

The Secretary read the clause in the Constitution relating to meetings.

THE PRESIDENT: It seems to me from that, that all that would be necessary in any event would be for fifteen members to call upon the Secretary to have these meetings.

MR. MAILLOUX: I think it would perhaps be the best way to have as many of the members of the Association as are willing to do so form a kind of compact among themselves by which they agree to a programme of this description and if they present a resolution to the general body of the Institute, by which they would seek official recognition in so doing, it strikes me that would be the best way. If there is no motion before the house I would like to move that the question be brought up to-morrow. Is there going to be any regular business at to-morrow's meeting?

THE SECRETARY: It is not a regular business meeting but of course we can transact business.

THE PRESIDENT: This matter can be brought up by you or any one else at the meeting to-morrow.

MR. MAILLOUX: The matter should really not take much time if it is brought up in the shape I suggest now. I move that a committee of three be appointed by the Chair to consider the matter and bring in a suitable plan or project and report at the meeting to-morrow. The motion was carried and the Chair appointed on the committee Messrs. C. O. Mailloux, Ralph W. Pope and G. E. Phelps, Jr.

On motion of Mr. Phelps the meeting then adjourned.

---

#### GENERAL MEETING.

May 19th, 1886.

The meeting was called to order at 10:40 A. M., by the President of the Institute, Mr. Frank L. Pope.

THE PRESIDENT: The hour set for the meeting was ten o'clock, but as the attendance is rather limited in consequence of the bad weather, we have waited a little while. I think, however, as we have much to get through with to-day, we had better commence. The first paper on the programme is a paper by Mr. Sidney F. Shelbourne, which Mr. Ryan will read. The title is "Underground Electrical Systems."

# UNDERGROUND ELECTRICAL SYSTEMS.

---

BY SIDNEY F. SHELBOURNE.

---

## I. DEFINITIONS AND PRINCIPLES.

There has been extended use, of late, of the word system as characterizing anything pertaining to construction for underground conductors. Thus he who has some form of box, or conduit material, or even a material in which to imbed underground wires is referred to as promoting "his system." Such misuse of terms is unscientific, loose, and confusing to the average comprehension. A *system* is "a whole plan or scheme consisting of many parts connected in such a manner as to create a chain of mutual dependencies and harmonious relations." An *electrical* system consists chiefly and primarily of a construction and arrangement of underground conductors, singly or in cables, connected with each other in lines of communication and so disposed *inter se*, or related to other material and space as to afford a harmonious and efficient electrical service for all uses. The conduits providing merely passages or ramifications of underground channels for the wires or cables, must always be considered a subordinate and minor part of the problem of underground electrical service.

The principles therefore which should control the preparation of this paper and the discussion upon it should be—(a), the exclusion of individual facts, materials and forms, except so far as they have a bearing upon the proper consideration and determination of systems of underground construction within the definition given;—(b) that prominent notice should be given to those elements which relate to the harmony of the different kinds of electric service when the conductors are assembled in conduits underground;—(c) the omission of details which must be essentially alike in all underground distribution, and on which the inventive mind has expended so much of sweating energy, as nipples, elbows, hand-holes, man-holes, separating bridges, insulating stuffing boxes, lead joints, and the division of lead covered cables, as well as the multifarious ways of connecting branch

pipes and house wires. These minutiae are better left to the obvious suggestions of individual promoters or the practiced skill of the finger and thumb electricians;—(*d*) the rejection from consideration, beyond a mere mention, of those pseudo-systems in which bare wires are buried in trains or beds of insulating material without the proper ceremony of even a pine box for conduit coffin. Such methods must be essentially vicious as to prevention of wire contacts, security of extraneous insulation, and the absence of consideration of dynamic induction as the chief element in the underground problem.

The French Government, 30 years ago, began its experiments in underground wires with this so called “solid system” and at periods until the present day we have heard of some new advocate of this “way” of burying the wires. So history repeats itself among the novices of science as in the recurring styles of hats and the bigness of bustles.

## II. CONDUITS FOR ELECTRICAL SYSTEMS IN CITIES.

It must be understood that conduits, as here referred to, are confined to cities which admit of something like a *system* of underground conductors. A single channel under a country road or a suburban highway leading to the hay fields may be maintained with almost any material which presents a reasonable show of durability. In large cities like New York the conduit question requires more consideration because of circumstances more difficult and intricate. Here the question of material is important—(*a*), in the protection of the wires and cables from mechanical injury and the chemical action of fluids and gases permeating the soil; (*b*), in affording a means of harmony between the several classes of service, by aiding to shield the wires from the currents of induction; (*c*), in the promise of a permanent durability; (*d*), in the economy of money outlay and underground space.

A few facts will illustrate the first point. A company put down in this city, about eighteen months ago, two armored cables, each containing seven copper gutta-percha-covered conductors. For a portion of the distance these cables were drawn into 6-inch cast iron pipes, and have suffered no harm whatever. For the remainder of the way, the cables were laid at the bottom of an open trench in a layer of clean sand and then covered with blue-stone flagging of a thickness of 2 to  $2\frac{1}{2}$  inches, the trench filled with earth and repaved as before. On this portion

of the line, at places, the gutta-percha insulation was softened and partially dissolved, under extraneous influences supposed to come from the pipes of water gas in the same street. The wires had become grounded through minute pin holes forced through the weakened insulation by the electric current. At one place on the same part of the line a pickman's stroke had split one of the blue-stone slabs and entering through the armor of the cables had denuded the wires of their insulation. Another company found recently in Wall-street that the insulation had failed in an electric light service, the superintendent of repairs giving as the cause, that a pick point had gone through the shell of a  $2\frac{1}{2}$ -inch wrought iron pipe which had become partially corroded by some years of service. Such facts are probably recurring in this and other large cities, as to various underground pipes and constructions many times every month in which street excavations are permitted. If these conduits for electric conductors are to be made of plastic compounds and placed in the networks of other pipes underground in this city or other cities, where excavations and repairs are constantly going on, how long may such a conduit be supposed to escape the recklessness of an Irishman's brawn with a 9-pound pick above his shoulder. Public authorities have therefore wisely excluded earthenware and concrete pipes from general use under the pavements, because of this liability to fatal injury, among other dangers, by which the service they were intended to perform might become interrupted. As to the character of iron pipes, on the other hand, to be selected, it is a well known fact that the thickness of metal and the purity of the iron regulate the choice to be made. The thickness of the iron is made to increase in direct ratio to the diameter of the pipe, and the corrosion is found to be in the inverse ratio of its purity. Therefore a  $2\frac{1}{2}$  inch wrought iron pipe affords but a low limit of life under oxidation and an equally low resistance to injury by penetration as compared with a cast iron pipe six inches or more in diameter. It follows, therefore, that the cheaper the material the greater the durability. The telegraph companies who have put down wires in this country by their own methods have generally recognized these facts. An earthen, cement, or concrete pipe for a conduit will not allow of calking like ordinary iron gas pipes, so that the joints have to be formed solidly with cement or cognate materials, and the lengths are torn apart by expansion and contraction, and thus destroy them-

selves unless buried at a depth so great as practically to secure an equable temperature, which again largely increases the cost of original excavation and renders required repairs difficult and expensive. Every one acquainted with the tables of the ratios of expansion of different materials can easily calculate the effects of thermal forces upon materials whose melting point is found at such low figures as  $150^{\circ}$  to  $200^{\circ}$  Fahrenheit. The co-efficient of expansion between zero and the melting point in materials of this class must of course be inordinately large. Of wood as a conduit material but little need be said. Such a conduit cannot, with ordinary care and expense be made water and gas tight, and even if this were done, a pick-axe in habitual excavation would soon disqualify that condition. Therefore such a conduit usually exists as a blind sewer or a nasty "hole through the ground" in which insulation can rot at discretion if not protected with lead, and if so protected then the lead in turn is eaten away in the rain water drainage impregnated with ammoniates and charged with carbonic acid derived from street droppings and vegetable decay in the soil.

Under the second point (b) all electricians understand the facts as to metals acting as screens to induction when giving a circuit or escape, in mutual connection, or with the earth and interposed between conductors or cables in use. A metal conduit thus shields the wires or cables within it from the dynamic induction of the conductors in use in a conduit alongside of it, by receiving itself the induced current and conveying it away to the earth at some available point or points in its length. If two or three separate metal pipes or conduits are placed side by side but not in general contact laterally, and each furnished with conductors or cables of distinctive service, a most beneficial anti-inductive agency would be realized from such a disposition of material. A misapprehension, however, has arisen founded it is believed on an error promulgated in an individual opinion or report made during the sittings of some committees in 1883 and 1884, under a self-constituted general committee on underground electrical inquiry. The opinion was given further extension in the first report of the Brooklyn underground wire commissioners, by misinformation, as though it had been made the deliberate conclusion of the committee on technique, which considered and ordered printed the individual report of 1884. A modification of the same opinion was urgently pressed upon the New York com-

missioners in the Autumn of 1885 and during the early part of the winter just past. I refer to the statement that iron conduits have the effect *to retard* the currents in the conductors within them. The theory on which such an effect is claimed has not been stated nor can such a proposition be assumed or proven from the facts. The theory of static induction and consequent retardation when precisely stated and referred to practical examples can give no ground for such a notion of the effect of iron as a conduit material. The idea can only be referred, for probable truth, to theoretical considerations of the effects of dynamic reactions due to magnetic influences.

The third point (c) has already been touched upon in speaking of the character and purity of iron as determining its durability. There can be no dispute that hydraulic cements or bitumen and cognate hydro-carbons either singly or combined with other inert substances if considered as *materials* are more durable than the commoner metals; but the question is not of the durability of materials *as such* but of the permanent character of the *construction* as a useful form of conduit into which the materials enter.

The commonest and cheapest sort of cast iron six inch conduit tube the metal of which has a thickness of three-eighths to one-half inch if boiled in a preserving bath, as is now done, and avoiding a salt water soil, will doubtless give continuous service for 40 to 50 years. Materials less strong than iron are exposed to the liability of damaging and breaking strains from the sagging of suspended lengths during undermining or contiguous excavations; the continuous line of plastic lengths and solid though weaker joints in conduits of mastic concretes cannot resist the forces due to changes of temperature, since there is no mechanical provisions for expansion and contraction and the solidly adhering parts must give way. Such materials too are exposed to the softening and warping or collapsing influences of heat from the steam pipes, and the constant danger of ruin from the implements of excavation.

Of the strength of cement and glazed and unglazed earthen ware pipes many of us have had practical observation in the number of pieces which have been found chipped and broken merely in handling and transportation from the factories to the points of delivery. It has been found necessary therefore where such materials have been used for conduits for underground electrical conductors that they should be made so solidly and

therefore so bulky of material that the openings or spaces left for the wires can bear but a small ratio to the total section of space required for the body of the structure. Hence we are met again with the question of expense for bulk of material and, more important, the essential room or trench which must be assigned to such structures under streets already variously lined with pipes of the several uses and at such random levels and make-shift positions as to render it quite impossible to lay out a line of regular construction. But such cements and other plastic compounds have been selected for electrical conduit materials for another reason.

It has been thought convenient, and until recently even necessary that conduits for the wires and cables should be made with a series of holes or passages through a body of material so as to allow of a division or separation of the cables into the different longitudinal channels or compartments thus formed, and that a metal could not be cast into such a form of conduit with money economy, nor properly and securely connected together in one continuous length. The reason for this leaning of favor is drawn from the settled experience that heavy conductors and cables in considerable lengths cannot be drawn into a single passage conduit in succession the one on the top of or alongside of the other because of the friction and the interference of movement between them. Hence a conduit body of plastic material has afforded the most convenient means of securing a considerable number of individual passages separated by walls or partitions in the material itself, so that each cable or assemblage of wires may have its hole or passage in exclusion. The English Post Office Department however has preferred to use separate small iron pipes instead of the pigeon hole structure, some of them of three inches of diameter into which 80 wires bunched together are drawn at one operation. In this country such plastic body conduits have been made to some extent, containing from three to seven channels for the wires of a diameter up to  $2\frac{1}{2}$ , 3 and 4 inches.

Such structures must be additionally very wasteful of space, besides the room required for solidity and strength of materials; for, if each passage can contain but a single cable or its equivalent of bunched wires, two-thirds of the wire space itself must probably remain unfilled by the cables. Had inventors sooner directed their energies to finding efficient means of drawing the cables and conductors successively as wanted for use, without injury, into

compact position within the same tube or conduit channel of simple and cheap construction the question of how to find room for the wires under our streets would, ere this have ceased its bothering in the direction of multi-channeled concrete conduits and their pretentious promoters. But the interest in conduits of such a construction has been kept alive and stimulated by the plausible idea that each company now using overhead wires could have its own pigeon hole or compartment in a compulsory underground service. It has not yet perhaps occurred to all of us that if each company or party using wires is to have but a single compartment channel how many it would require to serve even present existing interests without a single thought for the future. But such a limitation would not answer the requirements of existing *companies* which use already a large percentage of the wires now overhead. If therefore on the other hand each or any company should be allowed to occupy the service channels *ad libitum*, how many vacant ones would the prominent existing companies be likely to leave for prospective rivals? The question of space, therefore, and control of such a conduit under our streets becomes one of the greatest importance, outside of the question of cost and durability to say nothing of the fact that conduit materials of an insulating character, have no agency, like a metal, to obviate the effects of dynamic induction.

It remains to notice the even grander suggestions of abortive genius in appropriating the sub-pavement spaces for the wires. The prevailing notions of a "sub-way" are without sense or practical calculation, and the word, with the notions attached to it, has unwisely been thrust into the legislation of this State as to underground wires. The general conception is that a "sub-way" must be a large viaduct or passage underground, like the Paris sewers or the Harlem Tunnel, and the idea for electrical conductors was evidently borrowed from the Paris sewers. Such constructions may be used if existing, but are out of the question as prospectively considered for electric uses. And yet would be inventors have loaded the rooms of the electrical service commissioners for this city and Brooklyn with drawings and models, the practical adoption of which would require a space of 10 to 100 square feet of vertical cross section, and a cost of \$50,000 to \$200,000 per mile. Even if such subways were practicable as to space and cost they would still fail to meet the requirements as to inductive harmony of the wires within them, while to allow the



various companies to occupy them pell-mell with their different uses would be the culmination of a stupid folly. We may therefore dismiss a "sub-way" as thus conceived from the room of this paper.

The question of necessary first cost, for the same useful capacity, as between multi-channeled concrete, and a simple cast-iron pipe conduit, need not be attempted here, because, at best, hypothetical calculations for electrical service underground must be uncertain and of speculative value by reason of the varying conditions of the service proposed and the locality designated. We must therefore begin and stop at first elements. It is enough to say that cast iron pipe conduits as made in dry sand, and for the usual sizes, cost from one and a half to two cents per pound, while if the conduit be made of box castings with plates and shelves, which are required to be moulded in green or wet sand, the cost per pound will be 50 to 75 per cent greater. Concrete may be made of a weakness or strength, within its limit, depending upon the will or honesty of the contractor, whether of hydraulic cement or an asphalt and coal tar basis, and the cost will vary in proportion.

### III. SPECIFIC INDUCTIVE CAPACITY—INDUCTION—INSULATION.

No one has yet been able to tell us why it is that induction takes place through one kind of insulating material more readily than through another, any more than why, in the nature of things, copper should be a better conductor than lead. The essence and mode of electricity itself must perhaps be brought to demonstration before these questions can be answered. But it is clearly an experimental fact that inductive capacity of insulating materials has no immediate relation to quality as insulators. The table of substances experimented with shows a considerable irregularity and a remarkable variation in inductive capacity, ranging from 1.77 to 5 in comparison with the standard unit of dry air. The writer is led to speak of inductive capacities of insulations by the confusion which has arisen from the lack of proper distinctions in telephone service, between what is apparent as due to the conditions of static and dynamic induction respectively, and also because of the claims which have been made as to the merits of some of the underground cables.

It has come to be a tenet well received among electricians that "the better the insulation the greater the induction." This is

particularly true of dynamic induction, as is well observed on telephone air lines in the difference between a wet day and clear, dry weather; but it is not altogether true as to static induction as one of the practical difficulties of electrical communication, for we have the example of a rubber insulation giving a much greater static induction than a high class of gutta-percha, and it has been the boast of some of the English manufacturers that they have increased the insulating quality of their gutta-percha and at the same time reduce its specific inductive capacity some 20 per cent. In this country a claim has been made that by reason of the low specific inductive capacity of an insulation used, an anti-induction cable is secured, (evidently referring to dynamic induction,) while the insulation itself is claimed to be very high up in the megohms. Let us examine the possibilities of this claim. In the first place, dry air is the standard to which all insulations are referred as well as all inductive capacities of their materials. We have seen, secondly, that dry air insulation is more favorable to dynamic inductive effects than damp air, and as the lowest known inductive capacity of solid insulation is 1.77, as compared with the unit of air, the claim is a fallacy as to dynamic induction, but as to retardation, the result of static induction, the claim is true, because long since proven by the insulations used on the conductor cores of the ocean cables. It follows, therefore, that the claim is mixed with both merit and demerit. It should be founded upon a low specific inductive capacity and a *low*, but permanent quality of insulation. But even when predicated of static induction the claim is of less importance than other considerations in the case of subterranean cables consisting of many conductors together in the same general body of insulation. For example, if we have given a lead-covered cable composed of many small telephone wires in a body of insulation comprising their individual insulations and a general inclusive insulation whose diameter inside the lead may be an inch and a quarter, then, if a wire be selected for use at or near the centre of the cable and the others are not connected through instruments or directly with the earth, the conditions would be most favorable for a low static induction in the use of that one wire. If some or all of the other wires were connected with the earth the static induction would be increased in inverse ratio of the distance of the earth wires from the wire in use. If, instead of using the wires in such a cable as ground circuits they should be formed by pairs or quadruples into a cable of

strands and used as metallic circuits, the best invariable conditions of a favorably low static induction would be secured, aided, of course, by the low inductive capacity of the material of insulation and varied also inversely by the insulative quality or the amount of leakage indicated. But in cases of static induction, leakage and induction tend to the same disadvantage, because the greater the leakage the longer the time of charge, although the leakage to its extent, counterworks the static induction. Premising the conditions to be single insulated conductors in wet earth or water, the elements which determine static induction are four: the surface area of the conductor; the thickness of the insulation, or its exterior surface, which will vary in direct ratio in round forms; the insulation quality; and, lastly, the specific inductive capacity of the material of insulation.

While it is true that the specific inductive capacities of insulating materials have been experimentally determined alone in their relation to static induction, yet, if we may believe or assume that both static and dynamic induction are referred to the same source or origin in the nature of electricity and stand for the modes of its energies, there is no reason to deny, so far as any promulgated experiments are known, that insulating materials may not have a like capacity with relation to dynamic induction. At least we shall here assume the fact to lie in the majority of probabilities in favor of such a capacity. So that, as to dynamic induction between any two conductors insulated from each other, the elements are: the quantity and intensity of the current; the distance between the lines of average of parallelism of the conductors; the character of the insulation or the leakage *between the conductors*; and lastly the specific inductive capacity of the insulation.

Dynamic induction acts by laws and under conditions as invariable as the forces of gravity and yet we find repeated again and again the experiment of simple parallel wires bunched in cables and used for short distances with fair success, when at once the happy self-styled inventor rushes into print with a certificate from a climbing electrician, and the word "anti-induction" in heavy block capitals.

Of insulations but little need be said, because the subject is hackneyed of words. The whole list is good—better—best, and every new man can give us the best, because, he says, God has made him the Mahomet of a new revelation. Gutta-percha and caoutchouc

are well known and long tried. For salt water, gutta-percha is unexcelled, but for underground lines it becomes hard and cracks and is subject to peculiar influences of decay, often of local and undetermined character. Para rubber of low vulcanization is better for underground work, but costliness excludes it from general use. The great cost of these chief insulators early led investigators to seek for substitutes. The lists of hydrocarbons were explored. Prepared bitumen and coal tar were brought into use and combined with other substances, mineral and vegetable. It is a fact as old as the cyclopædias of our day, that vegetable oils heated with a proper percentage of flowers of sulphur added at a limit of temperature, will become tough and elastic, yielding an artificial caoutchouc. This property has been made the basis of many of the patents for new insulations, the claims of which relate mostly to manipulation and proportion of constituents. The longest known "ites" are of this class. Other insulations are derived principally from the material of worn-out rubber boots and the scraps and bits from the rubber factories. Some of these also add to the "ites" a necessary toughness or elasticity. The fundamental process is simply the maceration and softening of the old material in oil of turpentine, and the separation and use of the available portions. Those insulations which have to be put on the wires by means of press and dies must always be considerably expensive for materials and labor. Then, too, some of these insulations are easily affected by ordinary weather temperatures. Copper wires have been known to drop by gravity through their gutta percha insulations when lying supported, simply by the softening of the insulation in summer heat. The steam pipes in this city would bring havoc to such insulations of homogeneity, softening at a low temperature. This fact has become so well understood by the experience of one of the companies that an injunction is in force, at this writing, restraining the Steam Company from placing its pipes in the vicinity of wires previously laid.

An insulation for underground wires should secure the copper conductor invariably in a central line within it. It should contain no elements of chemical change or deterioration as an insulator. It should be cheap, easily applied, and not liable to injury in manipulation after it has been applied. A low insulation permanently maintainable is the best for short lines and local service. Such an insulation with large sized copper conductors was among

the first propositions laid down by the writer some years ago. In the Autumn of 1884, an experimental piece of underground telephone plant was put down in this city, in which the immediate insulation of the wires was cotton fibre in loose braidings on the wires which were then steeped in a hot bath of linseed oil. The insulation at first was very low, the best of it not giving per mile more than one-third of a megohm. In January, 1886, further tests showed that the insulation had so improved that the lowest gave a mileage resistance of one megohm, while the highest ran up to *seven* megohms. The writer ascribes this improvement to the slow oxidation of the oil into a thick gum of higher insulating quality than the fresh oil. It is maintained, as the result of experience with insulating materials, that a permanent insulation of from 50 to 200 megohms per mile is easily and very cheaply available for underground lines in which cotton fibre forms the basis of attachment or the vehicle of the prepared insulation.

#### IV. PROTECTION FOR THE INSULATION.

As long as the expensive and homogeneous insulations were almost exclusively used, their capability to exclude moisture for a long time rendered further permanent protection scarcely desirable. But the multitude of wires and cables brought into being by the progress of the telephone, called for the economy of cheaper insulations which required a durable extraneous protection. Even for aerial lines a light lead pipe, containing a large number of small wires, has come into extensive use. The tendency to adopt a lead jacket or covering for underground cables in the last five years has become almost universal, and only the older telegraph companies still adhere to homogeneous insulations and gummed taping for outer wrapping. The lead method thus far has been somewhat primitive and imperfect. At Philadelphia, in 1884, lead protected wires were exhibited, in which the thickness of the lead on one side was twice as great as on the other, and many productions of lead covering of the roughest exterior have been sold to telephone companies, with the insulation loose within the lead, and the shape of the finished cable neither round nor of any other ascertainable contour. Lead pipe coverings and lead press jackets put on thus loosely and unevenly are radically bad, since they do not exclude the air from the insulation, nor give assurance, therefore, against decay and deterioration. The perfection of the lead process is to be able to force the lead, while cold, close down upon

the surface of the insulation and, without injury, sealing up as it were, the insulation within a uniform thickness of metal having a round and smooth exterior surface in the finished cable. Such a lead covered cable, with a well considered insulation, and barring accident and mechanical injury, would afford a guarantee of permanency for indefinite years of the future.

#### V. NEW DANGERS, OR WATER GAS AND "WHAT IS IT"?

Reference has already been made to the solubility of gutta-percha insulation in cables exposed to the soil without conduit protection underground in this city, by some agency supposed to come from water gas. The first suggestion was that it was the naptha used in the manufacture of that gas. This must be an error, because the naptha does not exist in the gas in the form of *vapor*, but is decomposed in the manufacture and yields two distinct *gases*; *i. e.*, light carburetted hydrogen,  $C H_4$ , and olefiant gas,  $C_4 H_4$ . From the best judgment which can be formed without actual experiment it is probable that one or both of these gases are capable of attacking the hydro-carbon insulations, since these gases themselves are cognate members of the hydro-carbon family.

But a more surprising apparent observation comes from the Brooklyn Commissioners for underground wires, in which it is alleged that water gas or some constituent of it will act upon metallic lead so as to convert it into the carbonate or white lead of commerce. The writer has taken pains to investigate this question both on his own effort and through an analytical chemist. The theory of such action necessarily requires the exhibition of carbonic acid gas. Water gas contains the merest trace of it, since, as a deleterious constituent, it is carefully eliminated in the manufacture. But to supply this for the lead attack it has been surmised that the monoxide,  $CO$ , of which water gas contains from 25 to 30 per cent of its volume, presumably undergoes after its escape from the pipes into the soil an additional oxydization and becomes the dioxide  $CO_2$ , or carbonic acid. This is an extreme improbability since it is known that the general action of soils is de-oxydizing rather than aiding to a higher oxidation, except under peculiar conditions in the presence in the soil of vegetable charcoal, and even in such cases the action is limited and insignificant. But why go in search for an explanation to the water gas pipes, when a known one is of ready suggestion. The Brook-

lyn conduit was a wooden box, admitting fresh water surface drainage impregnated with carbonic acid and ammoniates from the street manure and the decaying vegetable matters in the soil. Cold rain water will absorb a volume of carbonic acid equal to its own, while the monoxide from the water gas is scarcely absorbable at all. We have therefore the conditions of a ready action upon lead as will appear from the memorandum of Mr. Lucius Pitkin, analytical chemist, here following.

MEMORANDA ON CORROSION OF LEAD PIPES IN GROUND FROM  
LEAKAGE OF WATER GAS INTO SOIL FROM GAS PIPES.

1. There are present in the soil under the streets of a city like Brooklyn, where from traffic a considerable amount of organic matter is present on the surface, the organic acids resulting from their decomposition. I mention:

- |                         |                    |                     |
|-------------------------|--------------------|---------------------|
| (a.) Crenic acid. . . . | Watt's Dict., Vol. | II., p. 103.        |
|                         | do.                | do. VII., p. 393.   |
| (b.) Apocrenic acid..   | do.                | do. II., p. 103.    |
| (c.) Humic acid. . . .  | do.                | do. VIII., p. 1043. |

Experiments by Simon point to the conclusion that humic acid renders ordinary calcium phosphate soluble, showing thus considerable solvent action.

2. Parke's Text Book, Am. Ed., p. 16, states that the action of water on lead is great in those containing organic matter, nitrates, and, according to several observers, chlorides. These would occur in the soil water of Brooklyn from soakage and decomposition from surface.

3. *Medlock* attributes the greatest influence to ammonium nitrite formed from organic matter. Lead nitrate is rapidly formed and carbonate is then produced, the nitrous acid being set free to act upon another portion of lead.

4. The amount of carbonic acid contained in the air of the soil normally is high where the conditions are as in a city street.

"In some rich soils the amount contained in the air present in their interstices is 250 times greater than the ordinary atmosphere ratio."—*Bassingault*.

"The rain, already charged with carbonic acid in its passage through the lower regions of the atmosphere, becomes more largely impregnated with this gas when it sinks beneath the surface."—*Wilson's Hygiene*, page 141.

In view of all the above causes present in the case, the amount

of action due to any ordinary leakage from gas pipes containing the small percentage they do of carbonic acid, is practically nothing under the conditions stated by you.

LUCIUS PITKIN, PH. B.,

To S. F. SHELBOURNE, Pres't.

Chemist.

Prof. Silliman says: "Lead is acted upon by distilled water and by rain water. Water, by reason of its affinity for the oxide of lead, acts like an acid upon metallic lead. A bright slip of pure lead is tarnished almost immediately in pure water, and after a short time becomes covered with a pellicle of carbonate of lead."

Whatever may be the true explanation of the formation of the lead carbonate in the Brooklyn case just stated, the argument from the facts would be that those cables should have been placed in iron or other conduits, excluding both water drainage and gas, so that no corrosion of lead could have been possible.

## VI. ELECTRICAL HARMONY OF USES.

It follows from what has been said of parallel wires and dynamic induction that to harmonize the use of the heaviest currents for light and power, with the feeblest for the telephone, something further must be provided than underground possibilities of distance between the conductors. It is stated that with the present aerial spaces between them it is impracticable to work the telephone lines on lower Broadway after nightfall because of induction from the arc light conductors on the opposite side of the street.

There are two possible ways to harmonize the uses of the wires. One by induction screens forming circuits with themselves, or with the earth; and secondly, by a scientific arrangement of the conductors themselves in relation to each other and with reference to the different uses. These two methods may be combined with each other, and when so combined the best possible conditions of harmonious use will be realized. Metal screens may be so placed and associated as to protect individual conductors in relation to each other, or classes of conductors as between the classes. These provisions may both exist together, i. e., both screens for the individual wires and for the groups or classes may be combined in the same examples of construction. This may be



done with the individual wires in ground circuit, or, better still, with metallic circuits for the trunk lines between the exchanges, operated in connection with ground circuits for local wires of short distances and deviating direction.

With reference to arrangement of conductors, here also two possible methods are admitted, though one of them rather belongs to the theoretical than the practical phases of the question. Theoretically, and with sufficient space at command, electric light circuits may be placed with their limbs parallel and separated from each other in the same general line of sub-way or conduit space and the telephone wires brought alternately for equal lengths within contiguous relation with the one limb and the other by crossing at regular intervals. Practically, with many wires of different uses, such an arrangement could not be economically available nor in any case can it afford a protection against dynamic induction between wires of the same class, which are usually in the closest assemblage in cables underground.

The single practical arrangement therefore of the wires is to arrange those of each class anti-inductively, when necessary, between themselves and then in the same manner as between the classes. This can be done with rigid economy of space by laying up the smaller wires in proper strands within cables, instead of parallel singularity, and by joining the limbs of the electric light circuits in fixed unity of relation with each other where ground circuits are used for the telephone wires, but where the latter are formed in metallic circuits, within cable strands, the electric light circuits may be used in straight-away or single limb lines presented to the telephone conductors, without inductive disturbance. It is reported that in exhibiting the Chicago underground wires at the beginning of the past winter a considerable stretch of telephone wire underground in connection with some miles overhead, and in ground circuit, was used successfully though passing underground for some two or three blocks parallel with and near to the underground electric light conductors then in service. It was not proclaimed, of course, that the two limbs of the electric light circuit were in the same conduit and probably exactly equi-distant from the telephone wire, for such a declaration would have been fatal to the object of the exhibition.

The whole problem of harmony of uses is of easy solution upon scientific principles well understood among electricians who have given attention to the subject, so as to make *a system*, as such, not only possible, but economically practicable.

## VII. WHAT WE HAVE COME TO.

The subject assigned to the writer by the Council and formulated in the caption of this paper is "Underground *Electrical* Systems." Can it be possible that we have been writing thus far without anything existing to write about? It seems to be so. If we look about the world for "Underground *Electrical* Systems," we can find none. Somebody has referred to the underground conduit and cable work in Chicago as an "embryo system." It can hardly be classed so far in advance as that; it must be *conceptive*. And yet there is a quarrel between Chicago and Boston as to which stands first in underground honors. Before this dispute can be settled, Brooklyn expects to canter forward as a dark horse and reach the reward offered, of a clean looking city. But Brooklyn has yet to nail up her boxes for four-fifths of the work promised, to say nothing of the cables to line them. Even in that inchoate achievement, under legal provision and supervision, there are no assurances, as yet, of any attempt to secure a *system*. The heavier and inductively hurtful uses of electricity which present the seemingly difficult elements of the problem have, thus far, been left in abeyance.

But while this paper has not been able to treat of the happy success and details of existing systems, it is to be hoped that what has been written will open more clearly to the thought of electricians and other students of science, and to legislative and popular comprehension the elements and the conditions, both legal and practical, which should be brought into action in *creating* "underground electrical systems" for the future. As has already been noted, an electrical "system" must combine the *electrical uses* so as to secure mutual harmony in the general service. The various companies have heretofore, in all the cities of the country, whether by law or self-will, put underground each its own wires in its own way, and for its own special advantage alone. Could any one expect harmony of uses in such a state of things, or could a *system* be hoped to exist under such conditions of diverse individual purpose and action.

## VIII. CONCLUSION.

A summary of the facts and considerations advanced will lead to the conviction that no underground electrical systems will be realized in this country until the several cities in which the overhead net works have become a nuisance awake to a conception of

their public rights and duties as to underground wires. It is very clear that the individual companies, pursuing their own interests, especially where valuable patents and monopolies are still for a few years at their aid, will seek strenuously to extend and establish those patents and monopolies by occupying the spaces under the streets with their own wires in their own way, so that both the wires and the spaces shall enlarge and perpetuate their own advantages to the exclusion of possible competition. If this were allowed there would soon come a war of contentions. The telephone companies must and would seek to exclude the deadly electric light conductors from the spaces near their weaker lines as has already been done with the conductors overhead. There would be a struggle and contention for spaces, a perpetual digging side by side and in succession in the same streets, until the annoyance would raise a public clamor to sweep away the nuisances as with a whirlwind. To build a conduit merely for the use in common of existing companies would be equally and even more disastrous in the end, since the companies themselves could not agree about their diverse wires with each other; nor would it be possible to assign by legal authority a division of privileges and spaces between them. The result would be that the strongest would win the fight, control the conduits, laugh at expectant rivals, and dismiss from their calculations all fear of competition.

There is only one practical solution for this underground wire problem. The cities themselves in this country, as the governments in Europe, must own and control *the whole system*—both conduits and cables—constructed and arranged in harmony of service beneath the pavements; or, if such a course is not within their municipal powers or consistent with public policy, then the city authorities, where wires are to go underground, must control, absolutely and perpetually, the single company allowed to occupy the streets, so as to fix at all times in the public interest and fairness to all users, the rental for the wires; and more important still, to see that equal opportunities are secured for new companies who have the means and the will to establish a fair competition in the public interest and for the general welfare.

THE PRESIDENT : We have listened with a great deal of pleasure, and I hope not without some profit, to the very interesting paper of Mr. Shelbourne, who, as we can all see, has given very careful attention to this subject ; a subject which I think you will all agree with me in saying is by all odds the most intricate and difficult one which the electrical engineering profession has to deal with at the present time. It affords abundant opportunity for discussion and probably will continue to do so for some years to come. I see Mr. Lockwood among the members present this morning ; he has paid a good deal of attention to this question in the course of his every-day duties, and I hope he may be able to favor us with a few remarks on the subject.

MR. LOCKWOOD : It is with much disappointment that I note the slenderness of the representation here to-day. I am quite sure that this room might have been full of members who could have listened with profit to such a paper. I am glad to say I have been instructed and interested, and perhaps I ought to say that some portions of the paper have even amused me. I say that in all deference to the ability of the author.

The paper of Mr. Shelbourne seems to refer more particularly to systems of wires which comprise all or a great number of the different utilizations of electricity. I am entirely in accord with his prefatory remarks regarding the use, sometimes totally unauthorized use, of the word system. The word has been applied to a great number of inventions and plans and schemes which are characterized more by lack of system than by any other one feature. Perhaps the company with which I am officially connected has done as much as any one concern in North America upon the subject of underground conductors. We have not believed that the overhead wires are so much of a nuisance as people who have nothing else to do but to think of underground wires, believe. We think that wagons, carriages, and carts, and sometimes buildings, though useful are at the same time not ornamental, but we are very willing to tolerate them for a few years longer upon our streets because of their uses, and believe that the same considerations should guide us as we listen to the cry which has been made about the uses of overhead conductors and wires, about their unsightliness and about the trouble which they bring on roof owners and everything that is said against them. In talking about these things however, we sometimes lose sight of their utility, and of the fact that

if they were not used and not useful they would not be tolerated for a moment; but we have also recognized that sooner or later the majority at least of the wires must be put out of sight, and we believe that ultimately the increased expense of burying the wires will be offset by the decreased expense of maintenance and by the comparative ease with which future discoveries will enable us to work them. In view of this, we obtained rights in Boston and ran a pair of conduits in two directions from the main central telephone office, at the corner of Pearl and Franklin, towards State, which is the Wall street of Boston, and another up Franklin street towards Washington street, and there are between 700 and 900 miles of wire now laid and operated as telephone conductors. The method we adopted was what is sometimes known as the Mackintosh system. It consists in establishing vaults or chambers underneath the surface of the earth, at street corners, and digging trenches from chamber to chamber and depositing iron tubes in those trenches, surrounding the tubes with concrete or other cement, and then drawing cables through the iron tubes. The size of a tube is three to four inches with gas thread joints. We lay the tubes first between each two chambers, and draw the cables in, and to be perfectly fair we adopted for trial all the good cables we could find, and we found that they all worked fairly well mechanically. As for insulation we found the chief trouble we had was at the joints in the chambers, and at the ends where the wires were separated. We brought the tubes right into the basement, and then carried them up by lead-covered cables to the operating room. We ran the same grade of cables up to the top of the building where we finally distributed the lines to the several points of destination. As I understand it, by the law which is at present in force in New York, *that* is prohibited, and the wires must stay underground from the point they start from, to the point they reach; and, after that, they must stay underground, because no wires are allowed to be above the surface of the earth, even in buildings. But we found they worked fairly well. Even in a half-mile line, however, of telephone wires underground, retardation, due, of course, to static induction is perceptible, though not to the subscriber. But when a subscriber comes to add on to the length of his line, say from the central part of Boston to Jamaica Plain, retardation is plainly perceptible indeed. The subscriber does not know what to lay it to, and we do not usually tell him. He generally lays it to a bad battery or to

the transmitter, and he usually makes it the basis for an application for a rebate. There is another thing quite noticeable in this relation which I have seen referred to in the British text books with respect to the automatic system in vogue in England. Messages originating at the end of the underground section can be carried to the other end of the overhead line and will come up and be reproduced in articulate speech much easier and clearer than messages going the other way. Messages, for example, originating at State street will come out fairly clear at Jamaica Plain, but speech transmitted from Jamaica Plain comes out in a very muffled sluggish way in Boston. This is entirely as it should be. Although I am not particularly impressed with the result as being favorable to business I am glad to think that it corroborates theory, because when the electricity generated by the induction coil of the transmitter starts out from the underground end it is fresh. It has the hardest part of its work to do while it is fresh and consequently it does it well, and the overhead part of the line is comparatively easy on account of the distance from the earth and is traveled over with facility, whereas coming the other way the telephone current is slender. A little leaks off at every point of support, and when it arrives at the point where the hard work commences there is not much left to it. The consequence is that it nearly all is dissipated upon the surface of the conductor. In Pittsburgh, Mr. Shelbourne's paper to the contrary, notwithstanding, I think there is more telephone wire underground than in any city of the Union. There, wooden troughing is adopted, in which lead covered cables are laid. They are not more than a mile long, and a majority of them not more than half a mile. They are brought out on poles at the end of the underground stretches and distributed, and for some reason, retardation is not so perceptible in Pittsburg as in Boston. In Washington we have to put wires underground on account of the æsthetic tastes of Capt. Green. Capt. Green set out to find out what wires might be laid underground, and what wires not, and he interviewed certain electrical engineers, some of whom are in this room now, and in his investigations he found out that the British government had its wires in London in tubes under the sidewalks, and he did not care to investigate further, and consequently, from that evidence, jumped at the conclusion that as some wires are under ground for a certain length, all wires might be put under ground indefinitely, and he

made his report accordingly; and it is now stated by legislative bodies especially, that there are no wires overhead in Washington. Any person who has been in Washington lately, would find it hard to believe that there are any wires underground, so many are overhead; likewise in Chicago.

I noticed that, in Mr. Shelbourne's paper, the statement is made that all electricians understand that metal envelopes connected to earth act as screens for induction. Now, for the last five years, I have disclaimed the title of electrician, because I do not like to be in the majority. There are a great many electricians, and while they may all understand that metal envelopes connected to earth act as screens, I, not being an electrician, do not altogether agree to that statement. It is true, if you have two conductors, and place a metal screen between them, and charge one of them statically, that metal, especially when connected to earth, does act as a screen. It is not actually true that metal envelopes around metal wires connected to earth, act entirely as screens. There is no doubt that the induced current between the two wires is checked, to some extent, by any metallic covering, because the way it acts is to develop a current in the intermediate conductor, *i. e.* the metallic envelope itself and by connecting to earth we extend that wire indefinitely; that is, you make the earth a part of the screen, and by so doing you disseminate the induced current over a large amount of surface, and thus the effect is carried away to a certain extent from the adjacent conductors. Incidentally, I may mention that the United States patent which covers that point, expired yesterday; so we may now cover all our wires with metallic screens, if we wish to, indefinitely.

MR. SHELBOURNE: I referred entirely in my paper to dynamic induction. Such metal screens connected to earth increase static induction of course.

MR. LOCKWOOD: There was another point mentioned, based upon the statement in the report of the Brooklyn underground commission, which I thought myself was somewhat unaccountable—that the use of iron was detrimental to the flow of electricity in conductors—the use of iron in an envelope or screen. It has been found, and I think not very long ago, that different metals used as conducting envelopes had different results, and I have found, and my associates have found that while the results attained by the use of aluminum, bismuth, copper, brass, lead, tin, and many other substances, are all alike; and if you do not connect

them to earth there is no great effect, yet if you inclose the insulated wires in iron, particularly very soft iron, there is a very pronounced effect in the diminution of dynamic induced currents from one wire to the other. The reason I think is that the force of the induced currents by virtue of the doctrine of the conservation of energy is transformed in that soft iron covering into a certain amount of magnetism and is thus prevented from exercising itself adversely in the formation of an induced current between wire and wire.

There was a further statement made as to the relative effect of induction between telephone wires in wet and dry weather. It is an undoubted fact that telephone wires, especially long ones, have worked much better in wet weather than in dry. It is also a fact that telegraph wires, with bad joints in them, work better in wet weather than they do in dry, especially when the insulation is very good. In speaking of telephone wires we should remember that not only is the telephone such a sensitive instrument, not only is it subject to induction and to annoyances of all descriptions, due to the presence of other wires, to earth currents, to atmospheric currents, and to currents induced by crossing the magnetic meridian of the earth, but in addition to all this they are annoyed by adjacent telephone lines. We can hear other people speak who are not connected with the same wire that we are. This is more particularly amplified in my own paper, and I think the better effect we get in rainy weather is owing to the following circumstance: that a great deal of the interference between wire and wire is due, not to induction, but to leakage along the cross-arms and through the covering, and from point of support to point of support, and this, of course, explains readily why the lines should work better and more quietly and should have less interference one with another during heavy rain storms when the supports and cross-arms and poles are covered with a surface of water; and it is not distilled water altogether, for it is pretty well charged with saline matters, and it makes a reasonably good conductor, and affords a means of escape for the induced currents and carries them away to earth at every pole, thus freeing the lines from interference with one another. A mere drizzle of rain makes a kind of a weather-cross; but, after all, the poles, so many of them, make a better conductor to earth than the different wires would.

With respect now to static and dynamic induction, I am some-



thing of a purist in terms, and it has often mortified me extremely to hear professors of electricity, I mean practical professors, not college professors, because they are as a rule correct—talk about the two interfering effects of electricity, namely induction and retardation, whereas retardation is nothing more nor less than the result of induction; and in the prosecution of my investigations and considerations, I have about come to the conclusion that static and dynamic induction are really but different phases of the same thing. If we send a charge into an insulated conductor a corresponding charge is induced in an adjacent conductor. If we send a current into a conductor an induced current is induced in an adjacent insulated conductor, and I have come to believe that therefore the difference is nothing more than this—that dynamic induction is induction brought about under circumstances where it has a chance to flow; whereas static induction is the same thing thrown upon a body where it has not a chance to flow, and consequently must stay there. That is, static induction is merely dynamic induction in a state of rest.

Now, with respect to the lead covering. Mr. Shelbourne's paper stated that many lead cables—I think I am using his own words—have been sold to telephone companies of the roughest exterior. It is rather hard on telephone companies, but I presume he referred especially to telephone companies which are not licensed by the Bell Telephone Company, those being the ones of the roughest exterior. As a matter of fact, there have been some very bad lead cables sold; but many bad lead cables have been made and they have to be sold. The lead is generally much better than the contents. I think they would sell better if they would adorn the lead a little more; because books sell better when they are bound well although there be nothing but trash inside. As a rule, now, telephone, and electric light, and telegraph companies are more particular about the article they order than they have ever been before. Everywhere I go, I find a new thing has come up and it has been talked of; I am very chary in telling them what I think of it, because I don't know myself—well, they say, "We think it is a pretty good thing, but we want some one else to try it first." Most of the lead-covered cables, however, which are now being manufactured, are of very fair character, having high specific insulation and pretty fairly low inductive capacity; because nearly every manufacturer has found it to his interest to adopt the best methods, to use the best materials at his disposal,

and to pay good prices for skilled labor. They found they must do it to hold their own, and whether the insulating material be paraffine or rubber, or the material which in Pittsburg they call ozite, they all try to get the best effects out of it, because if they do not they won't sell much. They may sell a cable to an unsophisticated new manager, who is in his first position, but they won't do it again; because it does not take a manager long to find out that his position depends on the cheapness and expertness with which he can get through his work. It is a fact that a lead cable placed in the earth without protection is attacked by gases. I am very glad that I can concur generally in the remarks which were given in this paper, and I think, with regard to the gases that attack lead, that it is abundantly proved that ammoniacal and carbonic acid gases attack lead more severely than any others, and when they do attack it the effect is extreme. But it is also found, and this is based entirely upon experiment and upon experience—I see it mentioned in the Brooklyn Commissioners' report—that by alloying the lead with tin these results are avoided to some extent. That is true, and by alloying the lead with antimony the same results are avoided. The lead will then stand almost any gas. Limey soils, I understand, are also very hard upon lead.

Now, I can hardly agree that it is judicious that one concern, whether it be a city government or a state government, or an organized corporation, should be allowed to monopolize the conduits of a city, and say to the telephone companies, "You may occupy *those* wires and use them," and, if you are a telegraph company, "You may take *these* wires and use them, and, if you are an electric light company, you may take *these* and use them." I think it would be very difficult, if there were troubles in one wire to convince the corporation running the wire that the trouble was in the wire. It would be in the sending instrument, or in the receiving instrument, or in the lamp or dynamo, anywhere but in the wire. A case of divided command is always productive of great trouble. If one commander wants to attack, the other one thinks it is best to make a three months' siege. Every case of divided command that ever I have seen has been productive of trouble and disturbance; not only that, but this corporation would take upon itself to say what kind of insulation should be used for one class of service and what kind for another. They would take it upon themselves to regulate the thickness of the insulation. Under those circumstances, it is no wonder that telephone com-

panies, and electric light companies, and telegraph companies, and every other sort of company utilizing electricity, should want to use their own conductors. Which of us would care to commit our property to the control of a foreign concern of which we know nothing, and, for all we know, we might find ourselves renting these wires of a foreign and inimical corporation. It would be very easy for one corporation, desirous of owning the earth, as I have known corporations to be, to own a controlling interest in the concern. In such a case it would be easy for them to do, as the Pennsylvania Railroad Co. did to the Baltimore and Ohio, during the period when the latter company advertised to run its own Washington line via the New Jersey Central. They said: "Certainly, you can have all of our locomotives and cars that you want." But to reach the Philadelphia, Wilmington and Baltimore road at Philadelphia, the trains had to pass through the Pennsylvania yard, and when we came to travel over that line we found that we were unavoidably delayed in the yard, at Philadelphia, three or four hours, and people found if they were going to Washington, or coming from Washington, they had better take the Pennsylvania trains, because *they* never had any trouble in the yards. *They* always got through on time. If I was running a company, if I was general manager of a concern, instead of being an humble official on a salary, I don't think I would want to trust my wires to any outside concern no matter how friendly they might be at the outset.

THE PRESIDENT: The experiences and conclusions of a practical man, like our friend Mr. Lockwood, are always of very great value. He has been seeking, in the course of his investigations, for the best result, and perhaps he occupies as impartial a position towards the various inventions, and methods, and systems, as any one man who has occasion to investigate them. I think he has given us some additional testimony as to the difficulty of the problem which we are attempting to solve; certainly some of his conclusions are entirely new to me, and probably to many others who are present. I would be very glad to hear from any one else who has any remarks to make.

MR. MAILLOUX: I have only one point to touch upon, which is called to my mind by my friend Mr. Lockwood's remarks, as to the analogy, if not the similarity, of cause and effect of dynamical and statical induction, and also, at the same time, to notice particularly the statement made in the paper by Mr. Shelbourne,

about the influence of inductive capacity—static inductive capacity on the dynamic induction. Now, I believe the paper said that the dynamic induction is affected by the static inductive capacity, of the medium. Now, I do not believe that there is any experiment or any demonstration at all that would uphold that, but rather the contrary; and this leads me to say that I agree with Mr. Lockwood in the belief that electro static and electro dynamic induction are identical, when we consider them in their relation to the great law of the conservation of energy, in the relation that action is always equal to re-action; they both act and produce retardation by their re-action. There is one thing that Mr. Lockwood has not, I think, noticed; that electro-static induction is largely influenced by the electro-static condition of the surrounding medium, while electro-dynamic induction has no reference to the electro-static condition of the medium around it. We all know that electro-dynamic induction is a phenomenon which involves the action of magnetic lines of force, and that there could be no current produced if there is no conductivity; or, to put it in another way, that the amount of electrical current produced by electro-dynamic induction varies inversely as the resistance of the medium, without any regard whatever to its electro-static inductive capacity. We may consider electro-static inductive capacity as being itself a function of a certain resistance, but that resistance seems to be of a considerably different nature, involving a certain amount of molecular tension, which is probably, at a right angle. It is an action taking place in an entirely different direction from the one in which electro dynamic induction takes place. I have no doubt at all that the direction in which the lines of force are propagated axially, or the stress which is produced by lines of force in the medium is in exactly the same plane as the electro-static induction, whereas, we all know that the current itself is at right angles to that, and there is a certain relation brought out by Clerk-Maxwell and others, that bodies which are non-conductors we generally find to be of the highest electro-static inductive capacity; whereas those which are the best conductors are the poorest.

MR. MAYNARD: I would like to ask two questions. What has been the experience as to the destruction of the lead covering of underground cables, and have there been any cases where fires have been caused by the current in electric light wires laid underground?

THE PRESIDENT: Can any one present give us any information on those points?

MR. MAYNARD: The first question is in regard to the lead covering of cables laid underground being injured by ammonia and carbonic acid. It is well known that those gases will destroy it, but what has been the experience, how long does it take?

MR. MAILLOUX: I remember distinctly that at the first meeting we had here in this room there were exhibited on that shelf a large number of samples of lead pipe and there were labels on them the same as on these samples. The degree of oxidation was of course shown by sections of the pipe, and I saw pipes there that had been used for carrying water for something like forty years, and which were apparently not at all harmed, having evidently suffered only a very slight disintegration. It appears to me like a sub-oxide of lead, or perhaps a form of carbonate, which had formed in the interior of the pipe, and yet the process did not appear to have extended sufficiently deep to impair the utility of the pipe. If a pipe can stand usage for forty years in carrying water, it ought of course to be able to stand usage for a long time in carrying electricity, provided we get it in the same condition. I do not know very much about the corrosion of pipes by ammonia gases and carbonic acid gases, but I should imagine there might be something of that nature. Some years ago, in working storage batteries, I had occasion to go into the corrosion of lead deeply, and there was at that time a great deal of discussion going the rounds of the journals in regard to the formation of sulphate of lead in storage batteries. Perhaps you may not see the evident connection between sulphate of lead and carbonate of lead, but, as I understand the chemistry of it pretty well, I can see that there is a great connection between the two. For a long time we were troubled with sulphate of lead forming in the batteries. In a short time sulphate of lead would have eaten up the plates, and would have produced a form that would have ruined them, and it was a very troublesome thing to deal with. The battery became useless very quickly, and there was no means of remedying it, and it was not discovered until a long time after, as the result of some chemical reasoning, simply that the thing was produced by some acids contained in the solution used. Some advocated a stronger solution of acid, others a weaker solution. But the gist of it turned out to be this, that in the ordinary sulphuric acid of commerce there was a slight amount of nitric acid as an

impurity. In the making of sulphuric acid they use nitric acid, which becomes converted into nitrous acid, and immediately takes another molecule of oxygen from the air and becomes nitric acid again, so you could go on indefinitely making nitric acid. Carbonic acid will not attack lead of itself. You may put a piece of lead in a solution of carbonic acid in water, or else put it in carbonic acid gas, and it will stay there an indefinite time without manifesting any change at all, but if there is some substance like nitric acid, which can oxidize lead and convert it into a nitrate, then almost any acid that happens to be lying about, and in this case carbonic acid, would be likely to attack it. So I don't doubt at all that the ammonia furnishes the nitric acid, in combination with the oxygen of the air, which produces the disintegration of the lead, and the carbonic acid takes hold, and forms a new combination, and leaves these other elements there to go on again for ever. So it appears to me if we put in a substance like antimony or tin, as Mr. Lockwood says, that it is not so likely to form stable compounds with nitric acid. I have no doubt at all that nitric acid is the thing we have to fight in the lead pipes. I think that if experiments are made with a view of tracing it to nitric acid, we will find out that that is the trouble, and, if we do find out that that is the trouble, we shall have made a step toward finding a remedy.

Mr. Lockwood: These remarks of Mr. Mailloux seem to me to accord very well with the text given us in Mr. Shelbourne's paper. He says, however, in respect to the pipes he saw in this room some time ago, that because they worked so well with water so many years, they ought to work well with electric wires. The doctrine of *ought* is very good, but it does not work in practice at all. We know there is another doctrine, namely, the depravity of inanimate things, which comes in there. The fact is that the very deposit on the interior of lead pipes, caused by the water, acts as a preservative. As far as the outside of the pipe goes, it depends altogether on two things—first, the nature of the soil, and secondly, the nature of the attacking agent. Not very long ago the Western Union Telegraph Company seized upon a street in Boston called Friend street. It is not much wider than this room, and the side-walks take up one-half the street. They put up one of their enormous lines of poles there, with the cross-arms, and a great number of wires outside the windows, and the tenants made a great cry about it, as they ought to have done. The Western Union

thought, as they put up their poles in the night, that possession was nine-tenths of the law, and that they would be able to keep them there. But the popular voice was successful. Property owners said they might go on the roofs if they wanted to, but they declined to do that, and went underground with their wires from State street through Friend street. Now, everybody who knows anything about Boston, knows that Friend street is lined with stables on both sides. These wires, of which samples were shown to me, were encased in lead, and it is not more than a year since they were laid down. The specimens they pulled up are very badly used up already. It must be owing to the refuse of the stables soaking the earth with these carbonic and ammoniacal gases which tend to form nitrates. These must be the "stable" products that Mr. Mailloux spoke of. (Laughter.)

MR. MAILLOUX: It strikes me that Mr. Lockwood had to lead his horse through a great many turns to get to the stable.

MR. SHELBOURNE: I am able to say in regard to this Brooklyn case that these cables, as I understand, were down some eighteen months. They were placed in the streets about the City Hall. The statement about them, which came from the Brooklyn Commissioners, was not correct. Of course they got their information from other persons, and perhaps were misinformed. I consulted Mr. Sargent about the conditions and facts of the case, and he gave me the exact particulars as he had learned them. This carbonate of lead appeared from these cables where they left the conduit, while being pulled out of it, and as Professor Plympton told me, this carbonate was picked up by the handful on the spot. I found, as against the theory of the water gas acting upon it, Mr. Sargent said that where the water gas escaped the most perceptibly, that is where the cables from the conduit entered the building of the Exchange, that there was no action upon them at all, showing that we must look for some other reason for the carbonate of lead than the action of carbonic oxide in the water gas. Now, if the carbonic oxide escapes from the pipes into the soil—it is well known that carbonic oxide is very light—it has about three-fifths the specific gravity of carbonic acid—carbonic acid of course being much heavier than air—it is apparent that the carbonic oxide, or monoxide, not being absorbable by water in the soil, on escaping from the pipes, would directly find its way out of the soil and rise in the air. The statement in regard to the wires in Friend street, confirms what

the analytical chemist says in his memorandum. It is not that the carbonic acid acts by itself upon the lead, for it will not; but, as that memorandum maintains, the animal manures penetrating the soil and the decayed vegetable matters produce nitrate of ammonia. Then the action on the lead is not direct, but there goes on a series of actions and re-actions till the result is the carbonate of lead. There are two or three actions and re-actions which take place, and which are quite intricate in the ordinary production of white lead. The ammonia nitrate is the first thing that is produced from these soils. Nor is it competent to the direct oxidation of lead. Lead does not oxidize under such conditions. Lead nitrate is first formed and then the oxygen of the air brings in some of these intermediate actions and re-actions in connection with carbonic acid which result in the production of the carbonate of lead. Mr. Sargent exhibited to me a piece of cable that was brought out of the pipes, and while it was very evident that corrosion had taken place from the pitted condition of the surface of the lead; yet, from the amount of waste or disappearance of the lead, as I could judge, that corrosion might have gone on perhaps for eight or nine years before the lead would have entirely disappeared. Another element enters into it. As the coat of carbonate of lead becomes thicker, it protects the metallic lead beneath it from further rapid progress of the corrosion.

In regard to the question about adulterating the lead with tin, etc., I was aware that the purer the lead the more readily it would be acted upon under such conditions. When I was a student in college, it was stated to the class in chemistry, by Professor Silliman, that rain water affects lead very readily, and the purer the water the more rapid the action; but, if you want to corrode rapidly a lead pipe, put it in a drain where it gets water impregnated with all the refuse of decaying vegetable matter; but as to the question of the cost of that tin adulterant, that is of some importance. If lead is taken at four cents a pound, suppose it requires three per cent. of tin, and metallic tin costs four or five times as much as lead; therefore, the cost of the tin would be a very considerable element. The tin, of course, was spoken of in the report of the Brooklyn Commissioners, and afterwards mentioned to me by Professor Plympton. I said that the cost of the tin required to enter into one hundred pounds of lead, would be something like sixty to sixty-five cents. I also mentioned to him the substitute Mr. Lockwood spoke of, antimony; and I also sug-



gested, as a preventive of the corrosion of the lead covering of cables, the adulteration of the lead with metallic arsenic, which we can buy at five cents a pound. Now, that is as far as I think I am able to answer Mr. Maynard's question.

In regard to another point discussed by Mr. Mailloux and Mr. Lockwood, that is, the distinction between dynamic and static induction, of course, when induction results in currents which interfere with clear and distinct service in the telephone, we understand that is dynamic induction; but as to the fact of there being no conductor outside of the insulation as remarked by Mr. Lockwood, as to static induction, to receive or carry away the current, look at the conditions in the Atlantic cables. There, outside of the gutta percha, you have the whole ocean to carry it away. Again, it is shown by the experiments, I believe, first of Sir William Thompson, in regard to the early Atlantic cables, that retardation was the same, whether the battery used was ten or a hundred cells. They first tried, in the cable of 1866, to get over sluggish action of the electric current by increasing the size of the battery. I believe they used as many as a hundred to three hundred or more battery cells upon that cable, and also dynamo machines.

A MEMBER: They used strong induction coils.

MR. SHELBOURNE: Of course you have there the gutta percha core of the cable surrounded by the whole ocean. The armor and the jute put around the core of the cable do not, of course, prevent the salt water from getting right in next to the core, consequently you have there the favorable conditions of static induction. The conditions are exemplified by the Leyden jar. Now, if the induction is greater—static induction—there being no surrounding conductor to carry it away, why then you could get a charge into a Leyden jar greater, when there is no connection with the earth, than you could if there be such connection. It is found, however, and laid down in the books that in the Leyden jar, if you do not connect the outside tin foil with the earth, you can get but a very slight charge. If you do connect it with the earth, the action and re-action goes on till the greatest possible charge is obtained under the other conditions present. Therefore, it seems to me, that there must be a distinction taken between the conditions of the action and re-action of dynamic induction and of static induction.

As to the better effect of iron than other metals as a screen of

induction connected with the insulation of the single wires, that was a point that I did not touch upon, and if Mr. Lockwood made his remarks, as based upon my paper, he misapprehended it. I very early became convinced that there was an additional effect to be produced by the use of iron as an immediate screen instead of any other material, but the difficulties in that case are so great mechanically as to make it impracticable. I took out, some years ago, a patent that was related to that subject, in which I claimed the use of the magnetic oxide of iron as an induction screen; but it is practically of no value, because under the conditions where it would be necessary to use it instead of the ordinary tin foil it would take up so much space, that for the benefit it would give, it was impracticable. My remarks as to the case were upon the use of iron as a conduit in which a large number of conductors or cables might be inclosed. Now, the statement is that such an iron conduit, in which lead covered cables are used, would cause retardation in the cables within it—I do not admit such a statement to be true, as we understand and speak of retardation being the result of static induction. In the beginning of the underground telephone business in Brooklyn, some persons who proposed to do some of the underground work—Mr. Sargent, as stated by Prof. Plympton to me,—wrote to Mr. Preece about the sort of conduits he would recommend; and Mr. Preece replied that these wooden boxes creosoted, he did not find advantageous, because he found that the coal tar or creosote would act upon the gutta percha insulation, and therefore, they didn't think of using them, and he concluded his letter by saying, "Why don't you take the ordinary iron pipe? That is a thing there will be no question about."

**MR. LOCKWOOD:** Would you put the entire pipe immediately in the trench or ditch in contact with the earth?

**MR. SHELBOURNE:** Certainly. The iron in such a case, being in contact with the earth, can only act as a conductor away to the earth the same as any other metal would do. There are, however, probably dynamic reactions that would take place between the iron pipe and the conductors, due to magnetic variations produced in soft wrought iron pipes, by the make and break or rapid variations of the currents in the conductors.

**MR. LOCKWOOD:** I think you are quite right, but there is this to be considered—if the enclosing pipe, be it iron or any other metal, be in direct contact with the earth, it virtually surrounds the con-

ductors with the earth, and, therefore, they are more exposed to the retarding influences of the static induction.

MR. SHELBOURNE: That is, so far, true; but I also spoke of the wires that were in the individual cables inside of the conduits being in contact with the earth, that is, in grounded circuits. In such cases, when those wires are not in use, and other of the wires in the cable are in use, those not in use admit the access of the inductive nearness of the earth in the same manner, and, perhaps, in even a greater degree than the conduits. There was one further consideration in regard to that, and it is this—so far as dynamic induction currents are concerned, we will suppose that the earth is in a condition of dryness around these pipes. Then the result of dynamic induction, from the cables in the one to reach the cables in the other, if the iron pipes are alongside of each other, and not touching, would be that the conduit itself—the iron pipe itself—would take up the current of induction, and if the earth is dry between them the pipes would carry the currents to some point on the line where the earth is wet. But the iron pipe would not afford any more formidable conditions of static induction than any other conductor, wet earth for instance. Now, it is found by the Commercial Cable Company that they get a greater charge in the wires, in other words, the conditions of static induction are greater when there is water in the earth, sufficient to go through the armor of the cable and thoroughly wet the jute under the armor, and hug, as it were, the insulation of each of the conductors, and thus afford the better conditions of static induction between the outer surfaces of the insulation and the wires within the insulation.

THE PRESIDENT: The Chair regrets to say that, owing to the lateness of the hour, it will be necessary to curtail this very interesting and instructive discussion. And if any other gentleman has further remarks to make, I hope he will be as brief as possible.

PROF. YOUNG: I had charge of a lead pipe aqueduct in Hanover, in New Hampshire, that was laid in 1810. It runs through the village, and every now and then it comes up in people's barnyards, and in the barn-yards where it comes up it lasts about five to six years. I had to replace some three or four of them in the twelve years I had charge of them. The pipe was inch and a-half pipe, and was perfectly good, except at some places where it crossed a road or went under barn yards.

MR. MAILLOUX: It does not matter at all whether the earth

touches the iron pipes or not. If a current passes through them is of a wavy nature, as it would be in telephone transmission, the current, as the wave rises or falls, would produce a change of magnetic condition in the conduit, and it is well known that the magnetic field around a conductor expands and contracts as the current rises and falls, and that each one of those expansions or contractions would tend to magnetize the conduit at that particular point where the wave happens to be in circumferential direction. Now, as this thing gets magnetized, it would exert a reaction on the impulse itself, and it doesn't matter whether it is one part of the conduit acted upon or two parts of the whole length.

**THE PRESIDENT:** In closing this discussion, I might mention one little thing which I happen to have read, that throws a good deal of light on the great durability of lead underground under favorable conditions. Long ago the early French explorers of the western country, I suppose one hundred and seventy-five years at least—I do not recollect the date exactly—in taking possession of the land on behalf of the French government, were accustomed to bury at the intersection of the principal rivers a lead plate with an inscription engraved on it, stating that the territory was taken possession of in the name of the king of France, etc. It is only a very few years since one of these plates was dug up, at the junction of the Ohio river and one of its branches, somewhere below Pittsburg, and the plate was found in a very perfect state of preservation. It was corroded but little and the inscription was perfectly legible, which, I think, is very strong evidence of the great durability even of the surface of a leaden body under favorable conditions.

**THE SECRETARY:** Before the discussion closes, I would say, in reply to the inquiry of Mr. Maynard, as to whether fires had originated from arc lighting wires underground, that I have kept pretty close track of that branch of the subject, being on a committee of the Electric Light Association, and no case of that kind has come to my knowledge. But this may arise from the fact that there is but a very limited number of arc lighting wires underground at the present time. The wires in Chicago are confined to isolated plants. There is no central system of street lighting as in this city; and with the exception of the wires in Chicago and those with which he is familiar in Washington, I believe there is nothing else in the way of underground arc lighting wires, ex-

cepting a system which has recently been established in Detroit by the Thompson-Houston, and that has been in operation only a short time, and therefore I have no information regarding it.

CAPT. MICHAELIS: I would like just to say a word, in confirmation of the Chairman's remarks in regard to what I might call the chemical refractoriness of lead. The Government had stored all over the country thousands and thousands of pigs of lead under all conditions, some of it in cellars. I have seen some in Fort Carroll, where it was exposed to spray, and I never saw a pig of lead that appeared to have degenerated in any manner whatever. Yet, not long ago, I had occasion to examine about twenty tons of English bullets that had been stored in a dry place, and they presented every sign of degeneration. They were incrustated with carbonate, and I have been led to think that this apparently inexplicable degeneration of metal is due to galvanic action, and where the lead is pure, and we used to get pure lead years ago, that this action is not so apt to take place as it is with bullets, which we know contain not only oxide of lead, but other metals, zinc, tin, etc., and there you have a favorable condition for galvanic action; and I have no doubt, where there has been marked degeneration of lead pipe, that it may be due to the impurity of the lead and the consequent galvanic action.

THE PRESIDENT: We will now listen to a paper by Prof. William A. Anthony, of Cornell University, on the great tangent galvanometer which he has recently constructed there, which in the absence of that gentleman will be read by the Secretary.