The Wisconsin engineer. Volume 17, Number 7 April 1913

Madison, Wisconsin: Wisconsin Engineering Journal Association, [s.d.]

https://digital.library.wisc.edu/1711.dl/7P3DBZ6M5SIJV8I

The Wisconsin Engineer

APRIL, 1913

Volume 17
$1.00 a Year

Number 7
20c a Copy

WISCONSIN ENGINEERING JOURNAL ASSOCIATION

Volume 17 Founded 1896 Number 7

The Wisconsin Engineer

$1.00 a Year 20c a Copy

Entered as second-class matter Sept. 26, 1910, at the postoffice at Madison Wis., under the Act of March 3, 1879.

CONTENTS

APRIL, 1913

Published monthly from October to May, inclusive, by the
WISCONSIN ENGINEERING JOURNAL ASSOCIATION,
Engineering Bldg., Madison, Wis.

Address all communications to The Wisconsin Engineer.

Subscription price $1.00 a year if paid before February 1; $1.25 a year after that date. Canadian subscriptions, $1.25 a year. Foreign subscriptions, $1.50 a year.

NOTICE

It is impossible for us to reach each one of our subscribers personally to collect over due subcriptions. If you have not paid your subscription drop it in the mail box or office and save us all the trouble of looking you up.

Thank you

ADVERTISERS INDEX

The Wisconsin Engineer

VOL. XVII APRIL, 1913 NO. 7

SCIENTIFIC MANAGEMENT

A. G. Christie

Within the last few years a new term, "Scientific Management," has crept into our language. It was a catching phrase and its usage soon became general. As is usually the rule when expressions become popular, the true meaning of this term has been frequently but vaguely understood. Hence in discussing Scientific Management, it becomes necessary to first define the expression and then discuss the aims and principles of this new science of management.

In Webster's International Dictionary the word "scientific" is defined as "agreeing with or depending on the rules or principles of science," while science itself is defined as "accumulated and accepted knowledge which has been systematized and formulated with reference to the discovery of general truths or the operation of general laws, and made available in work, life or the search for truth." Management is defined as "the judicious use of means to accomplish an end." It is not intended to discuss in detail these definitions but the reader is asked to keep them in mind and to note how forcibly these apply to the use of the term in later portions of this paper.

Science involves a certain mental attitude on the part of the person dealing with it. Leaders in the movement of scientific management have time and again pointed out the necessity of a complete change of mental attitude towards the work under consideration, both on the part of the executive officers and on the part of the workmen themselves. Science substitutes exact knowledge for rule-of-thumb and guesswork.

Scientific management can therefore be described as a system for directing the means of production according to fixed laws with the least waste of effort and material. It should be clearly understood by everyone that scientific management cannot be sold as a commodity and that it in itself has nothing to sell. One cannot buy slide rules or sets of forms for accounting and expect to have scientific management by simply forcing these into a shop. On the other hand it is not motion study or time study or bonus systems or cost systems, as many people have been led to believe. But systems of scientific management may include all these special features in the co-operative study of the means of production by the management and by the workmen in order to determine the best means of doing every elementary operation involved in a piece of work in the best way possible. Each party must assume a proper attitude towards the work before the system can be properly introduced. The executive is at all times looking for increased dividends, the workmen are striving for higher pay and no system of management can succeed which does not in a measure satisfy these two demands. Hence systems of scientific management must provide for increased returns to the executive by means of maximum production and low labor cost, while the workmen must receive added compensation for making this extra effort to increase his output.

In order to understand clearly the principles and aims of scientific management it is necessary to review briefly the condition prevailing in industry before its introduction. There generally existed a craft spirit among workmen of all classes. They have learned the details of their trade from time immemorial by observing the manner in which their associates worked and by receiving by word of mouth occasional instructions and suggestions for doing their work. The tools used were those that their predecessors had been accustomed to use. The force of habit and latent conservatism of the workmen tended to thwart any effort to materially improve methods.

There had also been an effort on the part of some labor organizations to limit the output of the workmen. This action was based on the belief that maximum production would result in throwing a large number of their fellows out of work. They did not realize that large production would result in decreased costs and in increased consumption. This deliberate limitation of output by workmen has become known as soldiering.

From time to time systems have been developed and introduced that provide for extra remuneration to the workmen. These generally can be grouped as piece-rate, premium or bonus systems. The standard of performance was usually set from previous work done and not from a scientific analysis and study of each operation. It, therefore, often happened that a workman commenced to earn very high wages through increased skill in performance. In consequence of this, the management reduced the standard which in itself may have been wrong in the first place. This cutting of the rates resulted in great dissatisfaction on the part of the workmen and they soon ceased to put forth their best effort.

Let us assume as an illustration of the old industrial methods, that a workman's duty in a certain shop is to nail some pieces of wood together and afterwards clinch the nails on the under side. This man is given a bench or table and then arranges his material, nails, etc., to suit himself. The hammer he uses is probably one that he has had for some time and also one which he selected on account of a special preference of his own, either for the weight of head, kind of handle or other feature which appealed to him. He proceeds with his work according to his own ideas and makes no special effort to devise methods to increase output or lessen fatigue in working.

Now, suppose a careful analysis and study were made of the task of nailing these pieces of wood together. The bench or table on which the job is done may be too low for the purpose and in consequence the workmen bends and strains himself in doing his work. This is needless and wasteful effort and may be removed if the management determines the proper height of table for the workman and insists on him using it.

The arrangement of materials by the workman may also be such as to require the expenditure of much energy in reaching for nails, for wooden strips or even for his hammer. A study of the process and of the motions involved in reaching for materials would develop facts relative to the time and energy wasted. An analysis of the results of this study should also indicate a possible arrangement of materials that would greatly lessen this loss and would permit the workman to pay closer attention to his job, as his mind would not be diverted in locating materials. The workman may also experience frequent delays either from lack of proper material or from slowness in taking away finished material. This can be avoided if proper provision is made for handling and routing this material through the shop.

Attention has already been drawn to the consideration involved in the selection of the workman's hammer. Suppose that a detailed study with a skilled workman was made with every kind of hammer obtainable and with all sorts and lengths of handle. It would be possible to select then a hammer of certain weight with some fixed length of handle which would drive the nail with the least number of blows and with the minimum effort on the part of the worker. This would then become the standard hammer for driving these nails.

Now, this case of a workman driving nails has merely been selected for illustrative purposes and is not taken from any specific factory. But it is apparent from the discussion that even the process of driving nails can be analyzed and standardized. The workman will then be given a new unit of performance that he must attain, but in order to induce him to make this extra effort there must be an incentive added in the form of increased pay.

In tracing out the improvements which might be made in this process, the three steps involved in the application of scientific management have been presented. First, there must be an analysis which will provide an accurate record of the productive effort and of preventable wastes. Second, there must be a standardization of the attainable maxima of performance both in tools and in processes, and conditions must be so established that it is possible for workmen to reach this maximum. Third, an incentive must be offered to the men to strive to reach this maximum.

Scientific management aims, therefore, to so arrange the work of each man that all unnecessary motions and waste time are eliminated and at the same time he is taught how to perform each operation in the best possible manner. This involves standardizing the operations of the machine as regards speed, accuracy, and constancy of operation for the particular work it has to do. Dr. Fred. W. Taylor has stated the four underlying principles of scientific management as follows:

"The first of these principles is the gathering-in of the great mass of traditional knowledge held by the workmen, recording it and reducing it to laws, rules and mathematical formulas. These deductions become of immense assistance in increasing the output. Rule-of-thumb knowledge is replaced by science.

"Secondly, it becomes the management's duty to study carefully every man in the plant, his capacities, possibilities and limitations, and to train each for the highest class of work for which he is shown to be fitted,—progressive selection and progressive study.

"Thirdly, the science and the scientifically trained man are brought together. This is difficult. It can be accomplished only by binding the workman to work by science. This, however does not cause appreciable trouble. Nine-tenths of the trouble experienced comes from forcing the management and owners to assume their burdens.

"And, fourthly, a great mass of work formerly done by the workmen is now partly taken over by the management until the whole is more equally divided. On the management's side there is generally one man for every three workmen."

The first principle the substitution of exact knowledge for rule-of-thumb may be applied in the following manner: Select a number of different men who are especially skilful in doing the particular work to be analyzed. Then a study must be made of the elementary operations which each of these men uses in doing the work which is being investigated, as well as the tools each man uses. The stop watch is next used to determine the time required to make each of these elementary movements. The quickest way of doing each element of work can then be selected. All false, slow and useless movements can be eliminated. Then after doing away with all these unnecessary movements, the quickest and best movements, as well as the best tools can be collected into one series and thus the one best method of performing the task can be determined. It will thus be seen that this involves the time, study and motion study of which so much has been written.

By the application of the second principle, the management is able to place each workman at a task for which he is naturally fitted and at which work he can earn his best pay. This results in better satisfied and more reliable men. It requires skill and patience to bring this about.

Dr. Kathrine Blackford of the Emerson Company has made a special study of the scientific selection, assignment and management of employees. Her methods of analysis are original and very comprehensive. They have been applied with very satisfactory results in a number of large industrial enterprises.

The third and fourth principles can be illustrated best by a description of the functional system of organization which has been used by Taylor and his associates. Under this system of scientific management the factory organization is divided into two departments, the planning department and the performing department.

The planning department has four functions which are represented by the following individuals: (1) The route clerk or the order of work clerk. His duties may be briefly summarized in the three words, "what, where, when." It is his duty to plan in advance the route that each unfinished or finished piece shall follow throughout the shops. He sometimes rearranges machinery to secure a more satisfactory passage of work through the shop. After he has decided on the path that the material shall follow and the machines which shall do work on it, he makes out route charts and route sheets which are turned over to the instruction department to be worked out in detail.

(2) The instruction card clerk works out in detail an instruction card for each element of the routing sheet. The instruction cards must tell the workmen in the greatest possible detail the task he is to perform and the tools to be used. The functional foremen must also be instructed as to what he must teach the workmen and what the workman is expected to do. In short, the instruction card man answers the question "how."

(3) The time and cost clerk keeps records of the time it took the workmen to perform each task and also of the cost of labor and material on each piece. This information is usually col-

lected in statistical forms and provides a true record of the prime costs of production.

(4) The disciplinarian has to do with all matters connected with discipline. It is his duty to prevent disagreements rather than to settle these matters. In many plants his work is light and he combines the function of disciplinarian with some other function in the planning department.

In the performing department there are also four functions, as follows:

(1) The gang boss who takes the place of the old time foreman, but in a different way. He sees that the workmen perform the operations exactly as called for on the instruction card. He also acts as a teacher and by instruction assists the men in reaching the maxima of production set by the planning department. He is generally paid a bonus on the work done by the workmen and thus has an incentive to get his men working most efficiently.

(2) The speed boss, who has nothing to do with the speed of the men but of the machines. It is his duty to see that machines and tools are run at the speeds called for on the instruction cards and to instruct the workmen how to secure these speeds. If there is any question as to the machine speeds, he must be prepared to demonstrate himself that such speed is not impossible and must teach the workmen how to comply with their instruction card requirements.

(3) The repair boss has charge of all repairs and overhauling as called for by instruction cards. In the nature of things he must be ready in emergency break-downs to rush out repairs even though no instruction card has been issued.

(4) The inspector not only passes on the completed work but it is his duty to prevent as far as possible any spoiled work, by standing by the workmen on every new job and instructing him as to the requirements necessary to pass inspection and to see that the workman understands these requirements.

This whole functional organization aims to assist the workmen in turning out the most work possible. His instruction card tells him what he is to do, what tools he must use, how the task is to be performed, the speed to run his machines, the finish of the work, the time allowed for the job and the bonus he will be paid above his regular wages if the work is completed in the time stated. He also receives instruction from the gang boss and speed boss and is given every assistance to attain his best effort.

On the other hand the executive assumes the duties of routing material, providing tools and keeping these in proper shape and of issuing detailed instruction cards to the workmen for every element of the task. Formerly these functions were largely performed by the workmen themselves. Hence the management now shares almost equally with the workmen the burden of production.

The previous outline is for organization based on the Taylor system. Emerson, on the other hand, does not adhere strictly to methods. He lays down twelve principles of efficiency and models the existing organization to conform with these principles. He also employs specialists in different branches of the work who bring their expert skill and knowledge to bear on the various elements of the operations. His methods can therefore be introduced into factories with less disturbance than could the Taylor system.

An incentive of increased pay must be offered to the workman in order to get him to put forth his best effort. This takes the form in the Taylor system of a bonus of from twenty-five to seventy-five per cent of his former pay after he has reached the point set by the management as the task. If he is unable to reach this production he gets no bonus but as soon as this limit is reached the bonus is added to his pay. It thus acts as an incentive to maintain full production at all times.

In the Emerson system, the standard of production is fixed by time studies and this is considered as 100 per cent. efficiency. Any other rate of production is expressed as a per cent. of this and an increasing bonus rate is paid for all efficiencies above about 70 per cent. Whereas on the Taylor system there is no further incentive to production after the bonus-paying point is reached, in the Emerson system the greater the rate of production the greater the rate of the bonus and hence there is every inducement to the workman to produce his greatest possible output.

Attention has already been called to the practice of cutting rates in piece work. It is one of the fundamental laws of scientific management that rates of production which have been determined by careful and accurate studies, must not be changed and hence the workman is given a square deal if by his skill he is able to exceed the limits first set. He has no fear of rate cutting or of increase in the task.

The reader must not assume that these are the only systems of scientific management now in use. There are a great number of others which are based on some or all of the principles embodied in the Taylor and Emerson system. Scientific management is a comparatively recent development and it must pass through various stages of evolution in the same way as all industrial improvements have in the past. It is therefore probable that the systems receiving final adoption may vary quite widely from those now in force though the underlying principles may not be altered. Scientific management substitutes exact knowledge for guesswork and establishes a definite unit of measurement to which all performances may be compared. The widespread attention and study that it has received, has brought about many changes and improvements in factories which have not adopted the systems in full. It has called the attention of superintendents and managers to the needless wastes of materials and effort that constantly take place in their factories and has also pointed out a way to make improvements. On account of the widespread appreciation of scientific management it behooves every graduate in engineering to acquaint himself thoroughly with its underlying principles and to read all the best literature on the subject.

Before closing it is well to direct attention to the attitude of labor. In general labor is very conservative and is governed largely by force of habit. In almost every case therefore where scientific management has been introduced a hostile attitude was assumed at first by the workmen. But this rapidly disappeared as the benefits of the system became appreciated. The men were able to earn more money and as they had to give closer attention to their work they became steadier and more reliable. When methods of scientific selection were applied, the men were soon placed on jobs for which they were naturally suited and this resulted in more contented men.

The labor unions on the other hand have violently opposed all systems of scientific management on the ground that it destroys collective bargaining by the introduction of the individual task and bonus, that by speeding up production it makes men into machines, kills individual initiative and lowers their vitality and also that it makes men specialists in one process only and does not provide such all-around skilled workmen as men produced by the old apprenticeship systems. These allegations at first sight would appear to be a severe arraignment of scientific management. But if one studies economic development, he will find that much the same objections were raised to the introduction of machinery in the early days of the industrial revolution. Yet in the end union labor accepted machinery. In shops where scientific management has been in use for sometime, there does not seem to be the serious results that labor leaders have prophesied. It seems therefore probable that scientific management will be introduced in spite of the unions. However if labor leaders are broad minded enough to see the advantages resulting from the elimination of wasted effort both in the work to be done and indirectly in reducing the high cost of living, they will adopt scientific management and force its use on all employers as a means of getting higher wages for their men. As a general rule labor leaders have never taken the trouble to investigate carefully the working of the system and to notice its effects on the laborers themselves.

The following telegram is self-explanatory. The Wisconsin Engineer is sparing no expense to get the very best articles for its readers, and when we heard of this article we immediately got busy. We acknowledge receipt of the cuts, etc., with many thanks to the Stevens Indicator.

Received at

4 CH G 52 COLLECT NL 3 EXTRA

HOBOKEN, N. J. APRIL 4, 1913

JOHN W. YOUNG

WISCONSIN ENGINEER,

MADISON, WIS.

Telegram received satisfactory to reprint any parts of article on Electrolysis from our October issue. Will be glad to loan you cuts for figures one two three four five and twelve as requested provided you give credit to indicator. Have forwarded cuts today by Parcels Post. Kindly return.

G. E. TERWILLIGER

Editor Stevens Indicator

713 Am. April 5, 1913

ELECTROLYSIS FROM STRAY ELECTRIC CURRENTS*

By Prof. Albert F. Ganz, M. E.
Stevens Institute

DEFINITION AND THEORY OF ELECTROLYSIS

Electric currents may be conducted in two ways, first, by metallic conduction, and second, by electrolytic conduction. Metallic conduction occurs when an electric current passes through a metal, and is characterized by the fact that no chemical change is produced in the conductor, the only effect being the production of heat. Where electric currents, therefore, pass through metallic conductors, such as copper wires, rails, or pipes, they produce no change in these conductors except to raise their temperature. Under all ordinary conditions stray electric currents found on underground pipes are not sufficiently large to appreciably heat these pipes. Under abnormal conditions pipes may however carry stray currents of sufficient magnitude to produce heating at moderately high resistance joints.

Electrolytic conduction occurs when an electric current passes through an electrolyte, and is characterized by the fact that the electric current is transmitted by a corresponding transfer of *ions* in solution, with the production of chemical decomposition at the electrodes where the current enters and leaves the electrolyte. Electrolysis may therefore be defined as chemical decomposition produced by an electric current. Electrolysis is usefully applied in the arts for the refining of metals and for producing chemical compounds. The writer wants to discuss here the destruction of underground structures caused by electrolysis from stray electric currents which reach these structures.

Chemical compounds in solutions of water constitute the ordinary electrolytic conductors. Pure water itself has such a high resistance that it may practically be considered a non-conductor. It is for this reason that an iron pipe full of ordinary city supply water does not have a lower resistance than the

---

* A lecture delivered before the American Water Works Association at Louisville, Ky., June 6, 1912.

same pipe without water. Water is, however, readily made conducting by the addition of small amounts of salts, and conduction through water is therefore always electrolytic.

The following is a brief explanation of the theory of electrolytic conduction. When a salt is dissolved in water, some of the molecules separate or dissociate into two parts, one part having a positive electrical charge, and the other a negative electrical charge, and these parts are called *ions.* The metal parts or the hydrogen constitute the positive ions and the acid parts the negative ions. For instance, copper sulphate, $CuSO_4$, when dissolved in water, dissociates into the positive metal ion Cu and the negative acid ion SO_4. An electric current is transmitted through an electrolyte by the transfer of these ions. The electrode by which the current enters the electrolyte is called the *anode,* and the one by which the current leaves is called the *cathode.* The metal or hydrogen (positive) ions travel in the direction of the current and carry positive electrical charges to the cathode, and these metal ions, called cations, are deposited upon or are liberated at the cathode. The acid (negative) ions travel against the current and carry negative electrical charges to the anode, and these acid ions, called anions, will corrode the anode if it is a metal which combines chemically with these anions. The cathode is not corroded. With an electrolyte of copper sulphate dissolved in water, a copper anode corrodes into copper sulphate and dissolves, while metallic copper is deposited upon the cathode. If the electrolyte is common salt dissolved in water, the anions are chlorine, and an iron anode would be corroded, the iron forming ferrous chloride; the cations are sodium, and these would decompose the water present and liberate hydrogen at the cathode. These examples furnish an illustration of the fact that the corrosive action of the current results in supplying the electrolyte with an equivalent of the amount of salt decomposed by the current, so that the electrolyte is continually replenished with salt and its electrolytic conducting power is thereby maintained. This salt will contain metal ions of the anode or hydrogen, and may be different from the original salt which started the action.

Street soils when entirely dry do not conduct electric currents. Under ordinary conditions, however, street soils contain considerable water with salts in solution, generally chlorides, and this makes them electrolytic conductors. When an electric current passes through soil it therefore does so by electrolytic conduction and by corresponding chemical decomposition at the electrodes. Where an electric current leaves an iron pipe for soil it corrodes the iron by this action of electrolysis. It has been claimed in the past that soils may conduct metallically, but this has been disproved and it is now recognized that conduction of electric current through soil is always electrolytic.

The separation of the metal or hydrogen ion from the electrolyte at the cathode absorbs energy from the electric circuit, and generally produces an electromotive force in the opposite direction to the current. The oxidation of the anode supplies energy to the circuit and generally produces an electromotive force in the direction of the current. If the oxidizing anode is of the same metal as is being deposited upon the cathode, and if the electrolyte is the same at the anode and cathode, then there is no resultant electromotive force due to the electrochemical actions, and the only electromotive force consumed is that due to the resistance of the electrolyte in accordance with Ohm's law, exactly as with a metallic conductor. If the metal deposited at the cathode is different from the oxidized at the anode, or if hydrogen is liberated at the cathode, or if the electrolyte at the cathode is not of the same composition or density as at the anode, then there will be a resultant electromotive force, which may be either in the same or in the opposite direction as the current. It has been assumed by some writers in the past that no corrosion from electrolysis can take place if the voltage between two metallic conductors in soil, such as between pipe and rails, is less than 1.5 volts, because this is the dissociation voltage of water. This, however, is entirely wrong, and it has been proven by investigations and is now generally recognized that the amount of corrosion produced by electrolysis is independent of the voltage, except in so far as this determines the amount of current flowing, and that the smallest fraction of a volt can produce corrosion from electrolysis under suitable conditions.

SOURCES OF STRAY ELECTRIC CURRENTS

Stray currents are electric currents which have leaked from grounded electrical distribution systems and flow through ground and through underground structures. Grounded telephone and telegraph lines produce electric currents through ground of such very small magnitudes that their effects upon underground piping systems can be neglected. Direct-current electric lighting systems in which the distribution is on the Edison 3-wire plan with the neutral conductor grounded, are in American practice provided with such large neutral conductors of copper that practically no stray currents are produced from such systems. This grounding of the neutral in Edison 3-wire systems is to serve as a safeguard and is not for the purpose of using the ground to carry current. Alternating-current lighting systems where grounded generally also produce only small stray currents, and the electrolytic effects from these small stray alternating currents are always negligible.

Electric railways using the running tracks for return conductors often produce comparatively large stray electric currents through ground, and these are the only sources of stray currents which need be considered in practice. Direct current is almost exclusively used for such electric railways and it is the common practice to supply current to the cars from an overhead trolley wire or from a third rail, and to return this current to the power station through the running tracks, supplemented where necessary by return feeders. A single-trolley electric railway is shown diagrammatically in Fig. 1, in which the path

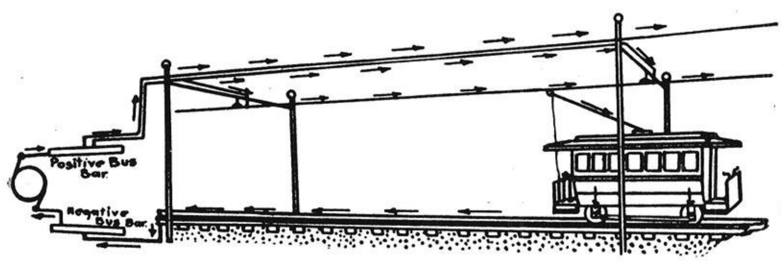

FIG. 1.—*Diagram of Single-Trolley Electric Railway Showing Path of Current from Generator Through Positive Feeders, Trolley Wire, Car and Rails.*

of the electric current from the positive terminal of the generator through the circuit and back to the negative terminal is shown. The running tracks consist of rail lengths about forty feet long, and these are mechanically fastened together by fishplates which consist of steel plates bridging across the rail ends and bolted to both rails. Such fishplates while mechanically fastening the rail lengths together do not form good electrically conducting connections between the successive rail lengths. For this reason, copper wires or straps, called rail bonds, are generally used to bridge across the abutting ends of the rail lengths for the purpose of affording a good electrically conducting path between successive rail lengths. The two rails of a single-track road, or the four rails of a double-track road, are also generally connected together at frequent intervals by cross bonds so that the two or the four rails may be available for the return of current. Instead of using copper rail bonds, the rail ends are sometimes welded together, or soft steel plates are welded across each side of the abutting rail ends, thus forming both a strong mechanical and a good electrically conducting connection between the successive rail lengths. A well bonded railway track should have a conductivity not less than 80 per cent. of the equivalent conductivity of continuous rails. To give some idea of the relative conductivity of steel rails, it may be stated that a single rail weighing ninety pounds per yard, which is a size commonly used where the traffic is heavy, has about the same conductivity as a copper wire one inch in diameter. Thus the two rails of a single-track line or the four rails of a double-track line laid with 90-pound rails and well bonded afford a good conducting path for electric current.

In the simplest form of single-trolley railway, already shown in Fig. 1, the rails are connected to the negative terminal of the generator at the power station, and the only path for current to return to the power station is by way of the running tracks. If the running tracks are laid upon wooden ties above ground with broken stone for road ballast, as is common on steam railroads which run on their own right-of-way, the rails do not come in direct contact with ground, and the return current will be practically confined to the running tracks. If, however, the running tracks are laid below ground so that the top of the rails is on the level of the surface of the street, as is common in cities, then the rails will be exposed for a considerable area to contact with soil. If the tracks are laid on a concrete base a considerable area of the rails will similarly be in contact with the concrete. Since both damp soil and damp concrete are under ordinary conditions conductors of electricity, part of the current returning through the rails will shunt from the rails through

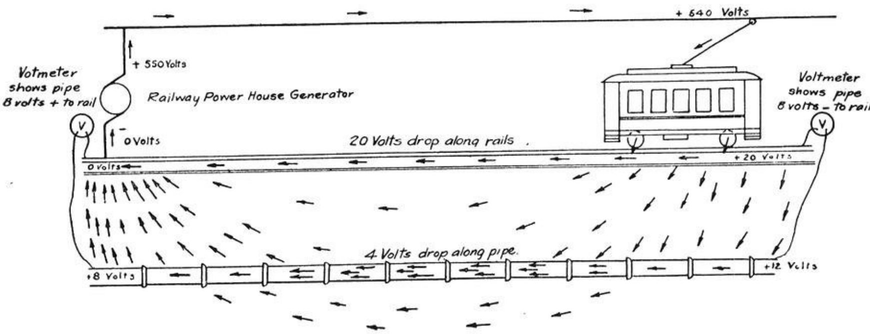

FIG. 2.—*Diagram Showing Stray Railway Currents with Assumed Distribution of Potentials Caused by these Currents.*

the surrounding soil, as is illustrated diagrammatically in Fig. 2. It will be seen that with the usual connection of positive terminal of the generator to the trolley wire, and the negative terminal to the rails at the power station, the current will leave the rails for ground at points distant from the power station, and return to the rails in the neighborhood of the power station, in its path back to the negative terminal of the generator. Since every electric circuit must be completely closed, all current escaping through ground must again leave ground to return to the dynamo so as to complete the electric circuit. Where underground metallic structures, such as gas or water pipes, lie in ground in the path of these stray currents, and where these pipes have electrically conducting joints, such as lead-calked joints or screw-coupling joints, current will flow from ground to such pipes and flow largely on such pipes in a direction towards the power station. In the neighborhood of the power station this current will leave the pipes to return to the negative terminal of the generator, as shown in Fig. 2.

If the negative terminal of the generator or negative bus-bar is connected to the rails at other points than at the power station, by means of negative return feeders, then at such connection points the rails will be rendered negative in potential to ground, and currents will tend to flow from underground pipes through ground to return to the rails in the neighborhood of these connections. Stray railway currents on pipes will therefore tend to leave these pipes to return to the rails in all regions where these rails are connected to return feeders.

From the above considerations it will be seen that the leaking of current from the rails of electric railways, producing stray currents through ground and on underground piping, does not constitute a source of loss to the railway company, as for instance would be the case with leakage of gas or water. On the contrary, by allowing the current to return by ground and underground pipes as well as by way of the rails, the total conductivity of the return circuit is increased, and the voltage loss in the return of this current is decreased, so that there is an actual saving of power for the railway company.

GENERAL EFFECTS OF STRAY ELECTRIC CURRENTS ON UNDERGROUND PIPING

The current flowing through the rails from the trolley cars back to the power station produces in these rails a drop in potential; that is to say, points in the rails away from the power station have a positive potential with reference to the rails at the power station. Since potentials are measured relatively it is convenient to consider the negative terminal of the dynamo, which is assumed connected to the rails at the power station, as at zero potential. The distribution of potentials in the rails of a simple electric railway system and in the underground piping is illustrated in Fig. 2, in which convenient values have been assumed. It will be noted that the stray current causes the underground pipes to be negative to the rails at points away from the power station and positive to the rails near the power station. It is also seen that the negative potential of the pipe, plus the drop on the pipe, plus the positive potential of the pipe, equals the drop in the rails. In the case assumed, there is a potential difference of 550 volts maintained at the power station; of this, ten volts is lost in the trolley wire, 520 volts is used by the motors of the cars, and twenty volts is left to bring the current back to the power station. If the negative bus-bar and the rails at the power station are considered as at zero potentials, the rails at the car in the assumed case will have a potential of plus twenty volts. Thus, for practical purposes, the ground with its underground pipes is subjected to a potential difference of twenty volts, and the amount of stray current produced is that due to these twenty volts. If the rails are laid in the usual way, that is, in contact with ground, the twenty volts in the rails will send some shunting current through the ground and through the underground pipe as shown in the diagram. Under the assumed conditions, there is a drop of eight volts from the rails to the pipe near the car, a drop of four volts in the pipe itself, and a drop of eight volts from the pipe through ground to the rails at the power station. It is therefore seen that it is the potential difference or drop in grounded rails caused by the return current which is the cause of stray currents through ground. Attempts should therefore be made to keep the potental difference or drop in rails as low as practicable in order to keep stray currents through ground down to a minimum.

From the explanation of metallic and electrolytic conduction given in the first part of the paper, it will be understood that where stray currents flow on underground pipes they do no harm except where they leave the pipes to flow to the surrounding soil. At such points corrosion of the iron from electrolysis will take place, and theoretically there will be a loss of twenty pounds of iron per year for every ampere of electric current leaving the iron. Some have assumed that with the low densities at which current generally leaves underground pipes, little or no corrosion is produced. A number of experiments made by the writer have clearly shown, however, that even when current leaves iron for street soil at an extremely low density corrosion is produced which is at least equal to, and frequently greater than, the theoretical amount. This increase of the actual over the theoretical amount is undoubtedly due to secondary chemical reactions set up by the action of electrolysis.

The underground structures which are most likely to be subjected to destruction from electrolysis caused by stray electric currents, are piping systems and lead cable systems. From what has been said above it will be seen that oxidation or corrosion of such pipes or cable sheaths will occur wherever current leaves the pipe or cable sheath for ground. In the simplest case, illustrated in Fig. 2, current flows from rails through ground to the pipes at points distant from the power station, flows along the pipes, and leaves the pipes to return through ground to the rails in the neighborhood of the power station. When the current flows from the rails to ground, the rails will be corroded, and where the current flows from the pipes to ground, the pipes will be corroded. If the pipe line is a uniform electrical conductor, and the relative arrangements are as shown in Fig. 2, then the pipes will be corroded only in the neighborhood of the power station. If, however, the pipe line is not a uniform conductor, as for instance, if there are one or more high resistance joints in this pipe line, then the current on the pipe will shunt around such high resistance joints and produce oxidation or corrosion on one side of the joint. This action gives rise to joint corrosion which is frequently found. Where there are two or more underground piping systems it also frequently happens that current shunts from one piping system to another through the intervening soil, producing electrolytic corrosion where the current leaves the pipe. Such shunt currents are often caused by accidental high resistance joints in one of the pipe lines, and such shunting may occur anywhere and without reference to the location of the railway power station. Where a direct-current trolley railway system passes through a town which has an independent piping network, and where the power station supplying the trolley line is in some other locality, then if stray electric currents are produced from the trolley line where it passes through the town, they will flow on the piping system making this piping system positive to ground and to rails in the direction towards the railway power station, and negative in the direction away from the railway power station. In this case electrolysis of the piping will be produced at the ends of the piping system towards the railway power stations.

When cast iron is corroded by electrolysis, the oxides of iron mixed with graphite usually remain in place leaving the outside appearance of the pipe unchanged. This material resulting from electrolysis of cast iron usually has the consistency of hard graphite and can be cut with an ordinary knife. There have been many cases in which a cast-iron main was carrying gas or water without any apparent leak, where a single blow with a hammer drove a hole right through the pipe. Here the electrolytic action had corroded the iron entirely through the pipe, and the oxide of iron had remained in place, and, together with the surrounding soil, had prevented the pipe from leaking. Whether or not the mixture of iron oxide and graphite resulting from electrolysis remains in place so as to maintain a pipe gas or water tight, depends upon the surrounding soil conditions. It is therefore seen that an underground piping system may be suffering severely from electrolysis without having given any outward sign of the damage. A physical examination with a test hammer is required in the case of cast-iron piping to establish definitely whether or not it has been damaged by electrolysis.

For a given current leaving an iron pipe, there is practically no difference in the amount of iron destroyed between cast-iron, wrought-iron and steel. The electrical resistivity of cast-iron is, however, about ten times as great as that of wrought-iron or steel, and the usual lead joints in cast-iron pipes also have a resistance which is many times greater than the screw-coupling joints usual with wrought-iron and steel pipes. For these reasons a given voltage drop through ground will cause a much smaller current to flow on a cast-iron pipe than on a wrought-iron or steel pipe, thus practically making cast-iron pipes much less subject to electrolysis than wrought-iron or steel pipes. The most frequent damage from electrolysis is found in the case of service pipes where these cross under trolley rails or other underground conductors to which they are positive.

ELECTROLYSIS SURVEYS

The diagram illustrated in Fig. 2 shows that voltage drop in the rails produces stray current through ground and through underground pipes, and produces potential differences between pipe and rails, making the pipe appear positive in potential where current leaves the pipe, and negative in potential where current flows to the pipe. The first step in an electrolysis survey of a town is, therefore, to measure potential differences between pipes and rails, at a number of points throughout every street on which there are electric railways. Where the main itself is not exposed, connections to the pipes for these voltmeter measurements may be obtained by means of service pipe or drip connections. Such connections are generally satisfactory because the voltmeter itself has a high resistance and takes only a very small current. Readings are taken at each point every ten seconds for ten or twenty minutes, depending upon the car schedules, and the maximum, minimum, and average results of the readings recorded. A convenient instrument for these potential readings, which can also be used for the drop measurements described below, is a Weston Model 1 combination millivoltmeter and voltmeter, with its zero in the center of the scale, and having ranges of five, fifty and 500 millivolts and of five and fifty volts. These instruments are made with very high resistances so as to be particularly applicable to electrolysis testing.

After such potential measurements have been made throughout the principal streets of a town, they are then conveniently plotted on a skeleton map of the town, in which the trolley lines are shown. The potentials of the pipes referred to the rails are laid off normal to the lines representing the railway tracks to some convenient scale, usually 1 inch = 10 volts. The ends of these potential lines are then connected, and the included areas are colored red where the pipes are positive in potential to the rails, and blue where the pipes are negative in potential. In Fig. 3 is shown a typical potential survey map, in which the negative areas are shown by dots, and the positive areas by section lines, instead of by blue and red areas. It will be noted that in the neighborhood of the railway power station the pipes are highly positive to the rails, and at points distant from this station they are negative to the rails. The existence of potential differences between pipes and rails is, however, no conclusive evidence of stray currents on the pipes;

they indicate at what points current is probably flowing from rails to pipes and from pipes to rails.

The net step in the survey is to measure drop between drip or service connections, which will indicate the probable existence and direction of current flow on the pipes. Such drop measurements cannot, however, be used for calculating the amount of current on the pipes. To determine the actual current flowing it is necessary to measure the drop between two points on a continuous length of pipe by means of a millivoltmeter. This drop expressed in volts divided by the assumed or measured in ohms of the included length of pipe gives the cur-

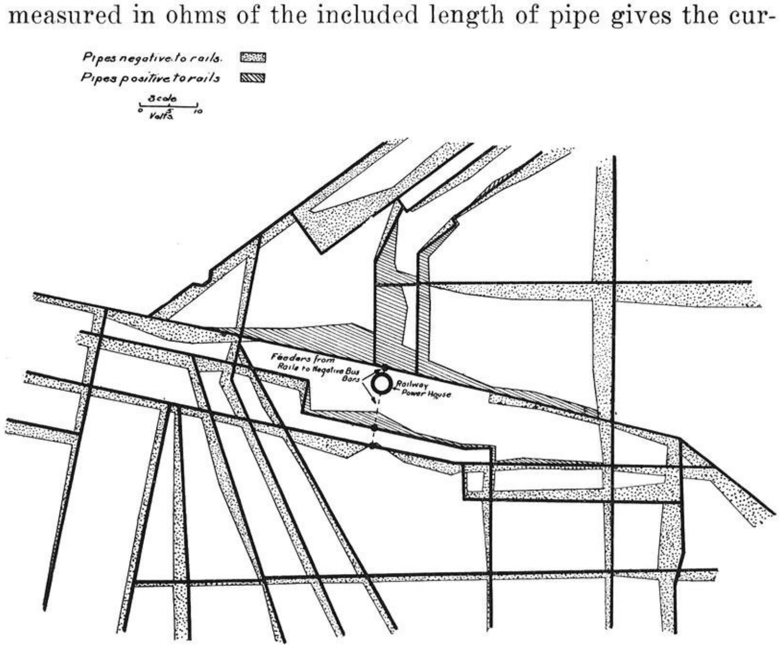

FIG. 3.—*Typical Potential Survey Plotted on Skeleton Map of City Showing Electric Railway Tracks and Potentials of Underground Pipes Referred to Trolley Rails.*

rent expressed in amperes. A convenient table giving the current in amperes for one millivolt drop in one foot of standard wrought-iron, steel, and cast-iron pipes is appended to this paper. To find the current flowing on a pipe corresponding to a given drop in millivolts for a measured length, multiply the amperes given in the table for one millivolt drop for one foot by the number of millivolts drop measured, and divide by the included length of pipe in feet. To measure this drop, it is necessary to expose the pipe and to make good electrical contact between the millivoltmeter leads and the pipe. A satisfactory method is to use a pointed piece of steel, about the size of an ordinary lead pencil, fastened in a wooden handle, with a flexible connecting wire soldered to it inside of the handle. The pointed steel is then pressed against a bright spot or into a filed notch on the pipe. A still better contact is obtained by soldering the connecting wire directly to the pipe or to a brass plug screwed into the pipe, which is particularly advantageous when readings are to be taken over a considerable time. When such contact wires have been soldered to a continuous length of pipe, it is usual to use rubber covered wires and bring them

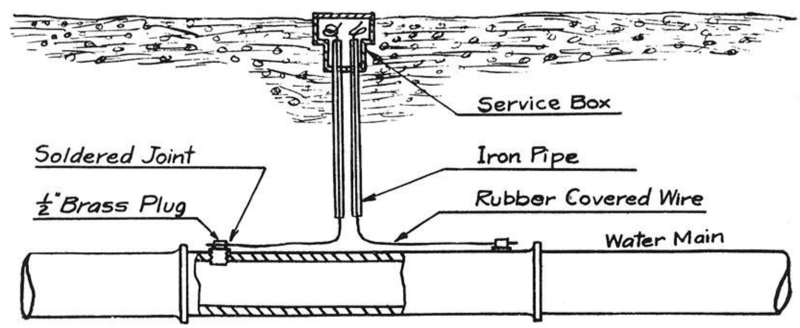

FIG. 4.—*Permanent Electrical Test Wires Attached to Main and Brought to Surface of Street Through Service Box.*

to the surface of the street, leaving the ends in drip or service boxes which then form permanent test stations for electrical measurements. This is exceedingly convenient because it is then possible to make current measurements on the pipe without again making an excavation. Such permanent contact wires for electrical tests are illustrated in Fig. 4.

When drop measurements between services and current measurements on pipes have been generally made on a piping system, the results are conveniently plotted on a skeleton map of the city in which the pipe lines are shown and the current flowing on these pipes are indicated by arrows. A typical current survey map of a portion of a city is shown in Fig. 5. It is seen that here the currents on the pipes flow in a general direction towards the railway substation.

FIG. 5.—*Typical Current Survey Plotted on Skeleton Map of Section of City Showing Underground Mains and Stray Currents Flowing on Mains.*

Since current destroys the pipe only where it leaves for soil, it is important to know where the current leaves the pipe. Current measurements on pipes are therefore frequently made at two or more stations simultaneously in order to determine the change of current on the pipe between the stations.

It is possible to trace the path of current flow through ground by measuring potential differences between points in the ground. Where small potential differences are measured between two points in ground and iron rods are used as electrodes, entirely incorrect results may be obtained because of possible differences in polarization voltages at the surfaces of the electrodes. To overcome this difficulty, a non-polarizable electrode'' was devised by Professor Haber. This consists of a glass tube with a porous cup cemented to one end and containing a saturated solution of zinc sulphate, and of a zinc rod dipping into the solution. A wire is brought out from this zinc rod through a cork in the top of the tube. To make contact to ground with this electrode the porous cup is pressed against the part of the ground at which the potential is to be measured, thus establishing contact between the ground and the zinc sulphate solution. This establishment of electrolytic contact between ground and the zinc sulphate solution eliminates polarization voltages. The polarization voltage between the zinc rod and the zinc sulphate solution, which is a definite known voltage, must be allowed for when using this electrode. It is also essential that when this electrode is used, the potential measurements be made by means of zero methods, and not with indicating voltmeters, because of the very high contact resistance produced with this electrode.

It is often also desirable to measure directly the flow of current through ground, as between a pipe and rails, or between two pipes. This can be done by means of an earth ammeter, which was also devised by Professor Haber. This consists of a wooden frame with two copper plates insulated from each other by a plate of mica or glass. Insulated copper wires are brought out from the two copper plates, and these wires are connected to an ammeter. To use the frame, the two copper plates are first coated with a paste made of copper sulphate and a twenty per cent sulphuric acid solution. A wetted piece of parchment paper is then laid over the paste, and the remainder of the frame filled with soil from the excavation where the current flow through ground is to be measured. The frame is then buried in ground normal to the direction of the current flow to be measured, and the ammeter will indicate the current flow which is intercepted by the buried frame. The object of the copper sulphate paste on each plate is to equalize polarization potentials at the surfaces of the copper plates. This earth ammeter is also well suited for measuring current flow between pipe and ground. For this purpose the frame is buried in the ground one or two inches from and parallel to the pipe. Measurement of current flow from a pipe thus made can be used to form an estimate of the probable amount of electrolytic damage to the pipe, and in cases where corrosion has taken place, this kind of test will often serve as evidence that the corrosion has been caused at least in part by stray currents leaving the pipe. By using a recording instrument in connection with the earth ammeter, the characteristic variations of the current leaving a pipe can also be determined and in this way the identity of the current can often be established.

From a study of the results of the survey it can be determined where current is leaving the piping. At a number of such points excavations should then be made and the exposed pipe examined with a test hammer for electrolytic corrosion. Where such corrosion and pitting is found at points where current is found leaving the pipe, it may be taken as evidence that the destruction was caused by electrolysis, because it has been conclusively proven that current cannot leave iron for surrounding soil without producing corresponding destruction of the iron.

Regarding the use and value of an electrolysis survey, it must be remembered that the object of the survey is to indicate the existence or non-existence of stray electric currents upon a piping system, and to determine where such currents flow on to the pipes and from the pipes. I have had occasion to examine a large number of electrolysis surveys and have found that many of these consist exclusively of voltmeter readings. Such readings by themselves do not afford a measure of electrolytic danger; they merely indicate where the greatest danger is likely to exist. Measurements of current flow on pipes are essential in an electrolysis survey because all current which flows on a pipe must leave it, and the amount of damage produced is proportional to the total current which leaves the pipe. I have seen some reports on the other hand, where it is stated that the current on a given pipe is zero, but where the instruments and methods employed were not sufficiently sensitive to detect current as large as two or three amperes, and where, therefore, the conclusion of zero current is not warranted. From a complete and properly analyzed electrolysis survey, a great deal of good can generally be accomplished. It will not always be possible to remove all stray currents from the pipes, but measures will be indicated by which the conditions can be greatly improved, and points of greatest danger will be located. If then trouble does occur at a later time at these points, the electrolysis survey may be most valuable in affording proof of the destruction of the property from railway currents and may be the means of compelling the railroad company not only to pay for the damage but also to make improvements in its return system so as to avoid the recurrence of such damage. I know of a number of electric railroad companies who are regularly paying for damage caused by electrolysis to piping systems. The knowledge that a pipe-owning company is making electrolysis tests and is keeping watch on the situation, also has a strong moral effect on the electric railroads.

REMEDIAL MEASURES

There is only one complete remedy for electrolysis, and that is the use of a completely insulated return circuit. Such railways may be provided with double overhead trolley wires, as used for example in Washington, D. C., Cincinnati and Havana; or with an insulated outgoing and return conductor in underground conduits, as used for example on the surface lines on Manhattan Island; or with separate insulated third and fourth rails for the outgoing and return current, as is used on the Metropolitan District Railway in London. With these systems the running tracks are not used as a part of the electric circuit, and as both positive and negative sides of the circuit are insulated no stray currents are produced.

Where a road operates on a private right-of-way, the rails can often be practically insulated from ground and the escape of current from the tracks prevented. For surface roads this can be practically accomplished by placing the rails on wooden ties above ground and using broken stone for ballast and keeping the rails out of contact with ground. In the case of railway lines operated on elevated structures the rails can be fastened to wooden ties and kept out of contact with the structure. These rails, supplemented where necessary with negative feeder cables, also insulated from the structure, can then be used for the return conductor. In this way the return circuit is quite thoroughly insulated from the elevated structure and from ground and stray currents are entirely prevented.

A number of remedial measures intended to reduce stray currents from electric railways using the grounded rails for a return conductor have been tried. These methods may be divided into two classes, the first class aiming to remove the current harmlessly from pipes by metallic connections or bonds between the pipes and the railway return circuit, and the second aiming to minimize stray currents through ground.

Since stray currents cause damage only where they leave pipes to flow to the surrounding soil, attempts are frequently made to prevent destruction from electrolysis by connecting or bonding the pipes or other structures by means of metallic conductors to the rails or to the negative return circuit, so as to remove the electric current by metallic conduction and thus prevent corrosion from electrolysis. This method can protect lead cable sheaths because they form continuous electrical conductors, but it is not generally applicable to underground piping systems, because the latter do not form continuous electrical conductors, but are more or less discontinuous networks. While lead-calked joints usually have a relatively low resistance, it frequently happens that they develop such high resistances as to make them practically insulating joints, due undoubtedly to the formation of oxide coatings. Cement joints and cement pipes have such a high resistance compared with iron pipes that they are practically insulating. Bonding of pipes to the rails or to the negative return circuit can only afford local protection to the extent that the piping connected forms a continuous metallic conductor, and this latter is an unknown and indeterminate quantity in a piping network. In the practical working out of a bonding or drainage system two opposing tendencies develop; first, there is a reduction in the difference of potential between pipes and rails in the positive areas, and consequent reduction of damage in those areas; and second, there is an increase of current flow on the pipes throughout the entire system, thus increasing the danger of trouble at high resistance joints, or other places where two piping systems or separate portions of the same system are electrically discontinuous. As a rule, in the early stages of this system and especially in small networks when there are comparatively few bond connections, and the resistances of the paths over the pipes are therefore relatively high, the effect is apt to be beneficial, reducing the danger in positive areas more than it increases the danger elsewhere. As the system grows and the load increases, more and heavier bonds become necessary. The current on the pipes may finally become so great that the trouble from current shunting around joints or between separate systems will increase more rapidly than the danger in the positive areas is reduced, and any further increase in the bonding becomes an actual source of danger to the system. Since bonding transfers the trouble from the region where it was most evident to a new locality where it may require several years to manifest itself, the false impression is created that the trouble has been removed. It is due largely to this obscure manner in which trouble develops that has caused this method to become quite widely used. A number of cases have in fact been reported where a main bonded to the negative return circuit at the power station was completely destroyed by electrolysis a block or two away because of a high resistance joint in the main, forcing current to shunt around the joint and leave the main a short distance away from the power station. In one of these cases one entire block of main had to be replaced. This case is illustrated in Fig. 7. In another case, the water main on one side of the street was bonded to the negative return circuit at the power station, and a main on the opposite side of the same street, although connected through cross-piping to the bonded main, was completely destroyed because high resistance joints had developed in the connecting pipes. In addition, bonding pipes as a means of protection always renders the bonded structures a part of the negative return circuit, and therefore a source of danger to other underground structures which are not bonded. It has in fact been frequently found that where gas or water service pipes cross bonded cable sheaths, currents are caused to flow from the service pipes to the cable sheaths, and produce gradual destruction of the service pipes. In the case of one city nineteen service pipes were destroyed in the course of one year directly where these pipes cross telephone ducts containing cables whose sheaths were bonded to the railway return circuit.

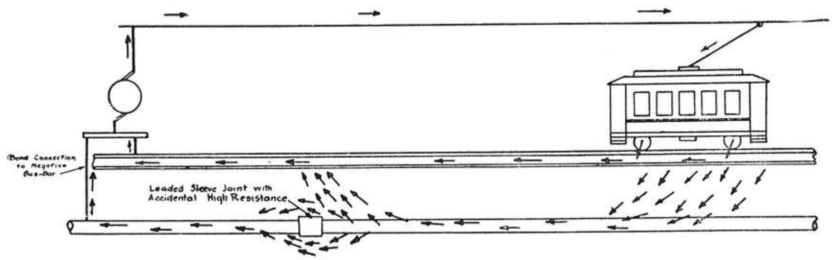

FIG. 7.—*Diagram Showing Increased Danger from Electrolysis from Bonding Pipe to Rails Caused by Accidental High Resistance Joint in Pipe.*

Among the methods which have been used to minimize the escape of currents on systems using the grounded rails for the return conductor are increasing the resistance between rails and ground, increasing the resistance between pipes and ground, increasing the resistance along the line of the pipe by means of high resistance joints, and decreasing the drop in potential in the grounded rails.

The resistance between rails and ground can often be increased by using broken stone ballast, whereby the rails are kept out of contact with ground and water is allowed to trickle away from the rails thereby maintaining high resistance between the rails and ground. Where an electric railway owns its own right-of-way, it is frequently feasible as already stated to practically insulate the rails from ground.

Attempts have been made to insulate pipes from ground by a large number of tests on such paints and dips have, however, shown that no dip or paint will protect a pipe against electrolysis in wet soil. The first difficulty is the mechanical one of applying the paint so as to form an absolutely perfect coating, and then to prevent mechanical damage to the coating. Where imperfections exist or develop aggravated trouble always ensues. Experience further shows that even where paints or dips are apparently intact and perfect, electrolytic action is not prevented, and in fact very serious electrolytic pittings have been found under apparently good coatings. It has been found that in most cases the coatings applied have either been completely destroyed by the effects of the wet soil and the electric currents, or defects in the coating have developed causing concentrated corrosion at such defective spots. The destruction of paints in wet soil where subjected to an electric current is due to traces of moisture finding their way through the coating, giving rise to the flow of a feeble current and resulting in a very slight amount of electrolysis. The gases and other products of electrolysis then form blisters and finally rupture the coating. The only kind of insulating covering which appears to afford certain protection is a layer of at least one or two inches of a material like coal tar pitch or asphaltum, of such a grade that it is not brittle and so will not crack, but yet is hard enough to remain in place. A pipe treated in this way with the work done so as to be mechanically perfect would undoubtedly be protected from electrolysis.

Current flow on pipe lines can also be practically prevented by using insulating joints for every joint. Cement joints as ordinarily made do not generally produce metallic connection between the two pipes and may practically be classed with insulating joints. The cause of the high resistance of cement joints is probably due to the fact that although every attempt is made to push the spigot end home into the bell when laying cast-iron pipe, as a matter of fact in most cases the two pipes are not in metallic contact. Even where there is metallic contact this is probably over a comparatively small area, if not at a point. As the end of the spigot is always heavily coated with scale, such metallic contact generally forms a poor electrical connection of comparatively high resistance. It is a simple matter to positively prevent metallic contact by inserting a ring of some cheap insulating material such as fiber or cardboard between the end of the spigot and the interior of the bell, and this has been done in some cases. The resistance of cement joints is then the electrical resistance of the cement intervening between the spigot and bell, and while cement is not an insulator but on the contrary is probably as good a conductor as ordinary ground, yet compared with iron the resistance is so high that the cement joints practically interrupt the electrical continuity of the pipe line. A pipe line laid with all cement joints or with all insulating joints is therefore a discontinuous electrical conductor and is not capable of carrying stray electric currents. Such a pipe line therefore cannot pick up current in an extensive negative area to discharge it in a restricted positive area, which is generally the cause of the most serious electrolytic danger. For this reason a piping system with all cement or insulating joints is on the whole much less likely to be affected by electrolysis than a piping system with all lead or screw-coupling joints.

While relief from serious electrolysis can at times be obtained by such special measures as insulating pipe coverings or insulating joints, it must be understood that all remedial measures should have for their first aim the reduction of the drop in potential in the rails to a minimum, because this removes the cause of the trouble. The first and most important step necessary to accomplish this is to maintain the rails perfectly bonded, so that the rails themselves form continuous electrical conductors. The next important step is to limit the radius from the power station to which the station supplies electric power, so that current does not have to be returned from excessive lengths of rail lines to any one power station. This is usually accomplished in practice by supplying power to electric railways from distributed substations. The next step is to remove the current from the rails wherever there is concentration of current, by means of insulated return feeders connecting from the rails at these points to the power station. In order that such insulated return feeders should be most efficient in reducing drop in potential in grounded rails, these feeders should be proportioned for equal drop, so that the rails at all points where return feeders are connected are maintained at substantially the same potential under average load conditions. This also requires that the rails immediately in front of the power station must not be connected directly to the negative bus-bar, unless a resistance corresponding to the average resistance of the return feeders is connected in the circuit. Where it is necessary to bring current back from a distant point in the rails, it is sometimes more economical to employ a negative booster in series with this return feeder rather than make this feeder of such large cross-section as would be required to maintain the distant point in the rails at the same potential as the nearer connection points. With this system part of the voltage drop is actually removed from the rails and transferred to the insulated return feeders from which current cannot leak to ground.

The reduction of drop in potential in rails, for the purpose of minimizing electrolysis, is the basis for various regulations and ordinances which have been enacted for the purpose of protecting underground metallic structures from electrolysis. For example, the well known English Board of Trade Regulations limit the maximum allowable potential difference between any two points in the rails to seven volts. In Germany, a joint committee representing the electric railway, gas and water interests, has adopted a regulation limiting the average allowable potential difference between any two points in the rails to 2.5 volts within a district encircling the urban district by a radial distance of two kilometers. Beyond this circle, the average potential drop in the rails must not exceed one volt per kilometer.

SUMMARY AND CONCLUSIONS

Experience shows that where there is serious trouble from electrolysis caused by large stray currents leaking from street railways, the bulk of this trouble is due to defective rail bonding, to ground connections from the negative bus-bar, and to lack of return feeders to bring current back from the rails to the power station. While stray currents can only be entirely eliminated by insulating the return circuit by the use of a double trolley, either overhead or in conduit, it is nevertheless a fact which is not generally appreciated, that where large stray currents exist, these can always be reduced to a small fraction of their present value by removing all ground connections of the negative bus-bar, and installing insulated return feeders proportioned for equal drop from radially disposed points in the track system located at some distance from the power station. By this method the rails are drained of current and any desired part of the voltage drop can be removed from the rails and transferred to insulated conductors from which currents cannot leak. In Europe, such radial insulated return feeders for bringing current back from the rails to the power station are made necessary by regulations limiting the allowable drop in voltage in the rails, and in most cases such installations of insulated return feeders have substantially removed serious trouble from electrolysis. This system of minimizing stray currents by means of radially disposed insulated return feeders has also been installed in a number of American cities, and the method is gradually being recognized as by far the best for minimizing stray currents. This system in fact removes the root of the trouble, by draining the rails of current and removing voltage drop from the rails and thus preventing substantial leakage of current through ground, and is therefore correct in principle. The railroad companies frequently object to this system claiming that it is prohibitively expensive. This is certainly not the case, as is evidenced by the fact that the method is in general use in Europe and in a number of American cities today. The fact is that in many electric railways there is practically no installation of negative feeders and the railway companies are often not willing to install even a moderate amount of return feeder copper. A mistake is often made in confusing the radial insulated return feeder system with paralleling the rails with copper.

In the decree recently filed in the celebrated Peoria case, the railway company is enjoined and restrained from injuring the property of the water company by electric current escaping from the rails or structures of the railway company. No particular method for preventing the escape of current is prescribed in the decree, because the court in its decision has already stated that a court does not have the power to prescribe by injunction any specific system, and that this power resides only with legislative bodies.

It is the author's firm conviction that such remedial measures as pipe drainage or insulating pipe joints should be used if at all only as a final measure and never until the return circuit of the railway has been improved so that only small amounts of stray current remain on the underground structures. This view appears to be entirely in accord with the Peoria decision, and is certainly in accord with the best engineering practice.

THE DRAFTING ROOM AND ITS OPPORTUNITIES FOR THE YOUNG ENGINEERING GRADUATE

B. K. Read

In the spring of the year the senior of an engineering class begins to feel that he does not know all there is to know about engineering, and asks himself, "Where can I go to get experience and what line of work shall I follow?" Although the young man must answer part of this question himself possibly he can gain a little advice from some one who has had considerable experience in the engineering profession. The field is big and unless the young engineer knows something of his qualifications, it is pretty hard to determine what to do.

The question is often asked, "Is the drafting room a good place to begin to gain engineering experience, or is it a place to avoid?" Some students during their college training know that when they leave college they will not enter the drawing room, and that they never could draw anyway. Perhaps the man to whom drawing is distasteful had better avoid the drafting room, but to the man who can draw well, the drafting room offers unlimited opportunities.

Along with the advantages of the drafting room, of course there are the disadvantages. The drafting board is perhaps not the best place to promote good health. The work in the drawing room is indoor work and very confining, but the person in good health will not be affected by a position in the drawing room.

Let us follow the young engineer, who chooses the drawing room as his beginning. Upon his graduation, he obtains a place in a drafting office, and brings his tools, slide-rules, reference hand books, and is assigned to a place to work. He just left his Alma Mater with flying colors as a graduate and calls himself an alumnus, but now, after he has just settled down to his duties in a drawing room, with the gaze of strange faces of draftsmen (many of them middle-aged men), he feels very much like a freshman during his first day on the campus. This young man has calculated stresses in machine parts, stresses in steel and gone to higher mathematics to get some of it. When the first work is assigned to him, he expects to get something along the same line he had in school. About the first assignment he gets is some simple tracing or copying. Sometimes he does not know where to begin and he is too timid to ask many questions. He stumbles along for a few weeks until he becomes aquainted with his work and his fellow workers, and accustom to the new environment. Generally the person in charge lets the new beginner go along with miscellaneous work for some time and gets acquainted with the man. After a few weeks the young engineer can make his efforts show results.

In order to receive all of the opportunities that the drawing room affords, the young man must first be able to represent ideas on paper and do it skillfully; the better he can do this the more notice he receives. There is nothing that leaves a better impression than a well executed drawing.

Ideas must be developed and shown on paper. They bring out reasoning and thought and at this point the young engineer can begin to show his worth. These ideas are usually brought from the men higher up in the engineering profession, and while some of these ideas are worth less and others are of great value. One can readily see the unlimited field and interest that is thus brought out.

The idea is usually brought to the drafting room from the officers of the company and assigned by the chief draftsman to different men. It is the association with these men that bring the opportunities where the draftsman is competent.

There is another side of the drafting room which probably is not as rosy as it might be. Some work comes to the draftsman's desk which is drudgery, and all drafting rooms have a certain amount of it.

The drawing room is a place where a young man probably should not stay too long. A good man may be taken out before he really had a good start. His superior officers see the qualifications in him and that is all that is necessary. With the experience of the drawing room and the general office methods this young man has a good foundation for the field.

Experienced engineers are continually making sketches of something which they want represented. With the experience of the drafting room, an engineer surely has the advantage over the man who has avoided the drafting room. When once having done drawing room work one can better supervise it when he has charge of such work.

The greatest advantage of the drafting room to the young engineer is the direct contact with the management of the company. With these associations men are picked from the drawing room and advanced to higher positions.

In preparing a young man for the drafting room, there is a certain amount of training which he must go through. First he must be able to handle his tools skilfully, and he must understand the subject which he undertakes to represent.

The work of the Machine Design Department of this University, attempts to present its course to the student similar to the manner in which he will receive the work in practice. The beginning subjects of the course requires a more detailed outline of the work to be covered. After the fundamentals have been passed over, the department places the student as an employee, and the work assigned just the same as with a commercial establishment. The student is left to look up his own references, and rely upon his own resources. The department does not intend that the student is to be turned loose and receive no instruction, but here the instruction takes a different form from that given up to this time. The student must be helped to find his material. As the student performs his work, he is told how to do it, just the same as a foreman of a machine shop would tell a journeyman how to do his work and where "short-cuts" can be made. With the exhibition of actual working drawings of various manufactories, the student can make his work conform to what is done when he enters the field himself. It requires additional work on the part of the instructional staff at first by following this method. The student has been so accustomed to having his work laid out for him that it is a new innovation. It is interesting to note under this system that the student will launch out upon his own initiative and search for more information than is required of him. The department feels that by the time the student has passed through a training of this character, and when he is taking hold of his first position in a drawing office (or elsewhere), he has a clearer idea of how to begin something he has little or no information upon.

While it is desired to show the opportunities of the drafting room, in order to correct general misinformation on this subject, there are of course many other places for a graduate to begin, but to the man that is capable as a designer and draftsman the drafting room affords unlimited opportunities.

The Wisconsin Engineer.

EDITORIAL

The news has come to us that Wisconsin is to lose two men from the faculty at the end of the semester.

Prof. C. C. Thomas, one of the best men that we have ever had is to leave Wisconsin to accept a professorship at Johns Hopkins. Our first acquaintance with this man was through a Thomas gas meter, a device which has revolutionized methods of gas measurement. For six years he fought for recognition for his tables of the specific heat of superheated steam,—at the beginning every authority was against him, but today he stands out head and shoulders about the rest, victor!

Mr. Rowse, an instructor in steam and gas, has accepted a fine position with the Cutler-Hammer Co., and if our experience with him here is any ground to judge upon, there is no doubt in our minds of his future success.

We hate to talk about ourselves all the time, but we have just received notice that one of the foremost technical papers in Germany, the Silicat Leikchrift, reprinted in full the article, in one of our recent numbers, on Magnesia Crucibles by Dr. Watts. Special mention was given to the *Wisconsin Engineer.* Notices of this sort are what make us feel the wide reaching effect of the *Wisconsin Engineer.*

Last month we spoke about the value of responsibility in a business. The manager made a verbal agreement with *The State Journal* to have the March issue of the *Engineer* out on April 9, Wednesday. Due to an unusual amount of work the *Engineer* was overlooked, until the Saturday before, when a chance remark by the manager to Mr. Oakey of the *State Journal* recalled the fact to his mind that the *Engineer* was due in three days. It seemed as though it was going to be an impossible task, but by crowding the compositors and press men to the limit, and working overtime, they managed to get the *Engineer* out on time.

We take this opportunity to thank the *State Journal* and the Grimm Book Bindery for their efforts in our behalf, and further we want you to take these two successful businesses as an example of what we tried to bring out before, i. e. the ability to shoulder responsibility. We had no written contract, no hide-bound agreement, merely a verbal understanding, and these firms in living up to this agreement showed the extremes they would go to to keep their word.

CAMPUS NOTES

[The writer is not trying to give an opinion of self-government, but is merely stating a few facts in regard to self-government that have been forcibly brought to our minds by the recent controversy, and we do not believe that anyone who is at all acquainted with actual conditions will dispute them.]

Student self-government has been through some trying periods in the last week or so. The court attempted to resign, and did, but on being reassured by the regents that they would have complete jurisdiction, except in cases where it was thought by the regents that the action of the court was unduly slow, they have returned.

For a time it looked as though we were to return to the "good old days" of hazing, but the court, after the usual delay, got on the job and has indicted about ten men who were connected with several parties in the Latin quarter. It seems to be understood around school that out of the entire ten, there is only one man who is really morally responsible for the "rush" mentioned. Such is student justice.

We have heard a great deal of dissatisfaction about self-government in the past few days and some of it seems to be based on good sense. The delays of the court in the Crile case were certainly inexcusable. Some of the stuff that comes up in the conference is almost as bad. For instance: the Union articles of control, as first presented by the committee,—which committee told how hard it "worked all summer on these articles,"—were absolutely impossible in the manner in which they took care of the election of members. Any child that could add three and two could show the fallacy that was present.

When anyone tries to get away with such crude work as that it is to be expected that someone will object.

(More later)

Eddie Samp has been appointed football coach by the trustees of Hamilton College. Hamilton is a well known small college in central New York and competition for such a position is keen.

Did you know that the world's pole vault record was broken by a Wisconsin man?

Our crew has been on the water several times but has had little decent weather. Capt. Sjoblom has been advised by the medical department to quit athletics and has resigned his position. He is an unusually good man and will be greatly missed by the crew. Sjoblom is a senior civil engineer.

ALUMNI NOTES

Herman Lochman, M. E., '09, is in charge of the duty tests of the Epping Carpenter Co., Pittsburg, Pa.

Victor L. Phillips is selling contractor's machinery in Kansas City, Mo.

W. U. Murrish, E. E., '11, is with the Sierra and San Francisco Power Company, Modesto, Cal.

J. D. Morton, E. E., '08, is the general manager of the Concounlly Light and Power Co. at Concounlly, Wash.

R. Crowell, E. E., '96, is with the Pacific Gas and Electric Co., Oakland, Cal.

J. M. Turner has left the engineering profession and is in the general merchandise and hay business in Angleton, Texas.

O. F. Goeke is a structural draftsman with the Chicago, Milwaukee & St. Paul Railroad and is located in Chicago.

L. H. Huntley, C. E., '08, is associated, as Assistant Engineer, with the Ford, Bacon and Davis Co., consulting engineers, Valier, Oregon.

Ernst L. Pflanz, C. E., '11, is a structural draftsman with the American Bridge Co. at Gary, Ind.

J. B. Wheeler, E. E., '11, is operating engineer for the Illinois Traction Co., St. Louis, Mo.

W. R. Muehl is in charge of the Woods Motor Vehicle Co.'s laboratories located at Chicago, Ill.

W. O. Sustins, E. E., '06, is connected with the Argo Electric Vehicle Co. of Saginaw, Mich., in the capacity of automobile engineer.

H. D. Blake is a civil engineer with the Wisconsin Highway Commission, Madison, Wis.

J. D. Sargent, M. E., '07, is now affiliated with the Chain Belt Co., Milwaukee, Wis.

A. A. Fisher is the general secretary of the Sun Coal Co., Caryville, Tenn.

Ray F. Robinson, E. E., '05, has the position of equipment engineer for the Pacific Telephone and Telegraph Co., Spokane, Wash.

Walter J. Schneider, E. E., '10, is a Telephone Engineer with the Chicago Telephone Co., Chicago, Ill.

Edward H. Schroeder, E. E., '09, is the contract estimator for the Western Electric Co. at Hawthorne, Ill.

Frank C. Schroeder, E. E., '07, is an instructor in mechanics at Fayweather Hall, Columbia University, New York City, N. Y.

A. A. Ort is the vice president, engineer in charge of the Pitometer department of the Municipal Supply Co. of Chicago, Ill.

Thomas Rust, C. E., '12, is a bridge draftsman with the Chicago, Burlington & Quincy Railroad, Eau Claire, Wis.

B. A. T. Rustone, C. E., '09, is a structural designer for Marshall E. Fox, Chicago, Ill.

Gania G. Ryder, Gen. E., '07, is an electrical contractor for the Twin City Electric Co., Minneapolis, Minn.

Kurt Schapper, M. E., '02, is the foreman of the Thor. B. Jeffery Co. of Illinois, Chicago, Ill.

Sylvester Schattsclmeider, C. E., '05, is doing research work under Prof. George C. Whipple of the Graduate School of Applied Science at the University of Harvard.

H. C. Scherer, M. E., '12, is with the A. O. Smith Co. of Milwaukee, Wis.

Walter W. Schilling, C. E., '12, has the position civil engineer in charge of construction for the Greiling Bros. Contracting Co. of Green Bay, Wis.

Andrew C. Scherer, C. E., '09, is affiliated with the Monterry Iron and Steel Co. and holds the position of rail inspector for the Robert W. Hunt Co. of Monterry, Mexico.

Harold L. Scherer is the production engineer of trucks department of the A. O. Smith Co. of Milwaukee, Wis.

Oliver J. Schieber is an instrument man for the Stone and Webster Construction Co., Big Creek, Cal.

F. C. Schmidt, E. E., '08, is the superintendent of construction for the Kansas City Street Railway Co., Kansas City, Mo.

H. E. Schmidt, Min. E., '11, is the Assistant Engineer of the Mahoning Ore and Steel Co., Hibbing, Minn.

To Our Subscribers

The May number is the last issue this year. There are a few subscriptions unpaid and in order to clean things up as soon as possible we should like to have our delinquent subscribers pay up immediately.

Thank You

Wisconsin Engineer.