, there has not been enough education and awakening of public interest. In the second place, smaller communities have not known what to do.

Prof. Phelps and his associates have worked out recommendations which apply to "water supplies taken from streams and lakes which receive the drainage of agricultural and grazing lands, rural communities and unsewered towns," as well as communities which have more heavily polluted water. And it is among small communities that anti-typhoid work is especially needed.

John W. Alvord, M. W. S. E.: I have listened with great interest to Professor Phelps' paper, which gives a comprehensive and general statement of the work that the United States Public Health Service is doing on the boundary water questions.

I think it is a very important work, and I fully agree with the statement of Dr. Evans that the results are not only of the highest interest as to sanitary condition of boundary waters in general, but are also important, as well, to the sanitary problems of the cities situated on the Great Lakes, whether they be located immediately on boundary waters or not.

The proper future sanitary policies of cities bordering on the Great Lakes present some of the most difficult problems with which the sanitary engineer has to deal, because of the close and complex inter-relation of the problem of sewage disposal and water purification. The proper adjustment of these two sanitary methods, properly solved, is a matter of difficult and delicate economic and sanitary balance.

The natural condition of the great cities bordering on the lakes commonly is, that they flow most or all of their sewage into the lake, usually through small rivers, improved as harbors, then at some other comparatively nearby point they draw out their water supplies from the same source. In the early histories of such cities, when populations were small and the created pollution was also small, this method was perhaps tolerable, although always open to suspicion, but with the growth of population and its attendant increasing pollution, such policies result in an insidious approach to the time when safety could no longer be said to be assured, and fortunate was that city whose farseeing and broad-minded administrative guidance caused it to be forewarned and forearmed in solving its sanitary policy. Too often it has been the case that future sanitary policy was neglected until the increasing death rate from preventable diseases sharply called the attention of the public to the negligence of their authorities.

The problems of rapidly growing population centers that deposit their wastes into their water supply sources, will continue to be increasingly serious, because, as I have said, there is probably no class of sanitary problems more difficult of proper adjustment, more sensitive in their economic balance, and more serious in their sanitary results than the question as to how far such lake cities should rely on sewage purification and how far they should rely on water supply filtration.

As matters now stand, the popular idea and the sanitarian's idea are quite far apart as to the relative importance to be given to water filtration and sewage purification. The sanitary engineer believes that water purification should be resorted to as the first line of defense at the first intimation or suspicion that the lake supply is becoming contaminated, and that, secondarily, sewage purification should be resorted to as a second line of defense long before the water purification plant becomes in danger of being overloaded.

The public, on the other hand, have an entirely opposite viewpoint. They believe that if sewage disposal is introduced in our lake cities, the water supply can be left in its natural states without danger. This attitude on the part of the public results from a misunderstanding of the nature and function of sewage disposal practice and an over-confidence in the ability of sewage purification works to fully and uninterruptedly remove polluting disease germs from natural waters at a reasonable cost, and also, as well, to an underestimate of the value and importance of water purification works, properly provided and operated for the same purpose.

In almost all of the problems now presented to the sanitary engineer by cities bordering on the lakes, he is confronted with the necessity of re-educating the public into a proper distinction of the relative economic value and sanitary efficiency of these two operations.

To illustrate this, I might mention the four last lake-city problems with which it has recently been my fortune to be connected,—the proper protection of the water supply and the sewage disposal of the City of Milwaukee, that of the City of Racine, and Kenosha, Wisconsin, and at the present time, of what is known as the North Shore Sanitary District, comprising Waukegan and the suburbs on Lake Michigan north of the Sanitary District of Chicago. In all of these cases the writer has been called in, either alone or in conference with other engineers, and asked by the cities involved to solve the *sewage disposal* problem, and in all four cities it was urged that additional authority be granted to consider the protection of the water supply as well as the sewage disposal problem. This is evidently because the municipal authorities have been somewhat loath to concede that the scope of these investigations should go outside the sewage disposal problem and cast suspicion upon the water supply, and in sympathy with the popular prejudice some cities have received recommendations for the purification of the water supply with obvious disrelish, so great has been the sentiment in favor of naturally pure lake water protected, in the popular imagination, from contamination by ideally efficient sewage disposal works.

As I have said before, the sanitary engineer labors under no such delusion. He does not believe that by sewage disposal processes alone he can keep the water supply of the cities of the Great Lakes continuously free from polluting influences, or make their waters potable for domestic consumption against all contingencies at reasonable cost, or in any comprehensively practical way. Sewage disposal, properly understood, must be mainly considered to be useful for the abatement of nuisances, and in its relation to water supply it should be considered only as a secondary line of defense to the public health in these cases where city wastes are emptied into their own or other cities' water sources.

Now, it is one of the duties of the engineering profession to educate the public to a proper perspective of the value of the different kinds of engineering works, their proper function and economies.

We must interpret for the public a rational adaptation of present day art to the laws of nature, and we must convince the public what course of procedure will produce the most effective results with the least possible effort, not only in terms of money but in terms of precaution and vigilance. All other things being equal, in the case of municipalities those methods which are most simple and fool-proof will be the most effective.

Sometimes in the past and in some directions we have unintentionally wrongly educated public opinion in sanitary matters. This is because sanitary methods and sanitation have made rapid advances in the last two decades.

For instance, it is recalled that the medical and sanitary profession held at one time to the belief that odors and sewer gas were among the chief carriers of disease. Naturally, they taught the public to be on their guard against odors and sewer gas, but later on when it was found that bacteria was most often the specific cause of disease, intelligent practitioners gave up the odor theory, but it took a great deal of time and pains to disabuse the públic of the belief which had been firmly instilled, and even today a large amount of unintelligent public opinion is swayed by the belief that the cause of disease is chiefly from odors.

Now, in a somewhat similar way, the people of the cities on the Great Lakes have popularly imbibed the idea that all they have to do is to divert their sewage from the lake, treat it in highly efficient plants and let the purified effluent flow back again. When this is done, they imagine the Great Lakes at their front doors will furnish an ample supply of pure natural water for all time to come, but in coming to this conclusion the public have forgotten the storm-water problem, the accidental pollution problem, and other polluting sources outside of sewage, and it has further placed too great confidence in the process of sewage purification and what it will properly do in a practical way. Who is chiefly to blame for this popular opinion, it is difficult to say. Possiby in the early enthusiasm for some of the new sewage processes the sanitary engineer has been somewhat sanguine, but the greatest amount of harm has been done by half-educated literary enthusiasts, who have catered to the popular taste for drama and novelty, and, through them, the public have, without really knowing it, imbibed a degree of confidence in sewage disposal works as germ eliminators, which is not warranted by such processes at any reasonable cost. Thus, unfortunate overconfidence must be overcome, and the proper relation of water purification and sewage disposal in the sanitary problems of our cities on the lakes must be popularly understood before we can properly solve these problems in the light of present day knowledge. The work, therefore, which the Boundary Commission and their experts have done is of very great interest, in that it correctly educates the public and enables the sanitary engineer to base his studies, opinions, and conclusions on more definite data.

L. K. Sherman, M. W. S. E.: The sewage of Chicago is now diverted and kept out of Lake Michigan with the sole exception of the pollution coming from the Calumet River in time of flood. There is, however, evidence of contamination at times, of the water from the various Chicago intake cribs. There is circumstantial evidence that this contamination comes from the sewage discharged into the lake by Evanston, and possibly other North shore towns, and also from Indiana towns just beyond the State line. It is important to have definite data as to the distance in the Great Lakes that sewage may be carried as to injuriously affect a neighboring water-works intake. In this connection, the work of Prof. Phelps is of great value.

If one municipality is having its water supply polluted by another, the remedy is in abatement of the nuisance through State or Federal Courts. It is not incumbent upon a city to filter its water supply in order to take care of another's disregard for sewage disposal in Lake Michigan.

Paul Hansen, M. W. S. E.: Statements in Professor Phelps' paper which interested me most related to the allowable limit of colon bacilli in untreated water suitable for domestic purposes. The limit of permissible polution of water that may be used as a public water supply is a matter with which state sanitary engineers are constantly confronted. No doubt the limit of 500 colon bacilli per 100 cc. of water is a very suitable one for the Great Lakes, but it would probably be not applicable to the waters of interior streams which present a far more complex problem to deal with. It appears to me that any standard applicable to stream waters cannot be based upon analyses alone, but must take into consideration various characteristics of the stream, including particularly variations in stream flow and relative location of water works intakes and sewer outlets.

Dr. Evans in his discussion referred to the past reputation of cities as typhoid fever pest holes. This reminds me that there still remain what may be regarded as typhoid fever pest holes in the form of chautauqua grounds, fair grounds, and construction camps. An epidemic of typhoid fever, involving probably 200 cases, recently occurred in the western part of the state. Upon investigation by the State Board of Health, the source of infection was definitely traced to a well in the Old Salem chautauqua grounds which had become contaminated by polluted water from the Sangamon River during a flood stage caused by recent heavy rains.

The insanitary conditions at many fair grounds, construction camps and chautauquas have been so impressed upon the State Board of Health, due to the epidemic just cited, as well as a number of recent inspections, that it has been decided to thoroughly inspect all such places within the State of Illinois prior to or during the next summer season.

One of the grave dangers of construction camps, as well as faulty handling of public water supplies, was illustrated at Galesburg recently. The Santa Fe railroad maintains a work gang, mostly composed of Mexicans, in old box cars placed along the right-of-way at points near the wells of the public water supply. The water from each well before being delivered to the pumps is passed through sand catchers of wooden construction with removable tops. As the sand catchers were very accessible and as the flowing water was cool and tempting, the Mexican women developed the habit of seating their babies in the sand catchers for a refreshing bath. This was very fine for the babies but rather hard on the population of Galesburg, which uses this water for drinking purposes.

Langdon Pearse, M. W. S. E.: Professor Phelps has presented a very clear view of the work of the International Joint Commission. Such detailed studies are of great value to the engineering profession as they serve to give a correct perspective to the relation of sewage disposal to water supply. The Commission has now defined the extent and intensity of the pollution. The outcome of the second phase of the investigation, the methods of relief, will be awaited with much interest. The resume of the opinion of the consulting sanitary engineers should be read by every public official who has to do with water and sewerage.

As the Public Health Service of the United States has loaned Professor Phelps for this important international investigation, it is not out of place to comment on the activities of the Public Health Service in studying interstate pollution, particularly on the Potomac and Ohio rivers. From these studies, a deal will be learned on the self-purification of streams, which will be presented to the country in a way that both the public and engineers may understand. It is usually difficult to arouse public interest in the sewage disposal problems of the public's own community, though most communities are quick enough to protest against conditions caused by others. With the growth of population and the increasing load of sewage on streams, the interstate problem is widening. To promote a settled policy, the United States Public Health Service should afford a very appropriate medium, with its organization of health officers, laboratory investigators and sanitary engineers.

When treatment of polluted water is mentioned, I always think of the Bubbly Creek filter plant, which has taken a mixture of sewage and water (in ratios from straight sewage to 1 of sewage in 10 of water) and converted it into a sterile clear water by the use of coagulation, sterilization by chlorine and filtration. This is probably the worst raw water handled anywhere, and a product was made which was drunk by cattle and by men, and is now used for boiler purposes, I am told. It is a remarkable example of the efficient use of strong sterilizing agents. The conditions discussed by Professor Phelps involve pollution of water, where much greater dilutions occur in the magnitude of 1 in 2000, instead of 1 in 10, so that the treatment required to make pure water is more normal.

The work of the Public Health Service along sanitary engineering lines should have the support of all engineers. Valuable information is being collected on water pollution, self-purification of streams, treatment of industrial wastes and the like, which will undoubtedly be published in a detailed and authoritative manner. Besides the monographs and leaflets, the service issues a weekly bulletin which frequently contains suggestions of value to the constructor as well as the sanitary engineer and health official.

W. T. Barnes, M. W. S. E.: I have but little to add to what the various speakers have said in their discussion of Professor Phelps' most interesting paper upon the work accomplished by the Joint Commission. I might possibly amplify what Dr. Evans points out as being one of the beneficial results of the work of the Commission. We are all aware of the difficulties that beset us when a state line cuts into any engineering problem. The very fact that representatives of two national governments can get together and work out their problems with such good results and with such pleasant relationship, leads one to believe that in a similar way many of the sanitary problems which confront adjoining states could be settled were each state but willing to delegate power to a similarly organized joint commission.

H. P. Letton: The work done by the International Joint Commission, as described by Professor Phelps, has been of considerable value in the investigation of the drinking water supplies of the common carriers of the Great Lakes now being carried on by the United States Public Health Service. It may be advisable to outline briefly just what this investigation includes, in order that the value of the work of the Joint Commission in this connection may be seen.

For the enforcement of the Interstate Quarantine Regulations, requiring that common carriers engaged in interstate traffic shall furnish a drinking water for the use of passengers of a certain specified purity, the United States has been divided into twelve Sanitary Districts. The area embracing the Great Lakes is known as the Sanitary District of the Great Lakes, with headquarters at the United States Marine Hospital in Chicago, and with Surgeon J. O. Cobb in charge. A laboratory has been established at this point, and inspections have been made of, and samples collected and examined, from most of the passenger boats operating on the Lakes during the past summer.

The water supply on vessels is a subject to which but little attention has been heretofore given, but when it is realized that over fifteen million people are carried as passengers on vessels of the Great Lakes each year, its importance is clearly seen.

The vessels, for the most part, take their drinking water directly from the water over which they are traveling, various methods being used for getting it into the ships' tanks. These methods are such that contaminated drinking water is the rule rather than the exception. We have been working on some satisfactory solution of the problem and believe that we are on the right track.

The work of the International Joint Commission showing the sanitary quality of the water at various points on the Great Lakes has been of considerable benefit to us. Undoubtedly, most of the contamination of the drinking water used on vessels comes from polluted harbors where the vessels dock, and it is believed that if the plans being worked out by the Joint Commission for handling the sewage at Buffalo and Cleveland are adopted, they will relieve the vessels at those ports from much of the load which they now have to contend with in regard to the sanitary quality of their drinking water.

S. A. Greeley: I am sure that Professor Phelps' address has been very interesting. While listening to his remarks and the discussions on them, a few things have come into my mind which may be of interest. The first was prompted by Dr. Evans' statement regarding rural typhoid fever and the fact that it is often more prevalent than it cities. This is partly because smaller communities do not have the organizations available for controlling this disease. It is, therefore, interesting to know that Professor Phelps about two years ago organized a group of towns for co-operative health work. No one of these towns could have individually had as efficient a health organization, but their collective activity worked out the problem very successfully.

My second thought was prompted by Mr. Alvord's statement of his experience with the sanitary districts where he was engaged to report on problems of sewage disposal and water supplies. In the State of New Jersey, when such sanitary districts are contemplated, it is required by law that they shall first secure a thorough engineering investigation and report upon which to base the organization of the district. In this way districts are organized for the proper and necessary work to be done and subsequently amendments in their charter are not required.

We have found that the quality of Lake Michigan water varies greatly in comparatively short times. In one city where hypochlorite was used for disinfection, the amount required for satisfactory treatment frequently varies in one day from five to fifteen pounds per million gallons of water. It is, therefore, necessary to give this treatment careful chemical supervision.

I have listened with great interest to Professor Phelps and the other speakers and desire to thank them for their information and entertainment.

W. W. DeBerard, M. W. S. E.: I would like to ask if any attention was paid to littoral, which is an indication of pollution in the water blown ashore. The extent of these deposits came to me very clearly recently on the beaches north of Howard Avenue to the Evanston pumping station. Really, the whole beach was so badly polluted it was nauseating. One could not help but feel that bathers, if they really saw what was underfoot, would never again go near the lake. From the nuisance standpoint no other beach has come to my attention that has had such an unsavory appearance and possibility for the spread of water-borne disease by the direct method.

The Author: It was impossible to take into consideration in this investigation the matter raised in Mr. DeBerard's question.

With regard to Dr. Evans' remarks, the state cannot contract with one another and there is no way in which one state can compel another state. There would be no use to do anything with the streams in one state, if the water should be polluted by another state.

A good many of these state problems will have to come into the hands of the National Government. The National Government can handle these problems and collect the information to much better advantage, but the National Government is very slow about taking up matters of this kind where the states are involved. It was easier to do so, however, in the case of the International boundary waters on account of the treaty with Great Britain. The results of these investigations in the International boundary waters can, of course, be applied to other streams.

LIGHT AND ILLUMINATION

Dr. Charles P. Steinmetz.

Presented at a Joint Meeting, Electrical Section, W. S. E., and Chicago Section, A. I. E. E., October 26, 1915.

Illuminating engineering, that is, the art of producing light, is relatively one of the most encouraging branches of engineering, as it has in the last ten or fifteen years shown a wonderful progress in increasing the efficiency of light production many fold. At the same time, however, we may also say that in the field of producing light is met a discouraging branch of engineering, because in spite of the great progress made in economy of lighting, as illustrated, say, in the gas filled "Mazda" lamp of today, the efficiency is still only about four per cent, and ninety-six per cent of the energy consumed in the lamp is wasted. Although the afficiency is still low, nevertheless the advance from the days when the efficiency of light production measured a fraction of one per cent, compared with that made in the last ten or fifteen years, means that we can hope for still greater improvement in the future. A wide field for such improvement remains, and instead of producing two candle power per watt, possibly twenty or more candle power may eventually be obtained.

It should be realized that the artificial production of light for illuminating purposes is comparatively recent, much more recent than is generally understood. I remember, for instance, my grandmother telling me that when she was young, resinous pine sticks were their only means for lighting; that was not so very long ago, and not in the wilderness, but in a civilized country. In my time vegetable oils were also used to illuminate, and I remember the first kerosene lamps, and that they had the reputation of being dangerously explosive and required careful handling. Gas was the street illuminant.

Then came the electric lamp. I remember the first incandescent lamp tried in my native city for street lighting, early in the '80s. I do not know whether it was a fifty volt or a hundred volt lamp. It was a small affair, giving a comparatively dull reddish yellow light not especially attractive. The first arc lamp there, however, was very different. Its exhibition was one of the startling features; the whole city, about the size of Washington, came to see the remarkable illuminant. All those things—incandescent lamps, arc lamps, even kerosene lamps, all our illuminants—are still within the memory of living generations. The whole field of lighting is really so new that only a very few generations back there was practically no artificial illumination applicable for general use.

In view of the progress of the art, within two generations, turning night into day, as it were, for useful work, we can imagine what future generations may accomplish, when we consider that there is still such a vast field for further improvements in efficiency.

Artificial light has always been produced by heat, first, by the heat of combustion, by burning pine sticks, vegetable oil, coal-oil, kerosene, gas, etc.; and, second, when the electric light came, in the same general way by heating the incandescent filament or the tip of the arc lamp carbon to a high temperature by means of the electrical energy put into it. Heat is produced in all these methods of lighting, and a small part of the heat comes out as light. The light is practically a by-product of the heat generated.

The first real advance beyond this way of obtaining light was made by Auer von Welsbach, who originated, in the Welsbach lamp, a method of lighting not dependent directly and wholly upon heat, but giving an illumination many times greater than any merely incandescent body would give at the same temperature. That was the first step toward a different method of producing light, a method that holds out a promise of possibility of efficiency greater than in producing light through temperature, that is, solely by heat.

To understand the subject better, let us first consider what light is. If a spring is slowly and regularly vibrated away from a contacting stop, we hear the stroke of each individual vibration. By moving it faster and faster until the frequency, or rate of vibration is about thirty per second, the ear will no longer distinguish the individual vibrations; they would run together, and blend into a continuous note, the deep bass C. If the spring is moved still faster, we would continue to hear a continuous note, of a higher pitch, however, corresponding to the particular rate of vibration.

This result can readily be accomplished by means of a star wheel aranged to rotate at any desired speed up to a very high rate, the teeth of which strike against a flat spring. For instance, if the speed be such as to obtain 250 vibrations per second, they are heard as a note in the middle C; and if the speed goes on increasing, we successively distinguish the notes D, E, F, G, A, B, and finally, at 500 vibrations, the next higher C of the musical scale, or C in the next higher octave. If the rate of vibration be decreased from 250, from middle C, down to half as many, or 125 vibrations per second, we hear the bass C, the C of the next lower octave.

So you see there is a definite scale for the frequency of vibration embraced in the octave, which, however, was originated long before people knew musical notes were the result of vibrations. And a system for the various frequencies of sound vibration has been established in the musical scale in which the octave is the unit. The octave changes from two to one; every time the frequency of vibration is doubled the same note of the next higher octave is produced; if the frequency is decreased to half, the same note of the next lower octave results.

But there is a limit to the ability of the ear to take cognizance of vibrations. Going from low to high and still higher vibrations the ear hears them progressively as musical notes of higher and higher pitch, finally becoming a screechy noise, no longer musical, when the rate reaches thousands of vibrations per second, and eventually a limit is attained generally between 6,000 and 8,000 vibrations, when the ear ceases to hear them, although sound waves are still being set up in the air and impinge upon the ear. The rate of vibration at which hearing stops is not the same with everyone; different persons hear higher up or lower down in the scale; but in general the range of frequency of vibration which can be heard as continuous sound or note is from about 30 vibrations per second, the deepest base, up to 6,000 to 8,000, the highest pitch, embracing, say, six to eight or nine octaves.

Now suppose we go still higher in frequency, not in thousands, but in tens and hundreds of thousands, and even up to hundreds of millions of millions of vibrations per second. We can then again perceive them with our senses, not, however, with the ear as sound, but with the eye as light.

Naturally vibrations at the rate of hundreds of millions of millions per second cannot be produced by any mechanical device, as the star wheel before mentioned; no body can be moved quickly enough to accomplish it. Moreover, the air cannot be utilized to transmit such rapid waves, because air, however thin it may appear to us, is altogether too dense and heavy a body to move so rapidly. Such extremely rapid vibrations have to be transmitted by a medium infinitely thinner and lighter than air, the universal ether, which is supposed to pervade all space and all matter, and transmits these very high frequency waves, some of which we can see as light.

When the rate of vibration of this ether is about four hundred millions of millions per second, the eye begins to see it as dark reddish light. At progressively increasing frequency we see it successively as orange, yellow, green, blue and violet light, until the rate reaches seven hundred millions of millions, when its effect upon the eye ceases and darkness ensues. There is, however, a frequency of vibration of the ether far beyond this, hundreds of times faster than the frequency of light. What we know as X-rays are perhaps the ultimate result of exceedingly rapid vibrations, amounting to many thousands of millions of millions per second.

We have seen that there is a range of vibration up to 8,000 per second perceptible to the ear, the air transmitting these comparatively slow vibrations as sound. Then there is another range of vibrations up in the hundreds of millions of millions transmitted by the ether, which the eye perceives as light. The range of frequency of sound waves is very wide, embracing about eight or nine octaves; but the range to which the eye is sensitive is only from about four hundred millions of millions to seven hundred millions of millions, relatively less than one octave. That is, the fastest vibrations which the eye can see are less than twice the slowest ones. Therefore, as regards the range of frequency of vibration the eye is much less sensitive than the ear; the eye perceives less than one octave, while the ear is sensitive to over eight octaves.

Now let us consider ways of producing sound waves. When one body is hit by another, say, by striking the table with a hammer, we hear a sound. Energy is expended by the blow and produces a mixture of vibrations of many different frequencies with no fundamentally predominating and controlling frequency, which are communicated to the air; the different frequencies result in a mixture of corresponding notes that are discordant or disagreeable in the musical sense, and thus we call such a sound a noise. Other noises, because produced by other different mixtures of vibrations of many frequencies, result from dragging a stone over a rough surface, permitting air under pressure to escape from a nozzle, swishing a whip through the air, etc.

Suppose instead of striking the table with a hammer, I strike a stretched steel wire, for instance, one of the wires in a piano. What is the result? The wire can vibrate as a whole at only one definite fundamental frequency, which determines the pitch of the note produced. It is true that superposed upon this vibration there may be others of a greater frequency, but, when present, they are so secondary to the fundamental wave as only to affect its shape in a minor degree, to the extent of determining the timbre or quality of the note and not its pitch, and do not cause a musically discordant result, that is, the vibration of the wires does not merely make a noise. It is, then, not able to vibrate like the table with a heterogeneous mixture of discordant vibrations of all kinds of frequencies with no controlling frequency, producing only a noise; the wire vibrates at a particular frequency, and the resulting sound will be a note, which, of course, is a noise in the most general sense, but not in the musical sense.

If, for another illustration, instead of making a noise by dragging a stone over a rough surface, I drag a bow across a violin string, the energy communicated will make the string move, but being able, like the piano wire, to move only at one particular rate of vibration it will produce a definite note, the particular note obtained depending upon the length of the string and tension upon it.

Again, take the case of an air blast escaping from a nozzle with a hissing noise. If I properly place a tin tube over the nozzle, the air in the tube will vibrate, but, like the piano wire, at some particular frequency depending upon the length of the pipe; thus the air blast can no longer cause an adventitious mixture of vibrations, but only that particular one which the pipe permits, and we get a definite note.

So you see we can create a noise by any sort of impact, but to get a definite note, that is, a noise produced by a definite frequency, the body which is set in motion must be so shaped that it can move only at one definite fundamental rate, like the violin string or the stretched piano wire or the air column in the pipe.

The art of creating and making musical instruments has always been to shape the material so as to get waves of vibration of definite stable frequencies and shape, the shape giving the difference in quality, color, or timbre of the notes of the different musical instruments. There must also be a rational method of supplying energy for producing such vibrations, by a felted hammer, as in the piano, or a bow, as with the violin, otherwise only a jarring noise is likely to result.

Analogous methods can be applied to obtain vibrations of the ether millions of millions times faster than sound waves, and which the ear cannot hear but the eye can perceive. If we put energy into a body by heating it, the body will send out ether vibrations at this higher rate. The collective vibrations thus obtained, translated into the language of sound, would be a noise, a mixture of waves of all kinds of vibrations with no particular fundamental frequency. If we heat the body to incandescence the same result is obtained. Now some of the waves, those which happen to be in the three-quarter octave, will be visible to the eye; while others in this ether noise, this mixture of vibrations, may be too fast or to slow to be seen.

Let us see how we can get some definite rate of vibration, some definite frequency of light. To get a definite frequency of sound you have seen that the vibrating body, the violin string, the piano wire, or the organ pipe, must be properly proportioned. For example, to get with an organ pipe a vibration of, say, 250 per second, the pipe should be about four feet long, because a column of air that length is able to vibrate at the required rate. But if the vibration is to be at the rate of five hundred millions of millions of cycles per second, which would produce a greenish-yellow light, naturally the body to be moved at that rate must be extremely small.

Now the smallest body which is available is the chemical atom. In a piano, when a particular note is to be sounded, the key corresponding to the wire having the correct length and tension is struck. But we cannot strike each individual atom of the steel wire separately. It is much more difficult to get a single atom into vibration by putting energy into it than to get a piano wire, violin string or a column of air vibrating, because we cannot act upon each vibrating atom directly but only on a big mass of them.

Atoms can, however, individually be set in vibration by various means. If an electric current is sent through a gas or vapor under low pressure in a vacuum tube, the individual atoms are set in vibration, and move with their own definite frequency, just as do the violin string or the piano wire, and give out, not an atomic noise, so to speak, but atomic notes of definite frequency. But while the violin string gives one frequency only, one note to the single string, we know now that the so-called chemical atom is not a simple thing, but has a very composite structure, and that it does not give a single note, but quite a number of different notes, corresponding in a measure to the sound produced by simultaneously striking a number of piano chords.

The chemical atom, therefore, gives a mixture of vibrations, not, however, as we get in noise, a mixture of all kinds of heterogeneous vibrations, but a definite number of separate definitely related vibrations, a so-called spectrum, representing the vibrations that the different components of the atoms, whatever they may be, are capable of producing. There may be a very great number of different vibrations, but with some materials we find in the visible three-quarter octave six different notes or colors, six different prominent vibrations constituting a spectrum of light, besides a number of lesser prominence and many more outside the visible range. These atomic vibrations are very complex, and the method which is very successful in producing definite simple vibrations of sound waves at low frequency, absolutely fails when we come to the high frequency of light. The best we can do with the atoms of gas or vapor is to get a definite number of distinct and related vibrations.

We can produce a noise, or all kinds of vibrations, at the high frequency of light, for instance by heating, just as well as it can be done at the low frequency of sound by impact. And atom-noise is really what is wanted for lighting. A definite frequency is undesirable; for example, a light which had only one definite frequency, say, the frequency of five hundred millions of millions, would be greenish-yellow, and would show everything of one color. Therefore, at least for general lighting, a mixture of frequencies is needed—what in sound we call a noise.

In the range of sound for many purposes—for signaling, drawing attention, etc.—a noise is generally just as good as a note. What we are after is volume of sound, regardless of whether by a noise or a single note, but in lighting what is wanted is really a noise. In sound waves the range generally perceptible is eight octaves; practically any mixture of frequencies in making a noise will usefully fall in the audible range, and very little will be wasted. But in a mixture of frequencies of hundreds of millions of millions of cycles of light waves the visible part is only three-quarters of an octave, and in such a mixture a considerable part of the vibrations is sure to fall outside the visible range, and become wasted as light. Thus the difficult problem of producing useful light is not only to produce all kinds of frequencies of vibration, but to produce as large a part of them as possible within the three-quarter octave that can be seen.

A most convenient method of producing frequencies of millions of millions of cycles is by heat, by raising the temperature of the body that is to radiate the vibrations. A steam heated radiator will send out vibrations at the rate of many millions of millions of cycles, but they will be just a little too slow to come within the visible three-quarter octave and are thus not perceptible to the eye.

Most of the vibrations from aluminum at the melting temperature, probably 99.75 per cent, are too slow to be visible, but a very small percentage have a high enough rate to be just within the visible range, where the eye perceives them as red, orange and yellow, with possibly a trace of green. The general result is a dull red-orange color.

At a higher temperature higher frequency radiations are obtained. At the temperature of melting iron more than 99 per cent of the vibrations are too slow to be seen; most of them appear in the lower end of the three-quarter octave, as red, orange and yellow, with some green, a few blue and still fewer violet radiations, the color mixture appearing nearly white. In the visible three-quarter octave the slowest vibrations appear red and the fastest are violet, and from the fastest to the slowest throughout the visible range the colors are successively red, orange, yellow, green, blue and violet, just as we have the octave of sound waves divided into notes, C, D, E, F, G, A, B, and the next C. The next C has no equivalent in light, that is, in passing over the visible spectrum from red to violet, red is not repeated again beyond the violet, the spectrum of vibrations continues on, however, beyond the violet into an invisible region known as the ultra-violet.

At a still higher temperature, for instance, the temperature of melting tungsten, the percentage of frequencies of vibration that come within the three-quarter octave increases to five or six per cent. We get red, orange, yellow, considerable green and blue and some violet. The considerable increase in the number of higher frequencies in the blue and violet parts of the three-quarter octave give a mixture which produces almost a white light, much whiter than in the case of melting iron.

If the temperature is raised still higher, say, to about 5,000 deg. C., 9,000 deg. F., about ten or twelve per cent of the total frequencies will fall within the visible three-quarter octave. The highest efficiency of light production by heat would be at about 5,000 deg. C., about the temperature of the sun.

The problem of producing light from heat, by combustion or by an electric current, therefore, involves raising the light-giving body to as high a temperature as possible, because the higher the temperature the greater is the percentage of the total vibrations emanated that fall within the visible range. But even at the very best, if it were possible to make use of a temperature of 5,000 deg. C., we could not get more than ten or twelve per cent of the vibrations as light. Unfortunately tungsten evaporates at between 3,000 and 4,000 deg. C., and other available substances vaporize at still lower temperatures; thus we are prevented in practice from attaining the maximum efficiency possible by radiation due to temperature.

Nevertheless, all the advance in illuminating engineering has been made by utilizing higher and higher temperatures. In the beginning, light was obtained through the temperatures obtained by combustion, ranging from lower to higher temperatures according to the combustible used, as flaming pine sticks, vegetable oil, whale oil, mineral oil, kerosene, etc., with an upper possible limit of about 2,000 deg. C., determined by loss of chemical affinity of oxygen for other elements at still higher temperatures. At the temperatures of combustion red, yellow, and at the highest limit, a whiter flame was produced, but all of them of low percentages of efficiency for obvious reasons heretofore given.

Then we came to the electric light. Although higher temperatures than 2,000 deg. C. cannot be reached by combustion, we can go higher by means of the electric current. Attempts at producing light by the electric current were made by heating wire conductors to a high temperature, and the first attempt at an incandescent lamp was with a platinum wire; but platinum melts at about 1,760 deg. C., therefore the efficiency of light production by this means is very low. Then Edison discovered that a wire of carbon—a carbon filament—could be used in place of platinum. Now carbon does not melt, or boil, until a temperature of about 4,000 deg. C. is reached. Consequently it should stand a very much higher temperature in an incandescent lamp than platinum. The old carbon filament lamps were run at about 1,800 deg. C., somewhat above the melting point of platinum, and thus with higher efficiency, and no danger of melting. About 45 watts of electrical energy were required per candle power.

The question arose: Why could not the carbon be operated at a higher temperature and thus at higher efficiency? If instead of running at a temperature of 1,800 deg., requiring 45 watts per candle power of light produced, the carbon was raised to 2,500 deg., the candle power would be doubled for the same watts. But the limitation there was, not that the filament melts or boils, but another limitation—evaporation. We know materials can evaporate below their boiling point, for example, that water at ordinary temperatures will evaporate within a few days, and that even ice and snow below the melting point gradually disappear. The carbon filament at 1,800 deg., way below the melting and boiling point, also slowly evaporated, the carbon vapor being deposited on the lamp bulb. With continuous evaporation the filament got thinner, thereby the temperature went down and the light became less. The deposited carbon vapor also obstructed the light. If the filament were raised to 2,500 deg. C., the temperature would rapidly go down through excessive thinning of the filament by evaporation, and the deposited carbon on the globe would blacken it to such a degree that even the filament itself would only faintly be seen through the glass.

So we were limited as to the operating temperature of the carbon filament because it had to be kept way below the melting or boiling point, where the rate of evaporation does not unduly reduce the light production, and efficiency of that production, within a reasonable time, say, 500 hours or so. That was the limitation to the efficiency of the old carbon filament light.

The problem later was to make it possible to run carbon at higher temperature without undue evaporation, and thereby get higher efficiency. Carbon is a rather indefinite body; there is carbon and carbon, for instance, the carbon obtained from bamboo fiber, the carbon from silk strands and that from cellulose, and so on. The material obtained by carbonizing fiber evaporates rather rapidly, but carbon deposited from gasoline at high temperature is of another kind, which does not evaporate so easily, and thus can be run at higher temperatures. Therefore, if a shell of carbon from gasoline vapor, is deposited upon the carbon filament of old produced from fiber, it can be run at higher temperature with equal falling off in light and blackening of globe, but we will get a higher efficiency, and this was done.

About ten or twelve years ago still another useful modification of carbon was found, represented in the so-called metalized carbon filament, which somewhat possesses the strength and resiliency of a hard-drawn metallic wire, and evaporates still less rapidly than the earlier carbon; therefore it can run at a higher temperature. This carbon is used in the filaments of the so-called "Gem" lamp, which can be operated at about twice the efficiency of the old carbon lamp with the same rate of evaporation, the same rate of blackening and the same light.

But even the temperature of the metalized carbon in the "Gem" lamp is still way below the temperature of boiling. We can produce light by running the temperature of carbon up to the limit, that is, to the boiling point, nearly 4,000 deg. C. We cannot do it with a filament, however, but must use the arc lamp, in which the current passes through hot vapor in the space between two slightly separated carbon rods and raises the tip of the positive carbon to the boiling point. The light emitted has the efficiency that would be obtained at about 4,000 deg.; all the evaporation takes place at the positive carbon, and probably eight or ten per cent of all the vibrations radiated are visible. Thus the arc lamp would give a very high efficiency were it not that an excessive amount of heat energy is conducted off by the carbon rods and carried away by the air. That is the main, and a serious loss.

The problem thus became one of finding something that can stand higher temperatures than carbon under all practical requirements. Tantalum, osmium and tungsten are all metals of extremely high melting points, but they have a characteristic advantage over carbon in that their rate of evaporation is much less at high temperatures. The carbon filament in the old incandescent lamp evaporated although it was operated at a temperature much below the boiling and melting point. Tungsten, on the other hand, can be run up high in the temperature scale nearly to the melting point with very little evaporation. So you see that the melting point, or boiling point, and the evaporating point have no necessarily fixed relation for different substances. Benzine and water, for example, boil at about the same temperature, but a plate full of benzine will evaporate long before a plate full of water. If carbon and tungsten are kept at the same high temperature, the carbon will evaporate rapidly while evaporation from the tungsten will be very much slower. Therefore we can run tungsten at much higher temperature than carbon with the same evaporation, although really the tungsten would melt before the carbon. Carbon will stand higher temperature, but it then evaporates too rapidly.

In respect to the three metals mentioned, osmium proved very good as the illuminant in a lamp, but is too rare to be generally used. Tantalum gave good results, having a higher resistance than carbon, but has been superseded by tungsten because the melting point of the latter is much higher, and it can thus be run at a higher temperature, and it is now used in all lamps having metallic filaments. The so-called "Mazda" is a tungsten lamp. Since the tungsten lamp can be operated at a much higher temperature than any carbon lamp, a greater percentage of all the vibrations produced come within the visible three-quarter octave. The carbon lamp requires three watts per candle, while the tungsten lamp requires only one watt because with the carbon filament only three-fourths per cent of the total vibrations are in the visible range, while with the tungsten burner we get about two per cent, or about three times the percentage.

Two per cent is, however, very little. Most of the vibrations are still outside the visible range, either too slow or too fast. So the further problem has been somehow to get a still higher operating temperature. In the carbon and tungsten lamps a vacuum has been used. Naturally the lamp having a carbon filament must at least be exhausted of air to prevent its combustion, but that is not the fundamental reason for the vacuum because the lamp bulb might be filled with a gas in which carbon will not burn, such as nitrogen, hydrogen, or argon. But to maintain the carbon filament in such a gas at the temperature it would have in a vacuum would require much more energy. By conduction and convection the gas will carry away a very large part of the energy supplied to the filament, which will be given up to the glass globe and dissipated uselessly, and therefore a much greater energy consumption is required, if the filament is to be maintained at the proper temperature. Without the extra supply of energy the filament would not attain a light-giving temperature. So the reason for the vacuum in incandescent lamps has been to avoid the enormous loss of energy through heat conduction and convection were the globe filled with a gas.

The use of a vacuum, however, is disadvantageous because it facilitates evaporation, and thus sets a lower and less efficient limit to the temperature to which in practice the filament should be raised, even though far below the melting or boiling point.

Now, the boiling point and rate of evaporation of water at other low temperatures depend upon the pressure. At ordinary atmospheric pressure water boils at 100 deg. C.; at higher pressure it will boil at higher temperature; and at lower pressure it boils at lower temperature. In a vacuum water may boil at the melting point of ice, and if the vacuum is excellent, no water will be present, the boiling point drops below the freezing point, and the ice passes directly into water vapor. If, likewise, in the incandescent lamp we can decrease the evaporation by lowering the boiling point, it follows that the vacuum is a disadvantage because without the vacuum, evaporation and blackening would be very much less at the same temperature.

Now, suppose that instead of having a vacuum in a 100-watt tungsten lamp it is filled with inert gas, say, nitrogen at atmospheric pressure. To maintain the filament at the same temperature as before will require more energy because much of the heat is carried away by the gas, the pressure of which, however, will cause the evaporation to be much less, therefore the filament can be raised to a still higher temperature with an evaporation no greater than with a vacuum. The pressure has raised the boiling point and reduced the evaporation rate for equal temperatures.

Assume the evaporation in a vacuum to be such as to limit the life of the lamp to 1,000 hours at the temperature produced by 100 watts, then with nitrogen at atmospheric pressure we could use, say, 200 watts with the same rate of evaporation and blackening. But this would raise the temperature, so that while 100 watts will give 200 candles, 200 watts would give 600 candles, were it not that the nitrogen carries a lot of heat away from the filament. Consequently an additional 100 watts must be supplied to make up for this loss and raise the temperature sufficiently to give the 600 candles. In this way the candle power of the lamp has been increased from 200 candles with an expenditure of 100 watts to 600 candles for 300 watts with the same evaporation, blackening and life, which means an increase in efficiency over the vacuum lamp from one candle per watt to two candles per watt.

Now, suppose we take another lamp, say one requiring 20 watts with a vacuum. If filled with nitrogen, the temperature could be raised, probably not so high as to get six times as much light, because a 20-watt filament is so thin the evaporation that occurs, even at the lesser rate due to the pressure, would wear it away too fast. Furthermore, the percentage of energy lost through the gas is very much greater, because the surface of a thin filament in contact with the gas is much larger compared with its volume, than in the large filaments of lamps of high candle power. Whether the loss of energy due to the gas will be more or less than the gain made by the higher temperature and higher efficiency depends upon the relation of surface to bulk of the filament. With a filament in the form of a closely wound helix, where there is a relatively small surface to carry away heat, the gain may be considerable. But with a straight filament of exceedingly small wire there may be only an insignificant gain, and even a loss. In the small "Mazda" lamp of 10 or 20 watts more would be lost than gained by filling the lamp with a gas. In the big units of 300 or 500 watts, very much more is gained than lost by using the gas. The gas filled lamp represents a compromise based on allowing a big loss by heat conduction and convection by the gas, which is more than compensated by the higher temperature permissible, because the rate of evaporation is kept down by the pressure of the gas.

All kinds of inert gases would not serve the purpose equally well. Other things being equal, obviously the gas having the lesser heat conducting and convecting capacity is the better. Thus nitrogen is much superior to hydrogen, and argon a little better than nitrogen. Therefore, while large lamps may be filled with nitrogen, in the smaller type of gas filled lamps, say, 100-watt lamps, in which nitrogen would result in no appreciable gain, it pays to use argon.

In the gas filled tungsten lamp, the efficiency is raised from the five watts per candle of the early carbon filament lamp of Edison to two candles per watt, an increase in the ratio of ten to one, due not only to the gas pressure keeping down the rate of evaporation and permitting a higher operating temperature, as before explained, but further to inherently different characteristics of the two materials, in that a greater proportion of all the vibrations emanating from tungsten, when at the same temperature as carbon, falls within the visible three-quarter octave. The radiations from tungsten in the "Mazda" lamp are thus to some extent favorably selective, compared with the radiations from the carbon filament.

True selective radiation was found out some years ago by Auer von Welsbach and utilized by him in greatly improving gas lighting. In investigating various elements he discovered that the rare oxides of some metals, as thorium and cerium, when heated to incandescence, give out much more light than materials in general, say, for example, carbon or platinum, at the same temperature. When platinum is heated to incandescence in a flame, it will emit visible radiations mainly in the yellow part of the spectrum. But place one of these rare oxides in the flame, and it will give a greenish-white light much stronger than the light from the platinum, and entirely beyond what would naturally be expected considering the temperature. Thus these materials have the curious property at flame temperatures of producing an abnormal number of vibrations of high frequencies falling within the visible three-quarter octave. Such oxides are in practice formed into a mantle, which is heated by a Bunsen flame, resulting in an increase of lighting efficiency much greater than is obtainable directly from gas. The high efficiency cannot be due to the temperature, because the temperature of a gas mantle is relatively low. The quality of the light corresponds in general to low temperature, and furthermore at no temperature could any merely radiating incandescent body give off just the same quality of light which these materials give. This was the first production of light not directly due to temperature but to some selective radiation, the nature of the materials resulting not in all kinds of vibrations, but more particularly in useful ones.

The question arises, is it possible to gain the same advantage for the incandescent lamp that has been obtained in gas lighting from the Welsbach mantle by using some such selective material for the filament? This has been accomplished to some degree in the "Nernst" incandescent lamp, but the gain was insignificant compared to that obtained with the gas mantle. The reason is this: The temperature of a gas flame is comparatively low, consequently it alone gives little light. But by selective radiation or "luminescence," that is, light not directly dependant upon temperature effect, the added mantle at the same temperature gives, say, ten times as much light, thus increasing the efficiency ten times.

Now in the "Nernst" lamp the temperature is much higher than the gas flame, so that we obtain, say, twenty times as much light as from the gas flame. And since the mantle gives ten times as much light as the gas flame and the "Nernst" filament gives twenty times as much light as the gas, the increase in efficiency of the "Nernst" lamp, partly due to selective radiation and partly to the higher temperature, is only 50 per cent. So the "Nernst" filament is more efficient than the carbon filament at the same temperature, but the increase is very small compared to the increase in the Welsbach mantle. The percentage of light added by luminescence in the "Nernst" filament is probably the same as that in the mantle, but the filament itself gives so much more light, due to the higher temperature alone, that eventually very little is gained. That is why the "Nernst" lamp did not show such a startling gain over the Welsbach mantle as compared with ordinary gas lighting, and further because it could not be heated to the increased temperature possible in the tantalum lamp and still higher temperature in the later tungsten lamp. The "Mazda" is much more efficient than the "Nernst" lamp, for while the "Nernst" lamp gains by higher luminescence, the tungsten lamp more than makes up for this by its higher temperature.

The only way to produce real selective vibration, corresponding with the note from the air column in an organ pipe, or from a violin string, is by causing vibration of the atom. But even here we get not a single vibration but a mixture of all the vibrations of which the atom is capable. Therefore it cannot be accomplished by means devised as one would build a piano, by an assemblage of wires of suitable lengths under proper tensions, because there are only a certain number of elements at command, and the atoms must be used as we find them, for we are powerless to modify them or their actions.

Solids and liquids are not available, because their atoms are so close together that they cannot vibrate freely. They may be compared to a heap of sand. While each grain, if separate, could send out its own vibrations and produce a separate color effect, in the heap all we get is a general sand color, a mixture of all those kinds of vibrations that are characteristic of sand particles. So a solid or a liquid can give no definite vibration of the spectrum, but only general vibrations of all kind of frequencies, like the incandescent tungsten filament. Only the atoms of gas and vapor give spectrometric light.

Let us see which of the gases and vapors give a large percentage of visible rays. Atoms of the same material, for instance mercury vapor, will give the same vibrations regardless of whether the temperature is high or low. With higher temperature the intensity will increase, but the frequency remains the same, just as with the violin string, the note is the same whether the string is bowed heavily or lightly, only in the former case the intensity or volume of sound will be greater than in the latter, it will be louder. So with atoms of vapor, whether they be highly heated or not, whether a large or a small current is sent through them, they still keep the same frequency of vibrations, only more or less intense, and thus giving more or less light, although there will also be other vibrations too fast or too slow to come within the visible range.

In order to secure efficient lighting in this way, that is, by luminescence, we should select those chemical elements that happen to have a considerable percentage of their natural vibrations in the visible range. There are practically three of them: mercury, calcium and titanium. In mercury vapor the green colors predominate, in calcium the orange and red, and in titanium vapor the atomic vibrations have frequencies fairly well distributed over the whole visible range. With any one of them, under favorable conditions, as much as 20 per cent of the total radiation comes within the visible range, the three-quarter octave, which is several times more than can possibly be obtained from an incandescent body at any temperature, even at the temperature of the sun. There is, therefore, a possibility in this direction of an efficiency in lighting materially higher than is possible with incandescence.

This brings us to the final consideration of the question: what improvements are possible? Take the gas filled "Mazda" lamp with which two candles per watt are obtained. Possibly the economy may be increased by going to a still higher temperature, close to the melting point of tungsten, and there is still quite a latitude permissible in this direction. It would mean higher gas pressure to keep the evaporation down, and a transparent globe of different composition than at present used because the gas would be very much hotter. Then the loss from heat conduction and convection under the greater gas pressure would be much increased. A better gas for the purpose than nitrogen might be used, perhaps argon. Possibly, an improvement up to three candles per watt could be obtained, but the prospect of any substantial gain is limited.

Another question is: can we find a material, a metal, having a higher melting point than tungsten? Doubtless, it must be an element, because for chemical reasons the melting point of any compound of two materials must lie somewhere between that of either of the materials entering into it. For example, all tungsten compounds have lower melting points than tungsten itself, all carbon compounds have lower melting points than carbon, and so on.

In conclusion, we may hope to increase the efficiency from two candles, to three or four candles per watt by incandescence. In the case of the luminous spectrum produced by an electric current flowing through a gas or vapor there is no theoretical limitation because definite rates of vibration result. With the most efficient vapors, those of mercury, calcium or titanium, we can probably get something like eight to ten candles per watt under favorable conditions, an efficiency much higher than can ever properly be expected from incandescent radiation, but this is under the most favorable laboratory conditions, not as yet at all attainable in any arc lamp in commercial practice. It shows, however,—and now we are considering theoretical possibilities—that within the range of luminescent lighting, exemplified in the vacuum tube, and in the luminous arc and flaming arc, there is no theoretical limitation of efficiency, while in incandescent lighting there is a limitation set by the unavoidable production of all kinds of vibration, of which the useful embrace only three-quarters of an octave. By luminescence we may, as already stated, probably attain an efficiency of eight candles per watt, but should some new way of producing luminescence be discovered by which all the vibrations would have a frequency, say, between four hundred and six hundred millions of millions of cycles per second, about 50 candles per watt would be obtained. This can be done, because the firefly does it, but we do not yet know how he does it.

Discussion.

W. E. Williams, M. W. S. E.: The author neglected to point out the efficiency of the old style lime light, the lime light of hydrogen and oxygen gas flame. About what was the efficiency of that light?

Dr. Steinmetz: It is difficult to say. Comparing the amount of light produced with the heat energy of gas consumed, the efficiency was extremely low because the radiator of the vibrations was lime. But the fair way probably would be to consider only the radiation efficiency, that is, the percentage of the visible vibrations to the total vibrations sent out by the lime cylinder; that efficiency must have been fairly good because lime at that temperature has luminescent properties. I do not know what the efficiency was, but it was probably in the order of magnitude obtained with the "Mazda" lamp, say, around a candle per watt.

A SHORT DESCRIPTION OF SOME OF THE CONSTRUCTION FEATURES OF THE GREATER WINNIPEG WATER SUPPLY

By James H. Fuertes.

Presented Oct. 18, 1915.

The Greater Winnipeg Water District is now building works for securing by gravity about 100,000,000 U. S. gallons of water per day from the Lake of the Woods, which lies about 100 miles east of and some 300 feet higher, in elevation, than the City of Winnipeg.

The Greater Winnipeg Water District is a corporation which includes the City of Winnipeg, the City of St. Boniface, the Town of Transcona, the rural municipality of St. Vital and portions of the rural municipalities of Fort Garry, Assiniboia and Kildonan, all of which adjoin the City of Winnipeg.

The corporation, under the Act giving it existence, has all the rights and is subject to all the liabilities of a corporation, and has power to acquire hold and alienate both real and personal estate for all its purposes; it has power to sue and be sued, and is capable of receiving by donation, acquiring, holding, disposing of and conveying any property, real or movable, for the use of the corporation, and of becoming a party to contracts and agreements in the management of the affairs of the corporation. The objects of the corporation are the supplying of water from a permanent source within or without the Province of Manitoba for the use of the inhabitants of the District for all purposes, and has the authority to extend its operations and exercise its powers outside the limits of the Province of Manitoba subject to obtaining any legal rights required therefor from the Dominion of Canada or any other authority besides the Province of Manitoba. The powers and functions of the corporation are discharged by an Administration Board consisting of the mayor and the other members of the Board of Control of the City of Winnipeg, the mayor and one member of the Council of the City of St. Boniface, and the mayor or reeve of the municipalities of Transcona, Assiniboia, Kildonan, Fort Garry and St. Vital. The mayor of Winnipeg is the convener of and presides at meetings of the Administration Board.

Personnel.—The undertaking of the corporation is under the management of a Board of Commissioners subject to the authority of the Administration Board, consisting at present of two members, although the Act makes provision for the appointment of three commissioners; one of the members, S. H. Reynolds, C. E., was named by the Board as Chairman of Commissioners, and the second member, James H. Ashdown, a former mayor of Winnipeg, is treasurer.

The engineering work of the Greater Winnipeg Water District is under the direction of the writer as Consulting Engineer and W. G. Chace, Chief Engineer. M. V. Sauer is Assistant Chief Engineer in charge of all designs, and next in authority under Mr. Chace. The division engineers in charge of construction on the different contracts are: C. J. Bruce, Contract No. 30; R. T. Sailman, Contract No. 31; Geo. F. Richan, Contract No. 32; W. R. Davis, Contract No. 33, and A. C. D. Blanchard, Contract No. 34. Mr. D. L. McLean is assistant to the Chief Engineer and has had charge of all the studies of sands, concrete aggregates and cement testing, as well as of the permeability tests. Mr. R. W. Haven is also assistant to the Chief Engineer at headquarters. All these engineers have been on the work since the engineering corps was first organized, and participated in the surveys for the location of the aqueduct, the location and construction of the District's railway, the erection of the telephone line and the final location of the aqueduct.

Prior to the creation of the District several reports had been made for the provision of a more adequate supply of water for Winnipeg, resulting finally in the adoption of a scheme providing for bringing the water from the Lake of the Woods by gravity, this having been shown to be the most desirable source in point of view of quality and quantity of water available, the cost of securing the supply, also, being within the means of the District to be supplied.

Preliminary Work.—After the organization of the District and appointment of the commissioners and engineers the first work was to select the route for the aqueduct and prepare plans for its construction. The first undertaking was the running of a continuous line of precise levels from Winnipeg to the Lake of the Woods in order to establish bench marks along the aqueduct line for future reference, and to be sure of the accuracy of the elevations obtained during the various preliminary surveys. These precise levels were run in the winter of 1913, and indicated a difference in elevation of about a foot between the preliminary levels and the precise levels, in the hundred miles from Winnipeg to the Lake. Later the precise levels were checked by transfer across the water of the Lake of the Woods from the U. S. Government bench mark near the town of Warroad, Minnesota, at the southerly end of the Lake, making corrections for differences in barometric pressure in the series of observations which extended over two days. By means of this check the precise levels were readjusted and the difference in elevation interpolated and distributed to all the bench marks in proportion to their distance from the Lake of the Woods. The amount distributed in the 100 miles was somewhat less than one foot.

The location of the aqueduct line required a great deal of patient, hard work. For the greater part of the distance the country is practically flat, the rise toward the east averaging 3 feet to the mile, the steepest slopes being not over about 8 or 9 feet to the mile. The whole country drops gently toward the northwest but the fall is so slight that rain water has great difficulty in getting away, and consequently has formed large areas of swamps, marshes and muskegs. The sub-soil throughout practically the entire distance is a sandy clay practically impervious to water. It is this condition of imperviousness combined with the flatness of the country which has caused the remarkably large areas of swampy land. In the course of ages these swamps have become grown up with grasses and mosses; bushes and trees which thrive in wet places, have grown up generation upon generation, and gradually built up, upon the impervious sub-soil, water-soaked, compressible, spongy masses of roots and moss in a more or less advanced state of decomposition. In some places these masses or beds of moss and primitive peat reach great depths, some, a few miles to the north of the location of the aqueduct line, being known to be at least 70 feet in depth. The deepest muskeg so far encountered along the line of the aqueduct is about 15 feet. In Figure 1 is shown a section of the aqueduct trench at mile 85, where the muskeg, which is seen exposed in the side of the trench, was quite deep. The bottom of the trench is being prepared for the aqueduct by placing therein a gravel bottom and driving piles along the sides, to carry the aqueduct, which will be reinforced with steel along this section for several hundred feet, on account of a soft, yielding sub-surface stratum.

It can readily be appreciated that running lines through a country such as above described is a tedious and heart-breaking operation. The country is practically unsettled excepting along the Brokenhead and Whitemouth Rivers, the only two streams worthy the name which cross the aqueduct line between Winnipeg and the Lake, and supplies had to be packed in on the backs of porters from the nearest railway, some 15 miles to the north, or brought up to the line of the survey in canoes on the Whitemouth River, or Brokenhead River or through the Lake of the Woods from the Kenora, which is some 40 miles from the point where the aqueduct line reaches the Lake.

The preliminary surveys showed that a feasible line could be had between the two termini and the first work, to which the engineers of the District addressed themselves was to determine whether such feasible line could not be materially improved. Two features of this line commended themselves for special consideration; one was to determine whether the summit cut where the aqueduct passed into the watershed of the Lake of the Woods from the watershed of the Whitemouth River could be reduced in depth, and the other was whether by increasing the length of the line and securing a grade more nearly approaching the average slope between the two termini the total cost of the aqueduct could be materially reduced.

The country is so flat and so thickly covered with timber and underbrush that it was impossible to judge by eye of differences of elevation for any distance, and for this reason lines of levels had to be run to the north or south, and sometimes to both the north and south, of the preliminary lines, sometimes as much as 8 or 10 miles, in order to be able to place contours upon maps with sufficient accuracy to determine approximately the desired location. By pursuing this method and by then running more accurate levels over the line located approximately from the contour map, adjustments and modifications were made until finally a line was secured which passed through the critical points on the profile and gave the fewest changes

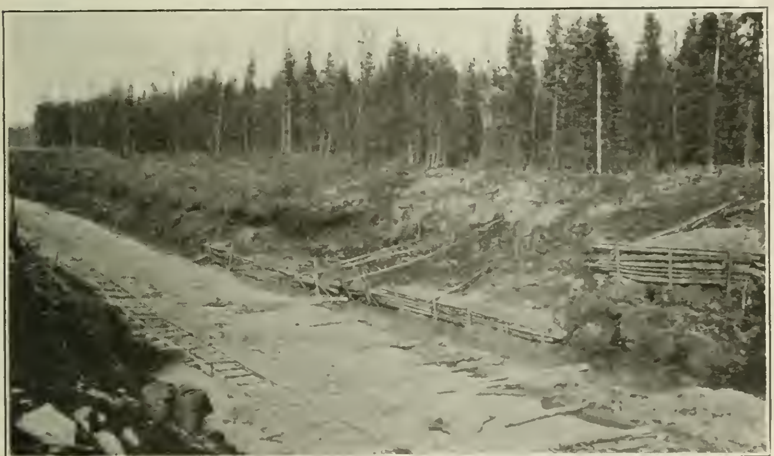
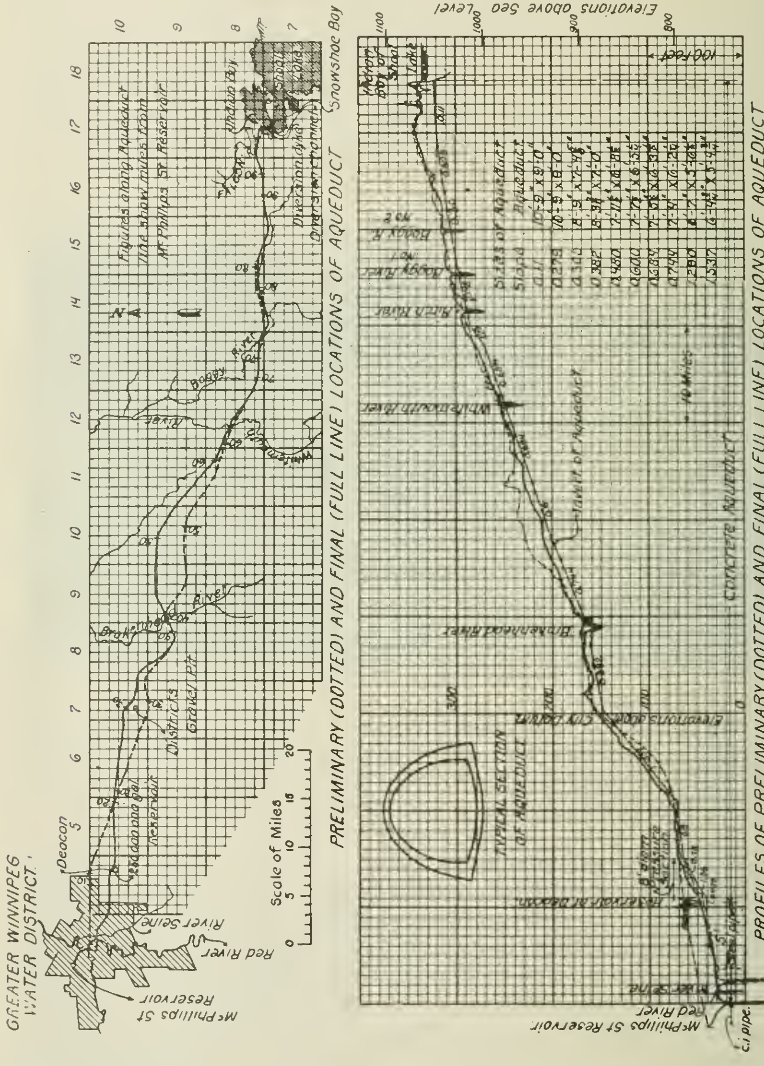


Fig. 1. Muskeg at Mile 85. Pile foundation for acqueduct required for several hundred feet because of soft sub-surface stratum. Extensive settlement (accompanied by rising of bottom of trench) shown on right. Trench had been re-excavated and covered with gravel when this view was taken.

of grade throughout the whole line. It is interesting to note that although the finally located line is longer by several miles than the preliminary line, careful estimates of cost show that it is cheaper by nearly a million dollars, the saving being largely in concrete. The condensed alignment and profiles of the preliminary line and of the line as finally located are given in Figures 2 and 3.

Construction Railroad.—Prior to entering upon the construction of the aqueduct proper it was necessary for the District to do a good deal of preliminary construction work. As can be seen from the description of the country no means of access were available for the delivery of the materials along the line of the aqueduct, the nearest railway being about 15 miles to the north, and there being practically no highways over which materials could be hauled. The first work done, therefore, was to let the contracts for the clearing of the right-of-way for the construction of a railroad from Winnipeg through to the Lake of the Woods and start the erection of a tele-



Figs. 2 and 3.

phone line. The contracts for all this preliminary work were let in the winter of 1913-14 and the railroad was laid through to the Lake by December of that year. Coincident with the construction of the railway a large amount of ditching and surface drainage was done by the District to free the ground of water in the vicinity of the aqueduct line as much as possible. Some of the off-take ditches were several miles in length. The railroad is standard gauge, with 60-pound steel rails on a heavily ballasted roadbed, the ballast being hauled from two or three gravel pits along the line opened up by the Northern Construction Company, the contractors for the building of the railroad. The cost of the road was about $1,200,000. Trains were in operation in the Spring of 1915. There are 102 miles of track built including sidings, and the equipment consists of four 52-ton Mogul locomotives, forty 20-yard air dump cars, 20 flat cars, 10 box cars, three cabooses and two coaches. Railway water tanks, sidings, miscellaneous railway buildings and engineer's quarters were established and contracts for the aqueduct proper were let during the year 1914.

Falcon River Diversion.—The water is to be taken from the westerly end of Indian Bay, a branch of Shoal Lake, which is itself a portion of the main Lake of the Woods. Indian Bay is a comparatively shallow bay. Its length is about 6 miles and its width from 1 to 3 miles, and its depth is from 24 to 26 feet over the whole area, excepting in the immediate vicinity of the shores, which shoal up more or less rapidly. Falcon River discharges into the westerly end of Indian Bay, the very dark brown drainage from the swamps lying to the northwest. In order to prevent the discoloration of the lake water by the discharge of the Falcon River into it, a dyke was built across the end of the lake and a canal cut through between the end of Indian Bay and Snowshoe Bay, which lies just to the south, and the discolored Falcon River water diverted from Indian Bay into Snowshoe Bay.

The construction of this dyke was begun in 1914 and finished in the early part of 1915. It is built of sand and gravel and riprapped on the side toward the lake with a bed of heavy stones obtained from a quarry right at the end of the dyke. The plan of the diversion works and a cross section of the dyke are given in Figures 4 and 5. Photographs Figures 6 and 7 show views of the dyke during construction and indicate the method employed. The dyke was formed by dumping the sand and gravel overboard from a bridge connecting the shore end with a scow held in position by spuds. The scow was gradually pushed out and the bridge dragged with it as the building proceeded. The cross section of the dyke as given represents the natural slopes to which the materials have settled under the water and the lines to which they were trimmed above the water level. The top of the dyke was covered with top soil and seeded with Brome grass. The results following the construction of this dyke are indicated in the following tabulations, which show that there has been a progressive reduction in the color of the water of Indian Bay.

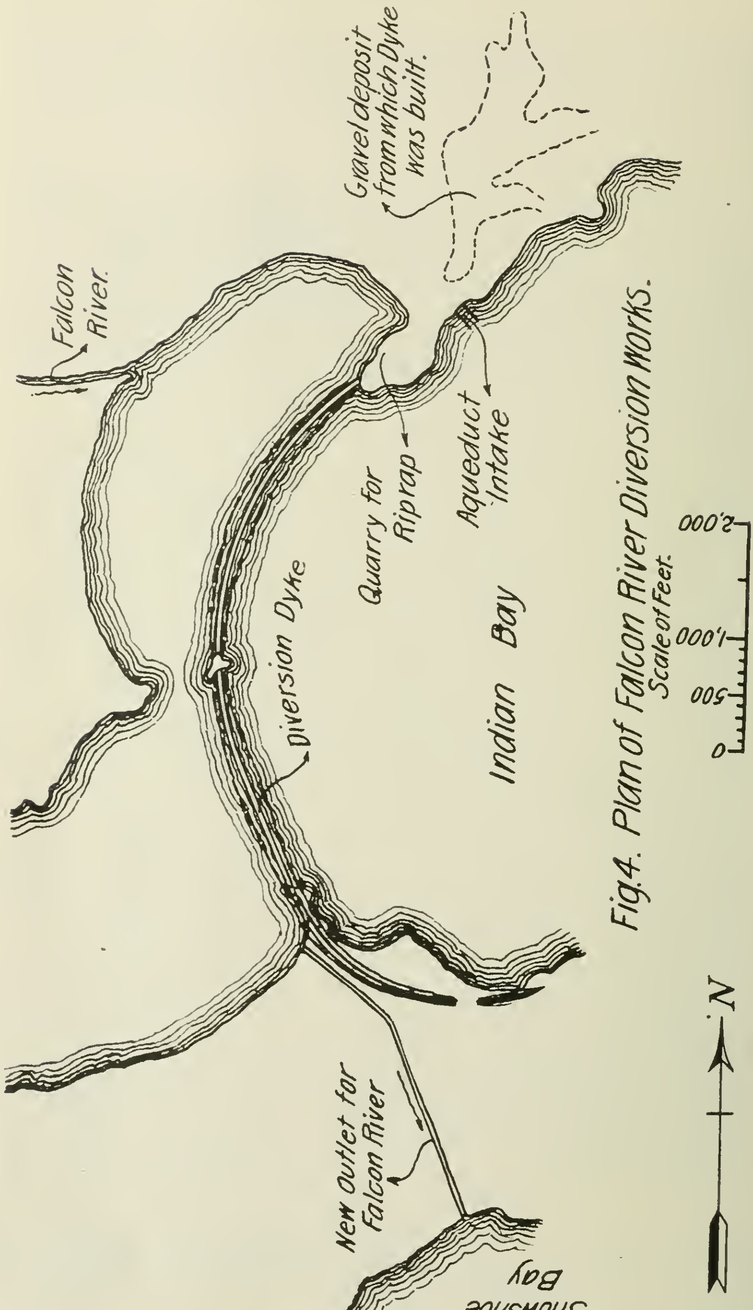


Fig. 4. Plan of Falcon River Diversion Works.

Table Showing Bleaching Out of Indian Bay Water after the Diversion of Falcon River.

Date	West Side of Dyke Near Mid-Length. (End of Bay Discolored by Falcon River.)	East Side of Dyke About Mid-Length. (Indian Bay Water.)	Opposite Proposed Intake 500 Ft. From Shore.	Remarks.
July 29, 1913.......	54	48	48	Before dyke was built.
Oct. 9, 1914........	186	46	37	Dyke about half finished.
Nov. 4, 1914.......	121	27	21	
Nov. 27, 1914......	138	27	..	
Dec. 4, 1914.......	...	..	19	
Jan. 14, 1915.......	69	23	18	
Feb. 2, 1915.......	53	15	16	
March 6, 1915......	48	15	18	
April 1, 1915.......	93	29	20	
April 14, 1915......	37	9	14	
May —, 1915.......	107	14	15	
June 7, 1915.......	107	9	14	
July 19, 1915.......	108	9	9	

The colors tabulated above were determined by standard color tubes manufactured by the Builders' Iron Foundry and rated by comparison with platinum Cobalt standards prepared in accordance with the recommendations of the report of the laboratory section of the American Public Health Association. It will be noted that since the diversion there has been a gradual reduction of color in the Indian Bay water, and also that there was no significant color reduction while the lake was covered with ice.

Aqueduct Contracts.—The work was divided into five sections and each section awarded as a separate contract; the first section which is called Contract No. 30 is 20.064 miles in length running from Deacon at mile 12.473 to mile 32.537. Contract No. 31 is 17.765 miles in length running from the end of Contract No. 30 to mile 50.302. The next contract, No. 32, is 18.201 miles in length, running from mile 50.302 to mile 68.503. The fourth contract, No. 33, is 16.089 miles in length running from mile 68.503 to mile 84.592, and the last contract, No. 34, is 12.919 miles in length running from mile 84.592 to mile 97.511. The estimated quantities of work on each contract, with the names of the contractors and the prices bid, are given in Table I.

The contracts have not yet been awarded for the steel pipe line from Deacon to the Red River nor for the tunnel under the Red River nor the 4-foot cast iron pipe line leading to the Winnipeg reservoir. The contract has been awarded, however, for core borings at the Winnipeg River crossing preparatory to making plans for this

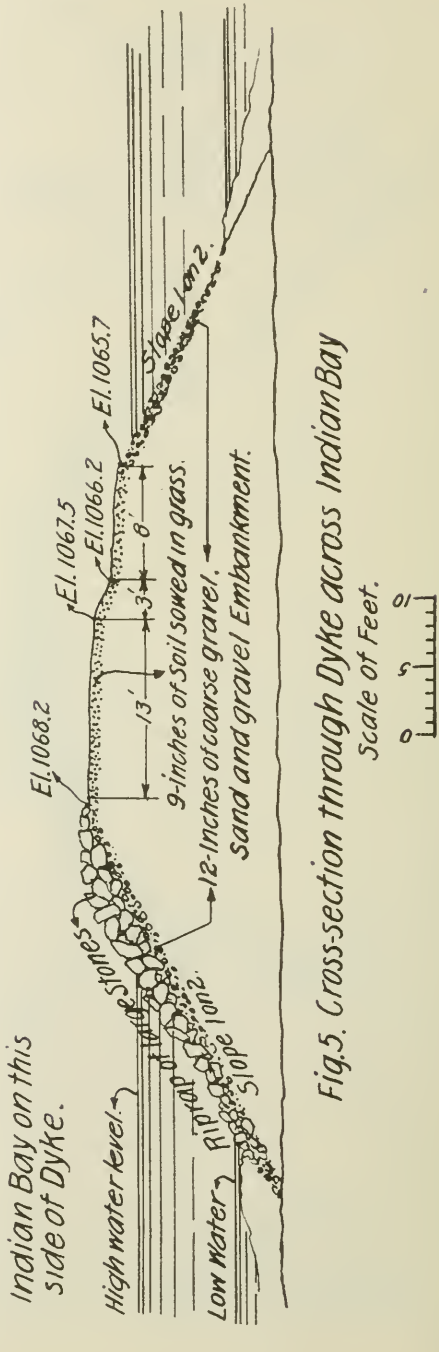


Fig. 5. Cross-section through Dyke across Indian Bay

APPROXIMATE QUANTITIES. TABLE 1. UNIT PRICES.

Description.	Contract Number 30.	31.	32.	33.	34.	Measure.	Contract Number: J. H. Tremblay & Co. 30.	Thomas Kelly & Sons. 31.	Winnipeg Aque. Const. Co. 32.	33.	34.
1. Top soil excavation	121,000	20,000	15,000	13,000	2,000	Cu. Yds.	$0.32	$0.50	$0.30	$0.30	$0.30
2. Earth excavation	190,000					Cu. Yds.	.29				
3. Earth excavation		280,000				Cu. Yds.		.60			
4. Earth excavation			358,000			Cu. Yds.			.55		
5. Earth excavation				371,000		Cu. Yds.			*1.50	.55	*1.50
6. Earth excavation					789,000	Cu. Yds.				*1.50	.55
6A. Rock excavation	300	6,000	9,000	4,000	1,000	Cu. Yds.	2.50	4.00	3.00	3.00	3.00
7. Refill and embankment	490,000					Cu. Yds.	.20				
8. Refill and embankment		429,000				Cu. Yds.		.40			
9. Refill and embankment			390,000			Cu. Yds.			.25		
10. Refill and embankment				314,000		Cu. Yds.				.25	
11. Refill and embankment					288,000	Cu. Yds.					.25
12. Foundation embankment	24,000	113,000	98,000	13,000	36,000	Cu. Yds.	.75	1.50	1.50	1.50	1.50
13. Sodding and seeding	161	95	97	107	87	Acres	15.00	200.00	100.00	100.00	100.00
14. Timber and lumber furnished and ordered left in place	1,300	2,700	1,600	1,700	2,400	M. F. B. M.	37.00	37.00	45.00	45.00	45.00
15. Piling furnished and in place		40,000	600	3,000	3,200	Lin. Ft.		.50	.60	.60	.60
16. Street piling furnished and ordered left in place		1,250	130	360	1,035	M. F. B. M.		50.00	50.00	50.00	50.00
17. Concrete in aqueduct	73,500	72,200	65,700	65,600	72,000	Cu. Yds.	6.50	6.25	9.90	9.90	9.90
18. Concrete in culverts, walls, etc.	700	2,200	725	960	500	Cu. Yds.	7.50	8.25	12.00	12.00	12.00
19. Reinforcing steel furnished in place	3,320,000	1,460,000	200,000	227,000	137,600	Lbs.	.034	.045	.05	.05	.05
20. Cast iron and steel furnished and in place	45,000	6,000	8,000	6,000	6,000	Lbs.	.07	.09	.10	.10	.10
21. Cast iron pipes and specials furnished and in place	6,000	4,500	7,000	5,000	7,000	Lbs.	.055	.05	.15	.15	.15
22. Cast iron gates and valves furnished and in place	180,000	1,000	1,200	2,000	1,000	Lbs.	.30	.12	.20	.20	.20
23. Testing portions of aqueduct	100	100	100	100	70	Portion	300.00	200.00	$300.00	300.00	300.00
24. Testing extra lengths	1,000	1,000	1,000	1,000	700	Lin. Ft.	1.50	1.00	3.00	3.00	3.00
									$3,000.00	$5,000.00	$5,000.00

*Siphon excavation.

tunnel work. The plans have not yet been drawn for the 250,000,-000-gallon reservoir at Deacon nor for the intake at Indian Bay, as these can be deferred until next year.

Progress Required.—Construction work is now progressing on all the contracts, and by the end of this working season possibly 10 per cent of the entire aqueduct may be completed and backfilled. The

Fig. 6.

Fig. 7.

schedule of progress required by the specifications calls for the completion of 6 per cent of the work by August 1st, 1914; 18 per cent by December 1st, 1914; 31 per cent by August 1st, 1916; 50 per cent by December 1st, 1916; 65 per cent by August 1st, 1917; 85 per cent by December 1st, 1917; and 100 per cent by September 1st, 1918.

TABLE 2

GREATER WINNIPEG WATER DISTRICT - TESTS OF PERMEABILITY OF CONCRETE MADE WITH VARYING PERCENTAGES OF CEMENT, SAND, INTERMEDIATE AND COARSE MATERIALS.

Purpose of Group of Tests.	Mechanical Analysis – Percentage by Weight Passing Screens: 1-1	2"	1-1/4"	1"	3/4"	1/2"	1/4"	1/8"	#10	#20	#40	#15	#100	Cement	Sand (Passing 1/8"): % of Sand by weight Passing #100 Sieve.	Sand: Ave. Wt. loose & Dry per Cu.ft.	Inter. 1/2"-1/8": Ave. Wt. loose & Dry per Cu.ft.	Coarse. 1-1/2"-1/2": Ave. Wt. loose & Dry per Cu.ft.	Gravel. 1-1/2"-1/8": Inter. to Coarse by Wt.	Gravel: Ave. Wt. loose & Dry per Cu.Ft.	Aggreg.: Ave. Wt. loose & Dry per Cu.ft.	Proportions (Loose and Dry) By Weight: Cement. Aggreg.	By Weight: Cement. Sand. Gravel.	By Weight: Cement. Sand. Inter. Coarse.	By Volume: Cement. Aggreg.	By Volume: Cement. Sand. Gravel.	By Volume: Cement. Sand. Inter. Coarse.	By Volume: 87½# bag of cement. Cu.ft. of Aggreg.	By Volume: 87½# bag of cement. Cu.ft. of Sand. Cu.ft. of Aggreg.	uee C 87 of
(2)	(3)		(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)	
Effect of Variation in Quantity of Cement (Aggregate (Ave. 8 Pits Sec.10.Tp.10-R.7E)	100		94.0	89.8	81.4	70.1	52.4	40.2	30.8	21.2	14.3	9.4	8.1	8.0	3.3	108	101	97	1:1	108	125	1 : 11.6	1 :4.03:7.48	1 :4.03:3.74:3.74	1 :9.20	1 :3.75:6.93	1 : 3.73:3.70:3.86	1 : 8.05	1 : 3.27 : 6.06	
	100		95.0	90.1	81.9	70.8	63.4	41.6	32.3	22.9	16.1	11.3	11.0	10.0	3.3	108	101	97	1:1	108	125	1 : 9.00	1 :3.15:5.85	1 :3.15:2.93:2.93	1 :7.20	1 :2.81:5.48	1 : 2.91:2.90:3.02	1 : 6.30	1 : 2.54 : 4.74	
	100		95.1	90.3	82.2	71.4	53.6	42.8	33.0	24.8	18.0	13.3	13.0	12.0	3.3	108	101	97	1:1	106	125	1 : 7.33	1 :2.57:4.76	1 :2.57:2.38:2.38	1 :5.86	1 :2.37:4.41	1 : 2.37:2.36:2.45	1 : 5.13	1 : 2.07 : 3.86	
	100		95.3	90.6	82.6	72.1	65.5	44.1	36.3	26.3	19.8	15.3	14.9	14.0	3.3	109	101	97	1:1	108	125	1 : 6.14	1 :2.15:3.98	1 :2.15:2.00:2.00	1 :4.91	1 :1.98:3.70	1 : 1.98:1.88:2.08	1 : 4.30	1 : 1.73 : 3.24	
	100		95.4	90.8	83.0	72.7	56.6	45.4	36.8	28.0	21.7	17.2	17.0	16.0	3.3	108	101	97	1:1	108	125	1 : 5.26	1 :1.84:3.42	1 :1.84:1.71:1.71	1 :4.21	1 :1.70:3.17	1 : 1.70:1.70:1.78	1 : 3.68	1 : 1.49 : 2.78	
Effect of Variation in Quantity of Cement - Aggreg. Higher in Inter. than Ave. 8 Pits Sec.10.Tp.10-R.7E	100		97.0	94.1	89.1	82.5	58.3	41.5	32.3	22.9	16.1	11.3	11.0	10.0	3.3	108	101	97	1:0.425	105	117	1 : 9.00	1 :3.15:5.85	1 :3.15:4.10:1.75	1 :7.70	1 :2.91:5.57	1 : 2.90:4.07:1.81	1 : 6.74	1 : 2.55 : 4.87	
	100		97.1	94.2	89.4	82.9	59.2	42.8	33.0	24.9	18.0	13.3	13.0	12.0	3.3	108	101	97	1:0.425	105	117	1 : 7.33	1 :2.57:4.76	1 :2.57:3.34:1.42	1 :6.26	1 :2.38:4.53	1 : 2.38:3.31:1.47	1 : 5.47	1 : 2.08 : 3.96	
	100		97.2	94.3	89.6	83.3	60.1	44.1	35.3	26.3	19.6	15.3	15.0	14.0	3.3	109	101	97	1:0.425	105	117	1 : 6.14	1 :2.15:3.99	1 :2.15:2.80:1.18	1 :5.25	1 :1.99:3.80	1 : 1.99:2.77:1.23	1 : 4.60	1 : 1.74 : 3.32	
	100		97.2	94.5	89.8	83.7	61.1	45.4	36.8	28.0	21.7	17.2	17.0	16.0	3.3	108	101	97	1:0.425	105	117	1 : 5.26	1 :1.84:3.42	1 :1.84:2.40:1.02	1 :4.50	1 :1.70:3.25	1 : 1.70:2.38:1.05	1 : 3.94	1 : 1.49 : 2.84	
Effect of Variation in Fineness of Sand (Aggreg. Ave. 8 Pits Sec.10.Tp.10-R.7E	100		95.0	90.1	81.9	70.8	53.4	41.5	32.3	22.9	16.1	11.3	11.0	10.0	3.3	108	101	97	1:1	108	125	1 : 9.00	1 :3.15:5.85	1 :3.15:2.93:2.93	1 :7.20	1 :2.91:5.42	1 : 2.91:2.90:3.02	1 : 6.30	1 : 2.55 : 4.74	
	100		95.0	90.1	81.8	70.8	53.4	41.5	33.0	24.1	17.7	13.3	13.0	10.0	8.5	111	101	97	1:1	108	121	1 : 9.00	1 :3.15:5.85	1 :3.15:2.93:2.93	1 :7.44	1 :2.84:5.42	1 : 2.84:2.90:3.02	1 : 6.52	1 : 2.48 : 4.74	
	100		95.0	90.1	81.9	70.8	53.4	41.5	33.5	25.3	19.4	15.2	15.0	10.0	15.9	114	101	97	1:1	108	125	1 : 9.00	1 :3.15:5.85	1 :3.15:2.93:2.93	1 :7.20	1 :2.76:5.42	1 : 2.76:2.90:3.02	1 : 6.30	1 : 2.42 : 4.74	
	100		95.0	90.1	81.9	70.8	53.4	41.5	33.9	25.8	20.5	16.3	16.0	10.0	19.1	115	101	97	1:1	108	124	1 : 9.00	1 :3.15:5.85	1 :3.15:8.93:2.93	1 :7.25	1 :2.74:5.42	1 : 2.74:2.90:3.02	1 : 6.35	1 : 2.40 : 4.74	
Effect of Variation in Fineness of Sand. Aggreg. Higher in Coarse than Ave. 8 Pits Sec.10.Tp.10-R.7E	100		92.8	85.2	72.8	56.2	47.5	41.5	32.3	22.9	16.1	11.3	11.0	10.0	3.3	108	101	97	1:2.98	104	124	1 : 9.00	1 :3.15:5.85	1 :3.15:1.47:4.38	1 :7.25	1 :2.91:5.82	1 : 2.91:1.46:4.52	1 : 6.35	1 : 2.55 : 4.92	
	100		92.8	85.2	72.8	56.2	47.5	41.5	33.0	24.1	17.7	13.3	13.0	10.0	8.5	111	101	97	1:2.98	104	121	1 : 9.00	1 :3.15:5.85	1 :3.15:1.47:4.38	1 :7.44	1 :2.84:5.82	1 : 2.84:1.46:4.52	1 - 6.52	1 : 2.48 : 4.92	
	100		92.8	85.2	72.8	56.2	47.5	41.5	33.5	25.3	19.4	16.2	16.0	10.0	15.9	114	101	97	1:2.98	104	124	1 : 8.00	1 :3.15:5.85	1 :3.15:1.47:4.38	1 :7.25	1 :2.76:5.82	1 : 2.76:1.40:4.52	1 : 6.35	1 : 2.42 : 4.92	
	100		92.0	85.2	72.8	56.2	47.5	41.5	33.9	25.8	20.5	16.3	18.0	10.0	19.1	115	101	97	1:2.98	104	124	1 : 9.00	1 :3.15:5.85	1 :3.15:1.47:4.38	1 :7.25	1 :2.74:5.62	1 : 2.74:1.46:4.52	1 : 6.35	1 : 2.42 : 4.92	
Effect of Variation in Fineness of Sand. Aggreg. Higher in Inter than Ave. 8 Pits Sec.10.Tp.10-R.7E	100		97.0	94.1	89.1	82.5	58.3	41.5	32.3	22.9	16.1	11.3	11.0	10.0	3.3	108	101	97	1:0.425	105	117	1 : 9.00	1 :3.15:5.85	1 :3.15:4.10:1.75	1 :7.70	1 :2.91:5.57	1 : 2.91:4.07:1.81	1 : 6.74	1 : 2.55 : 4.87	
	100		97.0	94.1	89.1	82.5	58.3	41.5	33.0	24.1	17.7	13.3	13.0	10.0	9.5	111	101	97	1:0.425	105	120	1 : 9.00	1 :3.15:5.85	1 :3.15:4.10:1.75	1 :7.50	1 :2.84:5.57	1 : 2.84:4.07:1.81	1 : 6.57	1 : 2.48 : 4.87	
	100		97.0	94.1	89.1	82.5	56.3	41.5	33.5	25.3	19.4	15.2	15.0	10.0	16.9	114	101	97	1:0.425	105	122	1 : 9.00	1 :3.15:5.85	1 :3.15:4.10:1.75	1 :7.38	1 :2.76:5.57	1 : 2.78:4.07:1.81	1 : 6.48	1 : 2.42 : 4.87	
	100		97.0	94.1	89.1	82.5	58.3	41.6	33.8	25.8	20.5	16.3	16.0	10.0	19.1	115	101	97	1:0.425	105	122	1 : 8.00	1 :3.15:5.85	1 :3.15:4.10:1.75	1 :7.38	1 :2.74:5.57	1 : 2.74:4.07:1.81	1 - 6.48	1 : 2.40 : 4.87	
Effect of Variation in Proportion of Inter to Coarse - Sand (Ave. 8 Pits Sec.10.Tp.10-R.7E) 3.3% Passing No. 100 Sieve)	100		95.0	90.1	81.9	70.8	53.4	41.5	32.3	22.9	16.1	11.3	11.0	10.0	3.3	108	101	97	1:1	108	125	1 : 9.00	1 :3.15:5.85	1 :3.15:2.93:2.93	1 :7.20	1 :2.91:5.42	1 : 2.91:2.90:3.02	1 : 6.30	1 : 2.55 : 4.74	
	100		92.8	85.2	72.8	56.2	47.5	41.5	32.3	22.9	18.1	11.3	11.0	10.0	3.3	108	101	97	1:2.98	104	124	1 : 9.00	1 :3.15:5.85	1 :3.15:1.47:4.38	1 :7.25	1 :2.81:5.82	1 : 2.91:1.46:4.52	1 : 6.35	1 : 2.55 : 4.92	
	100		97.0	94.1	89.1	82.5	58.3	41.5	32.3	22.8	16.1	11.3	11.0	10.0	3.3	108	101	97	1:0.425	105	117	1 : 9.00	1 :3.15:5.85	1 :3.15:4.10:1.75	1 :7.70	1 :2.81:5.57	1 : 2.81:4.07:1.81	1 : 6.74	1 : 2.55 : 4.87	
Effect of Variation in Proportion of Inter to Coarse (Sand (9.5% Passing #100 Sieve)	100		95.0	90.1	81.9	70.8	53.4	41.5	33.0	24.1	17.7	13.3	13.0	10.0	9.5	111	101	97	1:1	108	121	1 : 9.00	1 :3.15:5.85	1 :3.15:2.93:2.93	1 :7.44	1 :2.84:5.45	1 : 2.84:2.90:3.02	1 : 6.52	1 : 2.48 : 4.74	
	100		92.8	85.2	72.8	56.2	47.5	41.5	33.0	24.1	17.7	13.3	13.0	10.0	9.5	111	101	97	1:2.98	104	121	1 : 9.00	1 :3.15:5.85	1 :3.15:1.47:4.38	1 :7.44	1 :2.84:5.82	1 : 2.84:1.46:4.52	1 : 6.48	1 : 2.48 : 4.92	
	100		97.0	94.1	89.1	82.5	58.3	41.5	33.0	24.1	17.7	13.3	13.0	10.0	9.5	111	101	97	1:0.425	105	120	1 : 9.00	1 :3.15:5.85	1 :3.15:4.10:1.75	1 :7.50	1 :2.84:5.57	1 : 2.84:4.07:1.81	1 : 6.57	1 : 2.48 : 4.87	
Effect of Variation in Proportion of Inter to Coarse (Sand (15.0% Passing #100 Sieve)	100		95.0	90.1	81.9	70.8	53.4	41.5	33.5	25.3	19.4	15.2	16.0	10.0	15.9	114	101	97	1:1	108	125	1 : 9.00	1 :3.15:5.85	1 :3.15:2.93:2.93	1 :7.20	1 :2.76:5.42	1 : 2.76:2.90:3.02	1 : 6.30	1 : 2.42 : 4.74	
	100		92.8	85.2	72.8	56.2	47.5	41.5	33.5	25.3	19.4	15.9	16.0	10.0	15.9	114	101	97	1:2.98	104	124	1 : 9.00	1 :3.15:5.85	1 :3.15:1.47:4.38	1 :7.25	1 :2.76:5.82	1 : 2.76:1.46:4.52	1 : 6.35	1 : 2.42 : 4.92	
	100		97.0	94.1	89.1	82.5	58.3	41.5	33.5	25.3	19.4	15.8	16.0	10.0	15.8	114	101	97	1:0.425	105	122	1 : 8.00	1 :3.15:5.85	1 :3.15:4.10:1.75	1 :7.36	1 :2.76:5.57	1 : 2.76:4.07:1.81	1 : 6.46	1 : 2.42 : 4.87	
Effect of Variation in Proportion of Inter to Coarse (Sand (19.1% Passing #100 Sieve)	100		95.0	90.1	81.9	70.8	53.4	41.5	33.9	25.9	20.5	16.3	16.0	10.0	19.1	115	101	97	1:1	108	124	1 : 9.00	1 :3.15:5.85	1 :3.15:2.83:2.83	1 :7.25	1 :2.74:5.42	1 : 2.74:2.90:3.08	1 : 6.35	1 : 2.40 : 4.74	
	100		92.8	85.2	72.8	56.2	47.5	41.5	33.8	25.8	20.5	16.3	16.0	10.0	19.1	115	101	97	1:2.98	104	124	1 : 9.00	1 :3.15:6.85	1 :3.15:1.47:4.38	1 :7.25	1 :2.74:5.82	1 : 2.74:1.46:4.52	1 : 6.35	1 : 2.40 : 4.92	
	100		97.0	94.1	89.1	82.5	58.3	41.5	33.8	25.8	20.5	16.3	18.0	10.0	19.1	115	101	97	1:0.425	105	122	1 : 9.00	1 :3.15:5.85	1 :3.15:4.10:1.75	1 :7.38	1 :2.74:5.57	1 : 2.74:4.07:1.81	1 : 6.40	1 : 2.40 : 4.87	
Effect of Variation in Proportion of Sand to Gravel	100		95.8	91.5	84.5	75.0	60.2	50.0	39.0	27.6	19.4	13.6	13.3	12.0	3.3	108	101	97	1:1	108	120	1 : 7.33	1 :3.17:4.16	1 :3.17:2.08:2.08	1 :6.11	1 :2.92:3.87	1 : 3.03:2.06:2.16	1 : 5.35	1 : 2.56 : 3.38	
	100		95.3	90.7	82.8	72.5	56.2	45.0	35.4	25.5	18.4	13.4	13.1	12.0	3.3	108	101	97	1:1	108	119	1 : 7.33	1 :2.75:4.58	1 :2.75:2.29:2.28	1 :6.16	1 :2.54:4.26	1 : 2.64:2.27:2.38	1 : 5.38	1 : 2.22 : 3.72	
	100		95.1	90.3	82.2	71.4	53.5	42.8	33.8	24.6	18.0	13.3	13.0	12.0	3.3	108	101	97	1:1	108	125	1 : 7.33	1 :2.57:4.76	1 :2.57:2.38:2.38	1 :5.86	1 :2.38:4.41	1 : 2.38:2.38:2.45	1 : 5.13	1 : 2.08 : 3.86	
	100		94.5	89.0	78.8	67.5	46.3	35.0	28.3	21.4	16.5	13.0	12.6	12.0	3.3	108	101	97	1:1	108	116	1 : 7.33	1 :1.91:5.42	1 :1.81:2.71:2.71	1 :8.27	1 :1.77:5.02	1 : 1.77:2.09:2.79	1 : 5.47	1 : 1.55 : 4.40	
	100		94.2	88.4	78.9	66.0	45.8	32.0	26.2	20.2	15.9	12.8	12.7	12.0	3.3	108	101	97	1:1	108	116	1 : 7.33	1 :1.67:5.68	1 :1.87:2.63:2.83	1 :8.33	1 :1.55:5.24	1 : 1.55:2.80:2.81	1 : 5.53	1 : 1.35 : 4.60	
Effect of Variation in Proportion of Sand to Gravel (1/2" Maximum size of stone	-		-	-	-	100.	73.4	55.0	42.5	29.8	20.4	13.8	13.4	12.0	3.3	108	101	-	-	-	115	1 : 7.33	1 :3.58:3.75	1 :3.58:3.75 -	1 :8.37	1 :3.30:3.71	1 : 3.30:3.71 :	1 : 5.57	1 : 2.88 : 3.25	
	-		-	-	-	100.	70.4	50.0	36.8	27.6	19.4	13.6	13.3	12.0	3.3	108	101	-	-	-	115	1 : 7.33	1 :3.17:4.16	1 :3.17:4.16 -	1 :8.37	1 :2.85:4.12	1 : 2.85:4.12 -	1 : 5.57	1 : 2.57 : 3.60	
	-		-	-	-	100.	67.6	45.0	35.4	25.5	18.4	13.4	13.1	12.0	3.3	108	101	-	-	-	115	1 : 7.33	1 :2.75:4.58	1 :2.75:4.58 -	1 :8.37	1 :2.54:4.54	1 : 2.54:4.54 -	1 - 5.57	1 : 2.23 : 3.97	
	100		95.0	90.1	81.9	70.8	53.4	41.5	32.3	22.9	16.1	11.3	11.0	10.0	3.3	108	101	97	1:1	108	125	1 : 9.00	1 :3.15:5.85	1 :3.15:2.93:2.93	1 :7.20	1 :2.91:5.42	1 : 2.91:2.90:3.02	1 : 6.30	1 : 2.54 : 4.74	
	100		95.0	90.1	81.8	70.8	53.4	41.5	32.3	22.8	16.1	11.3	11.0	10.0	3.3	108	101	97	1:1	108	125	1 : 9.00	1 :3.15:5.85	1 :3.15:2.93:2.93	1 :7.20	1 :2.81:5.42	1 : 2.91:2.90:3.08	1 : 6.30	1 : 2.54 : 4.74	
Effect on Compressive Strength of Substitution of Limestone Screenings for Sand	100		95.0	90.1	81.8	70.8	53.4	40.5	34.8	26.2	21.2	17.9	16.8	10.0	21.6	-	101	97	1:1	106	-	1 : 9.00	1 :3.15:5.85	1 :3.15:2.93:2.93	-	-	-	-	-	
	100		95.0	90.1	81.8	70.8	53.4	41.5	32.3	22.8	16.1	11.3	11.0	10.0	3.3	108	101	97	1:1	108	125	1 : 9.00	1 :3.15:5.85	1 :3.15:2.93:2.93	1 :7.20	1 :2.81:5.42	1 : 2.91:2.90:3.02	1 : 8.30	1 : 2.54 : 4.74	

...ties of Material Set Concrete. ...pot ...reg. in lbs.	Per Cu.Yard Cement 350 lb. bbls.	Per Cu.Yard Loose & dry Aggreg. in Cu.Yds.	Density = Vol. of Solid Particles / Vol. of Set Concrete. Sp.Gr. of Aggreg. 2.65 Sp.Gr. of Cement 3.10	Average Tensile Proportions by Wt. Cement–Sand	Average Tensile Water % by Wt. of Dry Material	Strength of Mortar. Lbs. per Sq. Ins. Age in Days. 7	28	90	Ultimate Compressive Strength in lbs. per square inch of 8" Diam. X 16" Cyls. Age in Days. 28.A.	28.B.	90	Permeability Tests Age in Days.	Press. in lbs. per sq.ins.	Collected leakage in C.C. 5th Hour.	Flow into specimen minus water around pips in C.C. 5th Hour.	Remarks.
33)	(34)	(35)	(36)	(37)	(38)	(39)	(40)	(41)	(42)	(43)	(44)	(45)	(46)	(47)	(48)	(49)
-	–	–	–	1 :4.03	10.3	168	308	420	522	–	923	47	40	+	+	+ Leaked Freely (631 c.cs. in 30 mins.)
-	–	–	–	1 :3.15	10.1	223	410	524	825	749	–	95	80	0 +	16.0	+ Overnight showed small leakage (25th Hour = 1.6 c.cs.)
23	1.27	0.98	.822	1 :2.57	11.1	234	431	579	1488	–	2716	93	80	0 +	8.4	+. 24th Hour (End of Test) showed damp spot on bottom
19	1.43	0.95	.814	1 :2.15	11.3	318	433	515	1634	1758	–	93	80	0	6.8	Appeared Dry throughout Test
16	1.70	0.93	.818	1 :1.84	11.9	308	486	654	1745	–	3192	93	80	0	2.8	Appeared Dry throughout Test
24	1.06	1.06	.818	1 :3.15	10.1	223	410	524	1064	–	1806	42	80	8.6	72.7	Damp spots on Sides. White Flaky Suspended Matter through Bottom.
18	1.24	1.01	.796	1 :2.57	11.1	234	431	579	–	–	–	41	80	4.8	35.4	Moist spot on side
14	1.43	0.99	.787	1 :2.15	11.3	318	433	515	–	–	–	42	80	0.0	18.1	Moist spot on side which dried up during Test
13	1.65	0.97	.793	1 :1.84	11.9	308	486	654	–	–	–	42	80	0.0	5.1	Dry on Sides
-	–	–	–	1 :3.15	10.1	223	410	524	825	749	–	53	80	4.0	55.7	Dry on Sides & Top. Tested @ 95 Days. See Group A.
22	1.04	1.01	.807	1 :3.15	11.6	301	377		692	–	1765	41	–	–	–	Poor specimen (Stone segregated)
22	1.04	0.98	.806	1 :3.15	11.8	300	391		613	648	–	42	80	0.8	23.0	Appeared dry on sides & Top
24	1.06	1.00	.823	1 :3.15	12.3	265	365		1139	–	2038	42	80	1.0	21.0	Flow thru. bottom 50 C.C. and into spec.abt. 60 C.C.per hr.
25	1.07	1.01	.828	1 :3.15	10.1	223	410	524	821	–	1977	41	80	0	37.3	Damp spots on sides
23	1.06	1.02	.818	1 :3.15	11.6	301	377		962	1000	–	42	80	0	11.1	Appeared dry all over throughout test
24	1.06	1.00	.818	1 :3.15	11.8	300	391		1076	1080	–	42	80	1.3	30.1	Moist spots on sides which dried up
25	1.07	1.01	.825	1 :3.15	12.3	265	365		–	1024	1950	42	80	0	13.8	Sides dry
24	1.06	1.06	.818	1 :3.15	10.1	223	410	524	1064	–	1606	42	80	8.6	64.1	Damp spots on Sides.White flaky suspended matter through Bottom.
22	1.05	1.02	.807	1 :3.15	11.6	301	377		998	–	1597	43	80	60.0	180	Damp spots on sides.White flaky suspended matter through Bottom.
23	1.05	1.01	.820	1 :3.15	11.8	300	391		889	–	1830	44	80	50.0	120	Moist spots on sides
21	1.04	0.99	.811	1 :3.15	12.3	265	365		1011	–	1825	42	80	0	30	Sides dry
-	–	–	–	1 :3.15	10.1	223	410	524	825	749	–	53	80	4.0	55.7	Dry on sides and top. Tested @ 95 days. See Group A.
25	1.07	1.01	.828	1 :3.15	10.1	223	410	524	821	–	1977	41	80	0	37.3	Damp spots on sides.
24	1.06	1.00	.818	1 :3.15	10.1	223	410	524	1064	–	1606	42	80	8.8	64.1	Damp spots on sides.White flaky suspended matter through Bottom.
22	1.04	1.01	.807	1 :3.15	11.6	301	377		692	–	1765	41				Poor specimen (Stone segregated)
23	1.06	1.02	.818	1 :3.15	11.6	301	377		962	1000	–	42	80	0	11.1	Appeared dry all over throughout test
22	1.05	1.02	.807	1 :3.15	11.6	301	377		998	–	1597	43	80	60.0	18.0	Damp spots on sides.White flaky suspended matter thru. Bottom.
22	1.04	0.98	.806	1 :3.15	11.8	300	391		613	648	–	42	80	0.6	23	Appeared dry on sides & top
24	1.06	1.00	.818	1 :3.15	11.8	300	391		1076	1080	–	42	80	1.3	30.1	Moist spots on sides which dried up
23	1.05	1.01	.820	1 –3.15	11.8	300	391		889	–	1830	44	80	50.0	120	Moist spots on sides
24	1.06	1.00	.823	1 :3.15	12.3	265	365		1139	–	2038	42	80	1.0	21.0	Flow thru. bottom 50 C.C. and into spec. abt. 60 C.C.per hr.
25	1.07	1.01	.825	1 :3.15	12.3	265	365		–	1024	1950	42	80	0	13.8	Sides dry
21	1.04	0.99	.811	1 :3.15	12.3	265	365		1011	–	1825	42	80	0	30.0	Sides dry
21	1.27	1.01	.818	–	–	–	–	–	1823	–	2949	42	80	0	7	Sides dry
20	1.27	1.01	.810	–	–	–	–	–	1616	–	2896	42	80	0	6.6	Sides dry
23	1.27	0.98	.822	–	–	–	–	–	1488	–	2716	93	80	0	8.4	24th Hour
21	1.27	1.05	.820	–	–	–	–	–	1435	–	2443	42	80	0	17.6	Sides dry
22	1.28	1.05	.822	–	–	–	–	–	1302	–	2145	42	80	0	4.0	Dry on sides and top. Stony Mix
18	1.24	1.03	.797	–	–	–	–	–	1420	–	–	42	80	0	27.7	Sides dry
16	1.23	1.01	.786	–	–	–	–	–	1208	–	2126	42	80	0	40.0	Sides dry
19	1.25	1.03	.802	–	–	–	–	–	1269	–	1988	41	80	0	16.0	Sides dry. Stony Mix
15	0.99	0.93	.765	–	–	–	–	–	–	–	–	42	80	0	26.1	Dry on sides and top
-	–	–	–	1 :3.15	10.1	223	410	524	825	749	–	53	80	4.0	55.7	Dry on sides and top. Tested @ 95 days – See Croup A.
23	1.05	–	.813	–	–	–	–	–	969	–	1513	–	–	–	–	
-	–	–	–	1 :3.15	10.1	223	410	524	825	749	–	53	80	4.0	55.7	Dry on sides and top, Tested @ 95 days. See Group A.

In case the contractors fail to maintain the rate of progress stated in this schedule there is due and payable by the contractor to the District as liquidated damages $200.00 per day for each working day during which the work remains less fully completed than required at the specified dates, with the exception that prior to September 1st, 1918, no damages are charged by the District between November 15th in any year and May 1st next following. In case the contractors' rate of progress improves so the amount of work accomplished at any of the stated dates shall equal the amount required to be done at such dates rebates will be allowed in compensation therefor.

Excavation Plants.—The construction methods employed by the different contractors are quite interesting. The contractor for Contract No. 30, which is the prairie section, the greater part of which is through cleared and cultivated land, is excavating part of his

Fig. 8. Walking Dredge.

trench with a walking dredge and part with teams and scrapers. The walking dredge is a barnlike structure carried on four pads, one at each corner, with an intermediate pad at each side arranged so that by means of chains and winches the weight can be shifted from the four corner pads to the two intermediate pads, and the whole structure pushed forward by chains working on the legs resting on these pads. The machine straddles the trench and digs forward, throwing the excavated material to one side in a waste bank. Figure 8 shows the walking dredge working in front of the contractor's camp at Mile 24. The contractor for Contract No. 31 is using small Thew shovels for excavating the trench, putting all his waste along the north side of the trench; and the contractor for contracts Nos. 32, 33 and 34 is using drag line machines for excavation and dumping his excavated materials along the south side of the trench to form an embankment upon which to place the track for the conveyance of concrete and other materials to the work. These drag line machines stand at the end of the trench and work backwards, the bucket being dragged toward the machine and then swung out to the side to form the dump as stated. The machine is carried upon pads of heavy timber built in rectangular form about 8 feet wide and some 16 feet long, their area being calculated so as to bring the unit pressures upon the bottom of the pads to very small amounts; the machines are working successfully upon muskegs so soft as to be hardly able to bear the weight of a man. The machine moves itself forward by first picking up the pad nearest the end of the excavation and swinging it around behind itself in line with the trench, skids being then laid down upon the extension of the pads, upon which the machine pulls itself back by anchoring the drag line bucket in the ground behind, and dragging itself along on the skids on rollers made of 6-inch pipe. The rollers are then blocked and the machine proceeds with the digging of the trench. Moves are made very quickly, the machine doing its own grubbing for the placing of the pads. On account of the considerable cost of coal all these machines are provided with superheaters and every device for getting the greatest economy out of the fuel.

Concrete Plants.—The contractors for contracts Nos. 30 and 31 have very similar arrangements for handling the concrete. These consist of a track along the south side of the trench upon which the concrete mixer moves upon a car, the mixer being turned by a steam engine. Each contractor is required by the specifications to provide a platform along the District's railway, 300 feet long, upon which the District is to dump the gravel and sand. In order to get these materials to the mixers the contractors for contracts Nos. 30 and 31 have each provided a large stiff-leg derrick mounted upon trucks, on a broad gauge track, with bottom dump buckets holding 16 cubic feet. The sand and gravel is shoveled from the platforms in to the buckets and then swung around by the boom of the stiff-leg derrick and transported to the mixer; or else the concrete car is run back to a point opposite the stiff-leg. A good deal of difficulty has been experienced with these plants, owing to the very heavy weights which cause the truck wheels to break, thus delaying the whole work until new wheels are secured and the necessary repairs made. Ordinary cast iron wheels do not give satisfactory service and experiments with different grades of chilled cast iron, semi-steel and other materials have not yet secured a wheel that will stand the work; the trucks will probably have to be replaced by others with more wheels.

The contractor for Contracts Nos. 32, 33 and 34 has his concrete mixer located upon an elevated cribbing near the center of the length of his gravel platform, and an elevated trestle curves from the mixer both ways to meet the track laid on top of the dump along the south side of the excavation. A short track also runs the whole length of the gravel platforms and the gravel is shoveled into small dump cars which are pushed to the mixer site and elevated to the mixer in a boot worked by a chain from an engine which turns the mixer. The concrete is dumped from the mixer into small dump cars made especially for the work and hauled to the work by gasoline dinkeys on a narrow gauge track and shot down into the work through spouts. The maximum distance to which the concrete is transported from the mixer is about one-half mile; no difficulties have appeared in this long transportation, there being no segregation of the materials in the cars, and no difficulty in dumping the concrete even at the extreme ends of the work.

Forms.—All the contractors are using Blaw collapsible steel forms for the construction of the arch. The inverts are laid in alternate

Fig. 9. Troweling Invert.

blocks 15 feet long with copper expansion strips, having a V-shaped groove lengthwise of the center, at the end of each invert joint, steel forms being provided and set accurately to line and grade for the finishing of the inverts. Figure 9 shows the placing of invert sections at mile 32 on Contract No. 31. After a set of blocks has been laid and when the concrete is sufficiently hard the headers are taken off and the intermediate sections then poured to make a continuous invert. The arches are built in 45-ft. lengths with copper expansion joints at each end, the whole length of arch being formed in one continuous operation. The interior forms are moved on travelers on a 2-ft. gauge track laid on sized blocks upon the invert floor and accurately lined up, the forms being carried on jacks integral with the travelers and lined up by means of turn-buckles on rods hinged to the traveler frame. After a section of interior forms has been put in place the carrier is run out and the forms bolted up tightly, their surfaces being made flush and uniform. Figure 10 shows the interior form being moved ahead at mile 32 on Contract No. 31.. The exterior forms are made in 5-ft. sections bolted together to form the full 45-ft. length and are handled in different ways by the different contractors; some take them apart and move them by hand; some pick up each outside half as a unit and swing it forward; and some have a special carrier made which straddles the whole construction in the trench and runs on an auxiliary track (directly outside the arch) which picks up the whole outside form for the full length of 45 ft. and transports it as a unit, to the next section. Figure 11 shows one of these travelers with the exterior form lifted clear of the arch. Beyond are seen several alternate sections of completed

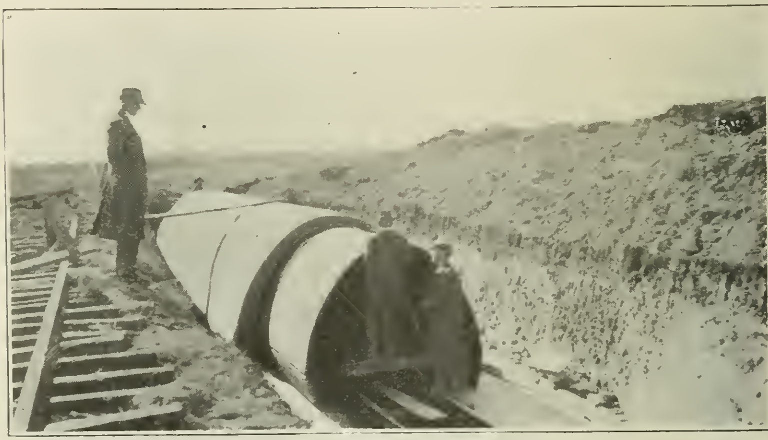


Fig. 10. Interior Form Being Moved Ahead.

arch. The arches are concreted in alternate lengths, the gap being filled by moving the forms back or forward as the case may be. Considerable difficulty has been had in holding the forms in line and surface during concreting owing to some structural imperfections and defects, but these are gradually being overcome and a system worked out by which the delays, now necessary to line up the surfaces and adjust the braces, will be greatly reduced.

For the screeding of the concrete in the inverts the most satisfactory device yet used on the work has been a 3½ by 3½-inch angle iron 16 feet long with handles arranged so that two men can pull at each end. Lighter screeds are not satisfactory because they will not push down the stones in the concrete sufficiently to enable the finishers to afterward obtain a smooth surface. Considerable experience has been required in the handling of the screeds to get a good invert. If the concrete stones come to the surface the floating and traveling produces a wavy face no matter how much care may be taken by the men, but the heavy screed, moved slowly and in a way to press down rather than dig up the surface, produces a very good result by going over the face only two or three times; and the trowelers can then get on a plank across the trench and trowel the surface to a very good finish.

To guard against leakage where the arch comes down upon the sides of the invert a strip of soft pine wood ⅝-inch thick by 1¾ inches high is sunk into the concrete about half its depth throughout the whole length of each side of each pad; and where two invert blocks join a little pine plug is driven in tightly between the ends of abutting wood strips. Leakage between the invert joints themselves

Fig. 11. Outside Traveler for Moving Outside Forms.

is prevented by the copper expansion strip already mentioned. This strip is about 6 inches wide and rolled with a groove about ⅜-inch high through the center, the edges of the groove being crimped close together to prevent entrance of mortar when the concrete is placed. The copper strip is bolted tightly through the bulkhead at the end of the invert section leaving about 3 inches to project into the concrete. The same detail is employed in the ends of the arches at the end of each 45-ft. length, the copper being bolted tightly into the bulkhead form at the ends of the arch. Figure 12 shows both the copper strip at the expansion joint and the wood strip in the edges of the invert pad to stop leakage. Mr. W. G. Chace, Chief Engineer of the work, is standing in front of the arch. The interior forms, in place, are shown, the exterior forms and bulkhead having been removed.

It has been found quite difficult to educate the men placing the concrete in the arch forms to properly spade the material so as to prevent the formation of air holes on the interior face of the concrete. Most of the labor employed is foreign and few of the men can speak English, and, as is usually the case, they will persist in spading too violently and without interest in the work. Better results are being secured, however, as the work progresses and some of the last arches poured do not show any imperfections or air holes.

Foundations.—Throughout the greater part of the work so far done an excellent bottom has been obtained in the trenches although in a few places springs have had to be stopped and considerable pumping resorted to in order to keep the water down. In some places the natural bottom has been too soft at the elevation of the invert to carry the work and in such places the soft material has all been

Fig. 12. Inside Forms in Place.

removed and an artificial bottom prepared by flooding the trench with water to a depth of a foot or two, dumping sand or gravel into the trench and casting it so that it settles into the water, the water level being kept always higher than the top of the fill. These foundation fills in cuts are carried up a few inches higher than the required elevation and the water is then pumped or drained out of the trench so that it passes down through the gravel instead of flowing off over the surface. By this means it has been possible to prepare a bottom so tight and hard that the invert can be laid on it almost as soon as the water is drained out, without fear of further settlement. Figures 13 and 14 show two stages in the formation of foundation fills in cuts. The sand and gravel placed this way pack so tightly that it is necessary to use picks and mattocks to do the trimming for the reception of the invert.

The material used for these foundation fills in cuts is, with the exception of a limited amount of pit-run material, the excess sand from the District's gravel plant, a material which would have to be wasted if not used in this manner, because the gravel pit contains more sand than is required to make an economical concrete aggregate.

District Furnishes Cement, Sand and Gravel.—Under the contracts awarded for the construction of the works the District supplies its contractors with the cement, sand and gravel necessary for the construction of the works. The sand and gravel is delivered to the contractor on his platforms for 75 cents per cubic yard, and the cement is delivered to the contractor at the cost to the District, which cost includes the cost of the cement, cost of inspection, handling, hauling and delivering of the cement to the contractor with a rebate for the sacks returned. The contractor's prices for concrete include the cost of the gravel and sand, but do not include the cost

Fig. 13.

of the cement, the cement being charged to the contractor as it is delivered to him and credited as it is used in the work.

Under the adopted policy of supplying the contractors with sand and gravel the District has been obliged to open a large gravel pit and install excavating machinery, tracks, dinkey locomotives, dump cars and a plant for grading the materials. The materials excavated from the pit are brought to this plant on an elevated track in 6-yard dump cars and dumped through a grizzly which leads to the foot of an elevator. The materials passing through the grizzly are carried by a belt and bucket elevator to a rotary screen in the top of the screen house which separates the material into three sizes. The screen is in three sections, one having ½-inch holes, the next having inch holes and the last 2½-inch holes. Since the material, as excavated from the gravel pit, contains a small percentage of moisture, it was found impracticable to screen it through fine screens owing to the clogging of the meshes. After screening, the materials pass from the storage bins under the screen through chutes leading to a belt conveyor, upon which the different sizes of material are spouted from the bins in the correct proportions to form a concrete aggregate. From the belt the material discharges into the boot of a second elevator which raises it to the top of the screen house and dumps it upon other belt conveyors which drop it into storage bins from which the 20-yard air dump cars are loaded. An inspector stands at the end of the lower belt conveyor and samples the materials carried by the belt, from time to time, and changes the proportions of fine, intermediate and coarse materials as required. The over-size, which passes through the rotary screen, goes back to a jaw crusher, which breaks up the stones, and they in turn are thrown back through the boot under the grizzly and carried up again to the rotary screen. A gyratory crusher has also been in-

Fig. 14.

stalled at the foot of the grizzly for breaking up large stones which will not pass through the 3-inch spaces between bars of the grizzly. The storage bins have not as yet been a success, the difficulty being that as the material drops from the belt into the bins the sand falls straight down and the stones, jumping further, run down the outside; this produces a very extensive segregation of the materials. Devices are now being installed, however, to prevent this so that the storage capacity of these bins may be utilized. Up to the present time the only extra storage that has been available at the plant has been in the 20-yard air dump cars. The material is spouted directly to these cars from the belt without appreciable segregation. The plan proposed for preventing the segregation of the materials in the storage bins is to have a vertical telescopic chute in sections, hung at the end of each belt so that the materials will fall down through this chute; and as the chute fills up the lower sections will be raised progressively to allow the materials to spread as the bin fills up. It is a device used extensively in collieries to prevent the breaking up of the coal when loading into storage bins, and it is believed it will work successfully to prevent the segregation of the materials as loaded into the storage bins. No difficulty will be experienced in loading materials from the storage bins to the cars.

Characteristics of Concrete Aggregate.—Owing to the percentage of sand in the gravel pit it is necessary to dig considerably more material than can be made into concrete aggregate. Thus during August there was excavated at the pit approximately 24,000 cubic yards of material, of which 6,000 cubic yards was stripping and 18,000 cubic yards of sand and gravel; of the 18,000 cubic yards, 13,000 cubic yards were concrete aggregate, a large proportion of which contained 50% of sand, and 5,000 cubic yards was ballast and foundation fill material. It is desirable that the percentage of sand in the concrete aggregate should not exceed 35% of the whole in order to have an economical concrete. With a larger percentage of sand the amount of cement required to make a water-tight concrete has to be increased. Studies are being made of means of operating the pit in such a way as to reduce the amount of extra excavation considerably. The screening plant can turn out 100 cubic yards per hour of sized and mixed material without difficulty, but when the material comes to the plant from the pit with 60% to 75% sand it chokes the hoppers and reduces the output aggregate. In order to avoid delaying the contractor by shortage of gravel during the coming year it has been decided to open another gravel pit near the eastern end of the work, at about mile 80, of as great a capacity as the existing plant, which is near the western end of the work between miles 30 and 31.

Under the terms of the contract the District agrees to deliver the sand and gravel to the contractor at a stated price per cubic yard. Actually the District is shipping these mixed, but billed as sand and gravel in accordance with the ratios of the volumes that the sand and gravel would make separately, these having been determined from an extended laboratory study of the materials. It would be impossible, within the limits of the present paper, to do justice to this phase of the subject, but for the information it contains a tabulated summary of some of the results of special tests made for permeability with different mixtures of sand, intermediate and coarse materials, and with varying percentages of cement, is given in Table 2. It will be noted that with a proper proportioning of the materials, particularly of the sand, by using certain percentages of sand passing the 100-mesh screen, it was possible to make concrete that was water-tight under 80 lbs. pressure per square inch, with about one Canadian barrel of cement per cubic yard of concrete. The Canadian barrel contains 350 lbs. of cement, instead of about 384 lbs., the customary net weight of the U. S. barrel.

From a long series of samples of the materials from test pits in the gravel deposits at the pit it was found that the average run of the better samples contained about 3.3% of fine sand passing the 100-mesh sieve, the percentage of sand to total aggregate varying between quite wide limits. It was also recognized that it would be desirable from the point of view of economical development to use as large a proportion of sand in the final aggregate as safety would permit, bearing in mind that the amount of cement required to make tight concrete should be kept to a minimum. The allowable percentage of sand was finally fixed at 35% of the total aggregate, by

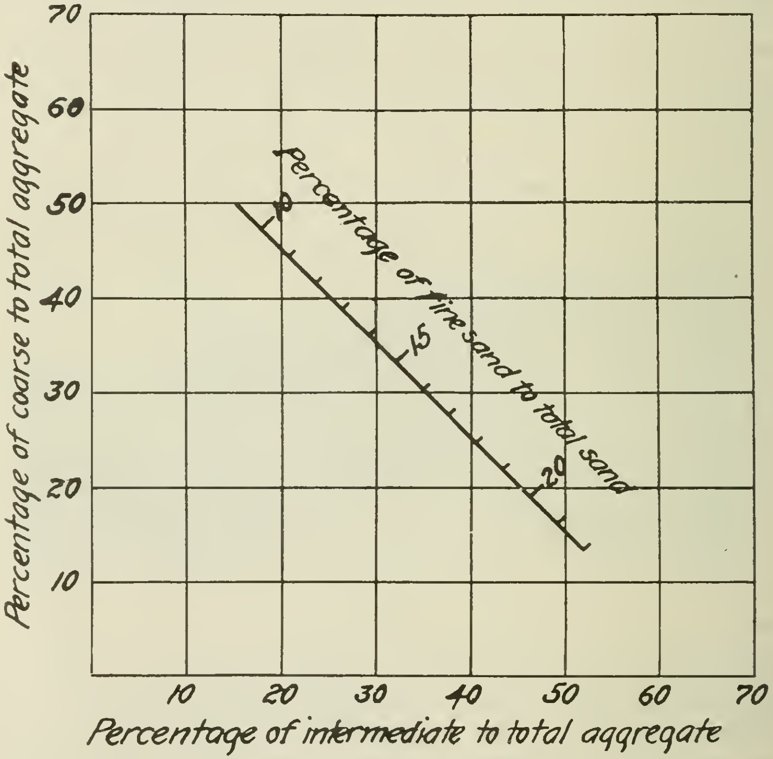


Fig. 15.

weight, and the series of tests for permeability, above recorded, are based largely on this percentage, although a few tests were made with larger and smaller percentages.

Figure 15, made up from the data in Table 2, shows the percentages of fine sand (passing the 100-mesh sieve) required to make water tight concrete with 10% of cement (370 lbs. of cement per cubic yard of set concrete) when the sand is 35% by weight of the total aggregate, with varying percentages of intermediate and coarse materials.

Using 12% cement, with sand having 3.3% passing the 100-mesh sieve, water tight concrete could be made with sand varying from 23% to 43% of total aggregate and with intermediate and coarse, in equal proportions varying from 77% to 57% respectively, or, if coarse were absent, with sand at 35% and intermediate at 65%. Fairly good results were obtained with 12% cement even with 49% sand and 51% intermediate, but this concrete slowly absorbed considerable water, showing a fairly large percentage of very small voids.

In order to be on the side of safety, in starting a new plant, the minimum quantity of cement that has been used when aggregate containing 35% sand has been shipped out, has been 12%, corresponding to about 1.27 bbls. (Canadian) to the cubic yard. The first cut in the gravel pit, arranged for a convenient layout for operating conditions has taken the excavating machines into a part of the deposits running high in sand, and, in order to keep the total sand in the finished aggregate down to 35% required a considerable wastage of sand after screening, which cuts down the net output and increases the amount of material to be handled. As the demands of the contractors have taxed the plant heavily, due to a number of causes, among which were delays due to breaks in machinery, lack of storage for the mixed aggregate, shortage of cars at times when the haul was long, or when large amounts of foundation fill materials were being shipped, it was found necessary, at times, to ship out material containing 50% sand, and in some cases, pit-run material. In such cases the cement has been increased to about 15% or 1.7 bbls. (Canadian) per cubic yard. This policy is very expensive, however, as it increases the cost of concrete to the District by about $1.00 per cubic yard, net, over the cost of concrete made with an aggregate containing 35% of sand. As the estimated volume of concrete in the whole aqueduct is about 330,000 cubic yards, the District is, this winter, planning to open another pit, equipped somewhat differently, near the eastern end of the line, to relieve the pressure on the existing plant both by furnishing more aggregate and by shortening the haul, thus getting better efficiency out of the transportation equipment.

The mixed sand and gravel is loaded into 20-yard air-dump cars at the screening plant, hauled to the contractor's platforms and dumped. The cars are loaded, as nearly as possible to a loose measurement of 23 cubic yards, then scaled, and billed out to the nearest even yard below the scaling. Of 110 cars loaded and billed out, in one test, 15 contained by scaling 22 cubic yards, 75 contained 23 cubic yards, 19 contained 24 cubic yards and one contained 25 cubic yards. The total measured yardage in the cars was 2583.1 cubic yards, and the total billing was 2536 cubic yards, a difference of 47.1 cubic yards or 1.85% more material shipped than billed for, due to taking the nearest even yard below the scaling; or, roughly, the deliveries averaged nearly half a yard per car in excess of the billing. A further excess of deliveries over billing in cars leveled off for measurement, also arises from the mechanical effect of the consolidation of the material in the cars of measured aggregate by the men when leveling off the cars. For example 17 cars were measured at the plant, then leveled off and trimmed. Before leveling, the measured contents was 392 cubic yards and after leveling off 380.6 cubic yards, a difference of 11.4 cubic yards, or 3% shrinkage due to consolidation by the men's feet.

The relative weights of the aggregate per cubic foot under different conditions as to moisture and compacting is shown in the following table, the sand in the moist aggregate being about 37% by weight.

Weight per cu. ft. loose and moist....................114 lbs.
Weight per cu. ft. shaken and moist..................122 lbs.
Weight per cu. ft. tamped and moist..................132.5 lbs.
Weight per cu. ft. loose and dry.....................125.0 lbs.

from which it will be seen that the percentage shrinkage from the loose and moist condition to loose and dry was 9.65 percent. and to shaken and moist 7 percent. and to tamped and moist 15.8 percent.

The shrinkage in volume during transportation from the pit at mile 30.8 to different points along the line is shown in Table 3.

Table 3.

Shrinkage in yardage of aggregate during shipment from mile 30.8 to different points along the aqueduct line.

(Aggregate 50% sand; 4 cu. ft. cement to 16 cu. ft. aggregate = about 1.7 bbls. cement per cu. yd. of concrete.)

Date—	Mile at Which Sand Was Delivered.	Cu. Yds. Billed.	Cu. Yds. Measured at Pit.	Cu. Yds. at Plant After Leveling and Trimming.	Cu. Yds. as Measured at Point of Delivery.	Ratio of Cu. Yds. Billed to Cu. Yds. Measured at Delivery.	Ratio of Cu. Yds. Measured to Cu. Yds. Delivered and Measured There.
Aug. 26	40	23	23.6	22.2	21.8	1.055	1.08
Aug. 26	43	46	46.6	44.2	43.3	1.060	1.08
Aug. 27	51	46	46.2	46.2	42.2	1.090	1.09
Aug. 27	57	69	69.6	67.8	66.6	1.045	1.055
Aug. 27	65	69	*68.1	68.1	64.1	1.075	1.06
Aug. 27	71	45	45.4	44.3	41.5	1.085	1.095
Aug. 27	77	45	45.4	44.8	40.8	1.100	1.110
Aug. 27	85	46	45.8	45.0	42.4	†1.085	1.08

In order to determine the ratio of aggregate billed out from the plant to the yardage of concrete put in place, measurements of both aggregate yardage and yardage of concrete laid were kept by all the division engineers for a week. Owing to inaccuracies in trim-

*Car leveled up for measurement at plant and settled in process of leveling.
†Side doors of car raised in transit about 2 inches and some material leaked out.

ming the bottoms of trenches and to the small excess quantities of concrete in the arch sections, due to hand finishing the tops a little higher than the theoretical lines, the payment concrete averages less than the actual quantities placed. These ratios are shown to be about as follows:

Total cubic yards of aggregate billed	= 3633.2	
Total cubic yards of concrete laid	= 3422.7	
Excess of aggregate over total concrete	210.5	= 6%
Total cubic yards of aggregate billed	= 3633.2	
Total cubic yards of payment concrete	= 3310.7	
Excess of aggregate over payment concrete	322.5	= 10%
Yardage of total concrete	= 3422.7	
Yardage of payment concrete	= 3310.7	
Yardage of excess concrete	= 112.0	— 3.4%

Costs of Preparing Aggregate.—The average cost per cubic yard of the aggregate, for preparation exclusive of overhead charges, and transportation to the contractor's platforms has been as follows:

Excavation	$0.118
Hauling to plant	.031
Screening and crushing	.139
Loading	.061
Repairs to plant	.019
Repairs to cars, crane and dinkey	.011
Office	.005
Fuel	.123
Total	$0.507

It is expected that this cost will be materially reduced during the coming season.

Estimated Cost of Aqueduct.—The original estimates of cost of the complete work as made and as given in the report of Consulting Engineers, 1913, was $13,045,600. On the basis of contracts already let there is reason to believe that the cost of the completed work will be about $1,000,000 less than this, including the cost of the railroad, the disposition of which, after the completion of the aqueduct, has not yet been determined upon.

The writer apologizes for the abbreviated manner in which the subjects discussed herein are presented, and for the omission of mention of many interesting phases of the work, such as the hydraulics of the problem, the details of construction, the form work and order of construction, cost data, camps and camp equipment, the drainage of the swamps to permit of construction operations, the handling of difficult foundations, the provisions for measuring and regulating the flow of the water in the aqueduct, and many other subjects; but almost any of these would alone form a subject for a special paper.

November, 1915

PROCEEDINGS OF THE SOCIETY

MINUTES OF THE MEETINGS.

Regular Meeting, November 2, 1915.

The regular meeting of the Society (No. 915) was held on Tuesday evening, November 2, 1915. The meeting was called to order at 8 p. m., by President Jackson, with about 200 members and guests in attendance.

There being no business to bring before the meeting, President Jackson, after a few introductory remarks, introduced the speaker of the evening, Mr. L. E. Johnson, President of the Norfolk & Western Railway, who presented his paper on "The Railroads and the Public," which was followed by very interesting discussion from Messrs. Willard A. Smith, Lyman E. Cooley, E. H. Lee, G. H. Bremner, John F. Hayford, Wilson E. Symons, Elmer T. Howson, O. P. Chamberlain, S. O. Dunn and E. N. Lake.

At the conclusion of the address and discussion Mr. O. P. Chamberlain moved that a vote of thanks be given to Mr. Johnson for presenting the paper before the Society, which was carried by a unanimous vote.

The Northwestern University quartette then rendered several numbers, at the end of which the engineers present enjoyed an informal get-together meeting with the aid of corn-cob pipes and refreshments. The meeting finally adjourned at 10:45 p. m., after one of the most popular meetings held during 1915.

Extra Meeting, November 8, 1915.

An extra meeting (No. 916), in the interests of the Bridge and Structural Section, was held on Monday evening, November 8, 1915.

The meeting was called to order by Mr. H. C. Lothholz, Chairman of the Section, at 8 p. m., with about 105 members and guests in attendance.

The Chairman of the meeting introduced the speaker for the evening, Mr. H. J. Hansen, who presented his paper on "Design of a Railway Pontoon Bridge," Discussion followed from Messrs. E. N. Layfield, Walter S. Lacher, H. C. Lothholz and Frederick G. Vent.

The meeting adjourned at 9:45 p. m., after which refreshments were served.

Extra Meeting, November 22, 1915.

An extra meeting (No. 917), being an informal dinner meeting, in the interests of the Electrical Section of the Western Society of Engineers and the Chicago Section of the American Institute of Electrical Engineers, was held at the Hotel Sherman, Monday evening, November 22, 1915, in the Italienne room at 6:30 p. m. There were 164 members and guests in attendance.

After the dinner, the meeting was called to order by Mr. W. J. Norton, Chairman of the Chicago Section A. I. E. E., who spoke of the recent sudden death of Mr. H. M. Wheeler, Chairman of the Electrical Section of the Western Society of Engineers, and a member of the Board of Direction, W. S. E., who had made all arrangements for the meeting and who was to have acted as chairman. As a matter of respect, all the members arose and stood for a few moments. Mr. Norton then introduced Mr. Leonard A. Busby, President of the Chicago Surface Lines, and requested that before Mr. Busby give the address of the evening that he say a few words about Mr. Wheeler, who had been employed as an electrical engineer by the Chicago Surface Lines. Mr. Busby responded by saying that Mr. Wheeler some time previous had arranged with him to present the address of the evening, and also spoke in glowing terms of his acquaintance with Mr. Wheeler.

Mr. Busby then presented the address of the evening, on "The Regulation of Public Utilities," which was followed by a short discussion by Mr. Bion J. Arnold. The meeting adjourned at about 10:00 p. m.

E. N. Layfield,
Acting Secretary.

PROCEEDINGS OF THE SOCIETY

MINUTES OF THE MEETINGS.

Extra Meeting, November 29, 1915.

An extra meeting (No. 918), in the interests of the Bridge and Structural Section, was held on Monday evening, November 29, 1915.

The meeting was called to order by Mr. H. C. Lothholz, Chairman of the Bridge and Structural Section, at 8 P. M., with about 120 members and guests in attendance.

The papers of the evening were then presented, being "Deflection of Trusses," by E. H. Casper and C. J. Kennedy, and "The Use of Influence Lines," by R. W. Flowers and H. N. Jones. After the presentation of the papers, discussion followed from Messrs. I. F. Stern, F. G. Vent and H. N. Jones. The meeting adjourned about 10:00 P. M., after which refreshments were served.

Regular Meeting, December 6, 1915.

The regular meeting of the Society (No. 919), was held on Monday, December 6, 1915, and was devoted to a "Smoker" the evening being given over to entertainment. The meeting was called to order at 8:00 P. M., by First Vice-President McCullough, with about 130 members and guests in attendance.

A reel of humorous pictures was shown, after which cigars were distributed and the members and guests were requested to join in the singing of old-time songs, which was followed by the telling of humorous stories.

Mr. McCullough followed with a lantern slide talk on the work of artillery, with especial reference to Battery B, of the Illinois National Guard, giving a detailed explanation of the pictures as they were thrown upon the screen, as well as some comparisons between foreign practice and the practice in this country. Moving pictures followed, after which refreshments were served.

Extra Meeting, December 13, 1915.

An extra meeting (No. 920), in the interests of the Hydraulic, Sanitary and Municipal Section, was held on Monday evening, December 13, 1915.

The meeting was called to order by Mr. Ernest McCullough, First Vice-President of the Society at 8:00 P. M., with about 135 members and guests in attendance.

There being no business to be brought before the Section, Mr. McCullough presented the speaker of the evening, Dr. E. V. Hill of the Health Department of the City of Chicago, who gave an address on the subject of "Ventilation," and demonstrated the methods used in making tests of different kinds. Discussion followed from Messrs. J. W. Shepherd, C. W. Naylor, Albert Scheible, H. P. Weaver, C. P. Barnes, W. E. Williams, and A. L. Wallace.

The meeting adjourned at 9.45 P. M.

Extra Meeting, December 20, 1915.

An extra meeting (No. 921), of the Society, was held on Monday evening, December 20, 1915.

The meeting was called to order by President Jackson at 7:30 P. M., with about 150 members and guests in attendance.

After a few introductory remarks, President Jackson introduced the speaker of the evening, Dr. W. F. M. Goss, Dean and Director, College of Engineering, University of Illinois and Chief Engineer of Association of Commerce Committee on Smoke Abatement and Electrification of Railway Terminals, who addressed the meeting on the "Electrification of Chicago

Railway Terminals." Numerous lantern slides were shown, with explanations by the author.

A general discussion followed from Messrs. P. Junkersfeld, A. Bement, Elmer T. Howson, Wm. B. Jackson, E. H. Lee, Albert Reichmann, W. E. Symons, J. N. Hatch and J. W. Lowell, members of the Society, and from Messrs. J. R. Bibbins, Judge Jesse Holdom and Charles L. Dering, followed by a closure by the speaker.

President Jackson then thanked the speaker on behalf of the Western Society for his splendid address, after which the meeting was adjourned at 10:15 P. M.

Extra Meeting, December 29, 1915.

An extra meeting (No. 922), a joint meeting of the Electrical Section, Western Society of Engineers, and the Chicago Section, American Institute of Electrical Engineers, was held on Wednesday, December 29, 1915, convening at 7:30 P. M., with W. J. Norton, Chairman, Chicago Section, A. I. E. E., presiding, and about 175 members and guests in attendance.

President Jackson, announced that nominations were in order for officers of the Executive Committee of the Electrical Section of the Western Society of Engineers for the ensuing year.

The following nominations were made:

C. A. Keller..Chairman
William J. Crumpton..............................Vice-Chairman
E. N. Lake.....................Member of Executive Committee, 3 Years

President Jackson announced that the above officers would be voted for at the next meeting of the Electrical Section. Also announced that the speaker of the evening at the annual dinner would be Mr. Samuel Insull.

There being no further business to be brought before the meeting, Mr. Norton introduced the speaker of the evening, Mr. Frank J. Sprague, Past President American Institute of Electrical Engineers and a member of the U. S. Naval Advisory Board, who gave an address on "Naval Preparedness and the Civilian Engineer." Discussion followed from Messrs. W. E. Williams, Albert Scheible, S. Montgomery, Wm. B. Jackson and H. H. Evans.

Chairman Norton on behalf of both Societies expressed thanks to Mr. Sprague for his excellent paper, after which the meeting adjourned at about 10:00 P. M.

E. N. Layfield,
Acting Secretary.

BOOK REVIEWS

THE BOOKS REVIEWED ARE IN THE LIBRARY OF THE SOCIETY.

MAINTENANCE OF WAY AND STRUCTURES. By William C. Willard. McGraw-Hill Book Company, New York, 1915. Cloth, 6 by 9 in.; 450 pp. Price, $4.00.

This excellent book is written in a clear and scholarly style, is well arranged and contains a large amount of valuable information for maintenance of way engineers, roadmasters, track foremen and others engaged in railroad maintenance of way work as well as for engineering students.

The introductory chapter gives some condensed statistics, brought to date, indicating the importance of the subject, as well as some discussion of the attitude of railway management toward maintenance of way expenditures. The author says: "There is a tendency among railway managements to disregard recommendations from the maintenance of way department, particularly if the company is short of funds and a policy of retrenchment is necessary. When it becomes necessary to reduce expenses the maintenance of way department suffers especially, for the management feels that the detrimental results of retrenchment will be less visible, at least to the public, here than elsewhere. . . . One of the most important duties of the maintenance of way engineer is to present clearly to the executive officials the desirability of improving the track as the traffic conditions become more serious."

The various phases of railroad maintenance of way are treated from the standpoint of fundamental principles and also of practical details and are brought to date as is shown by the treatment of the question of tie renewals "singly" or "out of face," which has caused so much discussion in the last few years, the references to the modern standard gauge dump car for maintenance work and similar matters. Present day practice in standards and methods are treated in great detail and for all sections of the United States and Canada.

The author has succeeded in making a very readable book and by far the greater part of it can be readily understood by the non-mathematical reader, although proper mathematical treatment is given to such portions as stresses in track, the calculation of frogs and crossings and such other matters as require it.

The book contains twenty-one chapters as follows: Introduction; Organization and Rules; Roadway; Ballast; Wooden Ties; Substitute Ties; Economics of Ties; Economics of Ties (Continued); The Preservation of Timber; Rails; Track Fastenings; Track Fastenings (Continued); Stresses in the Track; Design of Railway Track; Signs, Fences and Highway Crossings; Accessories to Track; Bridges, Trestles and Culverts; Switches, Frogs and Turnouts; Work of the Maintenance of Way Department; Roadway Machines—Small Tools and Supplies; Records; Accounts; Annual Program for Maintenance of Way and Structures. There are 232 illustrations, 24 tables and an excellent index of 24 pages in which the relative importance of the references is indicated by printing the page numbers in bold face type, italics and ordinary type.

The book is well worth a place in the office of every maintenance of way man.

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BOOK REVIEWS.

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INDEX

VOLUMES 1-20 (INCL.).

(1896-1915.)

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Chicago, Ill.

EXPLANATION

The Author Index is placed first because in most cases it is easier to find a paper in that index, if the author is known, than in the Subject Index.

The Subject Index begins on page 41.

The references in this index indicated as "Abstracts" refer to articles abstracted from other publications.

The user of this Index should bear in mind that it is not practicable to index a particular paper under every possible heading that might occur to the person who is looking for it.

If the paper is not indexed under the subject first looked for, it is probably indexed under some other equally logical subject.

Cross references have been used liberally, but it must also be recognized these cannot cover every possible contingency, and if the article desired is not found either under the subject first looked for or the cross references, it probably will be found under some other similar subject.

The following quotation from the Introduction to a well-known index is to the point:

> "This arises because the judgment of the indexer, in selecting entry headings for a given article or item, was probably different from what the user's judgment would be. Therefore, if the user's search under one or two headings does not bring results, he must try others until the item sought is located. A sort of analytical thought must be exercised to select a variety of possible entry headings in which the desired item may be concealed."

The names of deceased members, whose memoirs have been published in the Journal, appear in the Subject Index under "Memoirs," and also, for convenience, in the Author Index, under their names.

From 1881 to 1895 papers presented before the Western Society of Engineers appeared in the Journal of the Association of Engineering Societies.

The figures after each entry indicate the year and the page number of the article referred to.

AUTHOR INDEX

(Subject Index begins on page 41)

This Index also contains the names of deceased members, memoirs of whom have appeared in the Journal.

SUBJECT INDEX

BUILDINGS

CABLES (Electrical) (See also Conduits; Underground Construction)