

## AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

New York, October 26th, 1898.

The 128th meeting of the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS was held at 12 West 31st Street this date and was called to order by President Kennelly, at 8.10 P. M.

THE SECRETARY:—At the meeting of the Executive Committee this afternoon, the following associate members were elected:

Name.	Address.	Endorsed by
MURPHY, JOHN MCL.	Electrical Engineer, Safety Third Rail Electric Co., 5 Beekman St., Room 223 N. Y.	G. T. Hanchett. E. V. Baillard. Ralph W. Pope.
VREELAND, F. K.	2nd Ass't. Engineer, Crocker-Wheeler Electric Co., residence, 228 Orange Road, Montclair, N. J.	Henry Morton. F. B. Crocker. Gano S. Dunn.
WOODBIDGE, J. E.	Editor <i>Electrical World</i> 9 Murray Street, N. Y.	T. R. Taltavall. A. E. Kennelly. Townsend Wolcott
Total 3		

The following associate members were transferred to full membership :

Approved by Board of Examiners, Sept. 22d, 1898.

C. H. WORDINGHAM	City Electrical Engineer, Manchester, England.
WILLIAM STANLEY,	Electrical Engineer and Inventor, Pittsfield, Mass-

In the President's Inaugural Address at Omaha, a recommendation was made by him that the INSTITUTE undertake to bring about a plan of cooperation with the various colleges in regard to experimental research work. In accordance with that recommendation, the Council passed a resolution that a com-

mittee of seven should be appointed, and the President will inform you as to the action that was taken by that Committee to-day, and the progress of the work.

THE PRESIDENT:—I may say that the Committee has held its first meeting and a circular letter is being prepared to send to the various technical colleges and laboratories throughout the country, inviting their cooperation with the INSTITUTE, and submitting to them a list of problems in connection with practical subjects upon which measurements, observations and data are required. Sufficient encouragement has already been received from a number of college laboratories, to ensure the initiation of this movement, and it is hoped that all the principal technical institutions will take the matter up. The plan presents advantages to all parties concerned. The instructors receive information as to the practical work calling for observation and measurement from those engaged in electrical engineering. The students are stimulated to their best efforts by feeling that the work upon which they are engaged is of direct practical application. The INSTITUTE gains by the publication of the results obtained, as well as by the reception of material for good papers. It is not expected that the results of such investigations should be published exclusively or voluminously in the TRANSACTIONS. The main results of each investigation with the names of those engaged upon it, would be, as a general rule, all that the members of the INSTITUTE desire to obtain. In this way no extra expense is attached either to the INSTITUTE or to the technical colleges engaged in the experimental work.

It is desirable that the members of the INSTITUTE should communicate to the Secretary such problems as may arise in their practical work and which call for experimental investigation. The Committee would receive these suggested problems and add them to the list of material for investigation.

The paper before the meeting this evening is "An Electrical Survey in the Borough of Manhattan, New York City," and Mr. Knudson will now read it to us.

AN ELECTRICAL SURVEY IN THE BOROUGH OF  
MANHATTAN, NEW YORK CITY,  
SHOWING RESULTS OF STRAY CURRENT MEASUREMENTS BETWEEN  
ELECTRIC RAILWAYS, UNDERGROUND PIPES, ETC., ALSO  
RESULTS OF TESTS ON THE BROOKLYN BRIDGE.

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BY A. A. KNUDSON.

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The corrosive effect of straying currents upon underground metallic structures is now so well known and understood that obviously there is no need to dwell upon this fact as a reality, but rather it is the purpose of the author to show from actual tests, some of the locations and characteristics of the stray currents in New York city.

About eighteen months ago the question was raised by some of the municipal officers of this city as to the possibility of electric currents leaking or straying to underground pipes from the conductors of the "open conduit" electric railway on Lenox avenue, and adjoining streets at that time, as applications had been made to extend this system.

This matter was investigated at that time by the author, and some of the results becoming known to one of the officers of this INSTITUTE, he suggested that with some additional tests and the whole presented in a paper, it would prove of interest to the members and perhaps throw further light on this interesting subject.

I have since made a number of additional tests throughout the city, from Harlem river to the Battery, between various metallic structures such as "L" (Elevated railway) pillars, surface rail-

ways, water pipes, etc., and give the results here, trusting that they may prove acceptable, and possibly of some value.

Previous to making any tests on the Lenox avenue line, we had a well settled theory that in a double conductor system as this is, very little, if any of the current could be found diverted from the conductors to water or other pipes underground in its vicinity.

The tests were begun on Lenox avenue near the Metropolitan company's 146th street power-station, and continued south. From the first, unmistakable signs were encountered of railway current leakage from the rails of this road to both water and gas pipes, the sudden fluctuation of the voltmeter needle proving this beyond a doubt. It was noticed, however, that when a Lenox avenue car passed, there was no advance of the needle as should be expected, and when two cars passed, going in opposite directions, there was no advance of the needle at the moment; continuing down the street and testing at each fire hydrant and gas post the voltage tended to increase upon nearing 135th street. The readings during these tests were as follows, the rails being positive to the water and gas pipes.

Location.	Water.	Gas.	Remarks.
145th Street	$\frac{1}{8}$ volt	$\frac{1}{8}$ volt	During this test no trolley car in sight on 135th street Test repeated when the 135th street overhead trolley car crossed Lenox avenue tracks.
138th "	$\frac{3}{8}$ "	$\frac{1}{8}$ "	
136th "	$\frac{5}{8}$ "	$\frac{2}{8}$ "	
135th "	$\frac{1}{5}$ "	$\frac{1}{5}$ "	
135th "	$\frac{3}{8}$ "		
125th "	$\frac{1}{8}$ "		
116th "	$\frac{1}{8}$ "		
109th " and Columbus Ave	$\frac{2}{8}$ "		

It was apparent from these tests, that the most, if not all of this leakage, came from the Union railway company's line, operating the overhead trolley system, a branch of this road running through 135th street, and thereby crossing the rails of the Metropolitan company's tracks at Lenox avenue. This seemed the more certain from the fact that the maximum reading ( $\frac{3}{8}$  volt) was obtained when a Union railway car was crossing the rails at Lenox avenue, or was quite near. Further proof, however, was necessary to determine if that company was responsible for all or only a portion of this current escape; advantage was therefore taken of the period when the Union railway

cars stopped running for the night at 1:30 A. M., to make some further tests.

At this time there were no fluctuations of the needle whatever, and consequently no sign of a trolley current escape from the rails to underground pipes. Tests were made over the same route as during the day, as well as at other places, but although the Lenox avenue line was running (they have an all night service) no evidence could be obtained of current straying from those conductors to either water or gas pipes. What we did find, however, worthy of mention, was another current, emanating from an entirely different source, passing from the water pipes to the rails, the pipes this time being *positive*, which, as will be perceived, was the reverse of the polarity found during the day. This current was as perfectly steady as if from a galvanic battery. The difference of potential, however, was low, in some places  $\frac{1}{30}$ th of a volt only was found, while in others the reading was  $\frac{2}{30}$ ths. In my efforts to identify this current I consulted the Manager of the power station which supplied current to the Lenox avenue road, and he obligingly offered to shut down the plant for half an hour during that portion of the night when traffic is the lightest and give me a chance to re-test. This was done between the hours of 2:30 and 3 A. M., when both of these electric roads were then shut down so that no possible current could come from either one. The same steady current was found, however, as before, passing from the water pipes into the rails. The voltmeter proving insufficient as a means of completely identifying this current, telephone receivers were used, and with one at each ear there was no difficulty in recognizing the familiar sing of the incandescent dynamo. This test with the telephone was repeated several times by my assistant and myself so that there could be no possibility of error.

It appears from the tests made, that an open conduit system, or one in which an insulated metallic return is used, effectually confines the current to the conductors provided for it. For this reason it is preferable to the ordinary ground return, especially in large cities, where the space below the streets is so largely occupied with various lines of iron pipes, more or less subject to electrolytic action.

The distances the overhead trolley current would sometimes reach, were shown by a rise in voltage when a Union railway car

crossed the tracks of the Lenox avenue road at 135th street. This was found as far down as 116th street, where the latter road branches east and west; in fact, there was no portion of this road where these trolley current fluctuations could not be obtained when cars were passing through 135th street.

Desiring to learn the difference of potential between the elevated railway pillars, and water pipes, with the Union railway, if any, in this part of the city, tests were begun at 157th street (Harlem River) on the Eighth avenue line and continued down as far as 109th street, which is the western terminus of the Metropolitan company's open conduit system. Rather than make this paper monotonous with long tables of tests, some plans have been prepared of different locations in the city,

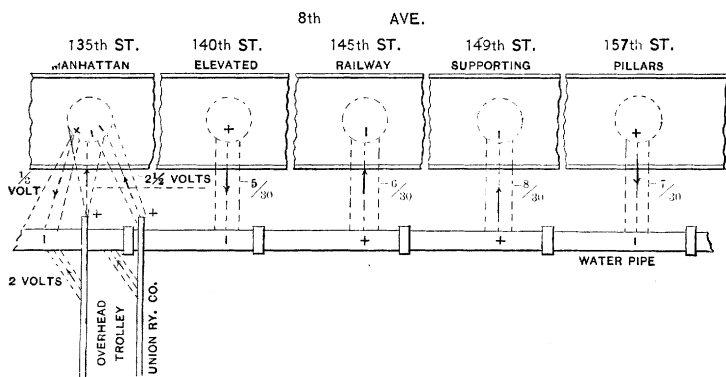


FIG. 1.

showing where these tests were made, and giving the difference of potential at the points indicated. It may be well to state here that the voltmeter used was a Weston two scale; the lower scale reading to 5 volts with 30th divisions; this scale was used in most of the tests, and accounts for the record being given in a number of cases in thirtieths of a volt. The upper scale read to 150 volts in 1 volt divisions.

The following is a general description of the method of procedure touching in detail at such points as may be of interest.

The starting point as already stated was at 157th street; from this point down to 135th street the tests are given in a table, as well as in plan, Fig. 1. The table gives both day and night tests for comparison, while the plan gives the day tests only.

The Union railway (overhead trolley) heretofore spoken of as

passing through 135th street, terminates at Eighth avenue; in fact, the ends of the two trolley wires of that road are supported by being attached to the "L" structure which as is well known passes through that avenue.

Location.	Day test 9 to 10 A. M.	Night test 1:30 to 2:30 A. M.
157th Street	"L" + to Hydrant $7/30$ Volt.	$7/30$ Volt "L" + to Hydrant
149th "	"L" — " " $8/30$ "	$3/30$ " "L" + " "
145th "	"L" — " " $6/30$ "	$1/30$ " "L" + " "
140th "	"L" + " " $5/30$ "	$2/30$ " "L" + " "
135th "	Rails U. E. Ry. + to "L" $2\frac{1}{2}$ volts	$2/30$ " Rails + "L" Ry.
135th "	" U. E. Ry. + " Hydt. 2 "	
135th "	"L" + to Hydrant $\frac{1}{3}$ volt	$1/30$ " "L" + " Hydrant
		Night readings steady throughout.

Referring to the table, it will be noticed that the reading at 157th street shows that the night test was the same as during the day. It was afterwards discovered that the last car of the Union railway had not then left the track, which accounts for this reading being higher than the other, as well as a trolley variation being shown. All of the other night tests, however, showed the same indications of an incandescent current as were found on Lenox avenue, as well as at several other places. One feature worthy of notice in the day test, shown in the plan, as well as the table, is the change of polarity found at different points on this section of the road.

The current passes into the water pipes and "L" structure from the rails of the trolley road at 135th street (they being positive) from 2 to  $2\frac{1}{2}$  volts maximum, then along the pipes for five blocks to 140th street, then reverses and passes along the "L" structure for another five blocks to 145th street, where it again reverses and takes the water pipes to another reversal at 157th street.

The cause of this erratic jumping of the railway current up some pillars and down others may be explained in two or three ways, two of which I will mention:

1st. Proximity of water pipes to the "L" structure, they being at some points closer than at others, offering a more favorable path for this portion of the current.

2d. The current passing into the water pipes at 135th street as well as the "L" structure at the same polarity, and possibly at a higher voltage at times to water may cause this change in polarity at different points along the line.

A few days ago tests were made over this same section of road with almost identically the same readings in each case as prevailed over a year ago. It was noticed, however, that the terminal rails of the Union railway company at 135th street and 8th avenue had recently been replaced by new ones which appears to be a good illustration of "cause and effect."

Similar conditions also prevail on the section of road below 135th street down to 109th street. At this point the "open conduit" road has its western terminus. Day tests have shown a maximum reading of  $\frac{1}{3}$  of a volt, the rails being positive to "L" pillar, and to water, the night test when Union railway was not running,  $\frac{2}{30}$  steady, showing plainly that the current was from that road.

Attention is now directed to the east side of this part of

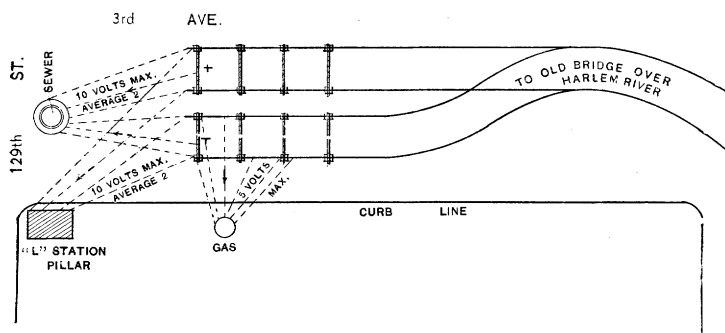


FIG. 2.

the city where another branch of the Union railway is located. Tests made here show even more pronounced results than at the branch running through 135th street to the west side. It may be stated that the power-station of this road is located on the Bronx river in Westchester county.

Something more than a year ago when these tests were made, this branch had a terminus at Third avenue and 129th street, immediately in front of the "L" station, the cars then passing over the Harlem river at the old wooden bridge, which is now being removed. The cars now pass over the new public bridge recently opened, to the new terminal at Lexington avenue. Fig. 2 shows the location of the old terminal when these tests were made, as well as the difference of potential.

It will be noticed that the maximum reading here was 10 volts,



rails positive to "L" pillar, sewer, and gas. A test was also made on the old Harlem bridge at the same time, which showed the same

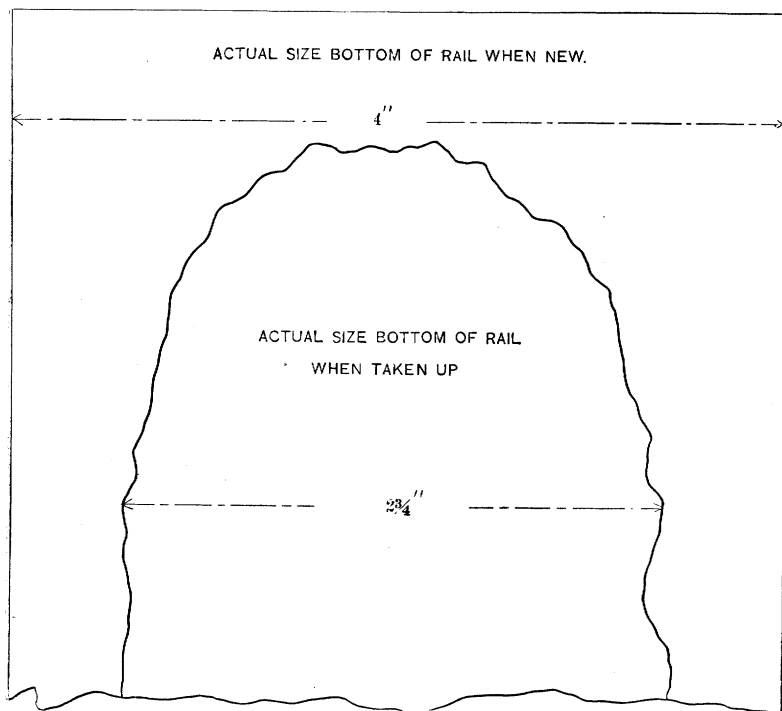


FIG. 3. Plan.

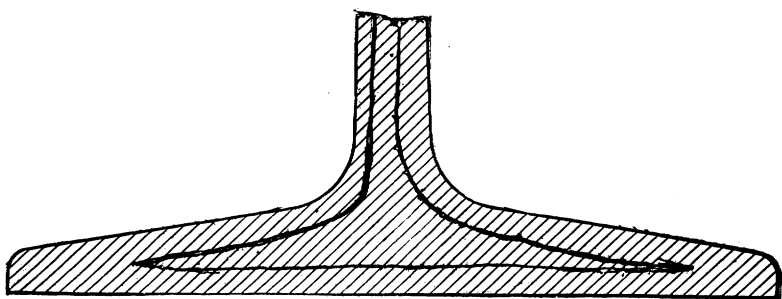


FIG. 3. Section

reading, except it was made to gas only, no other pipes being at hand. A few days ago this locality was visited with a view of obtaining

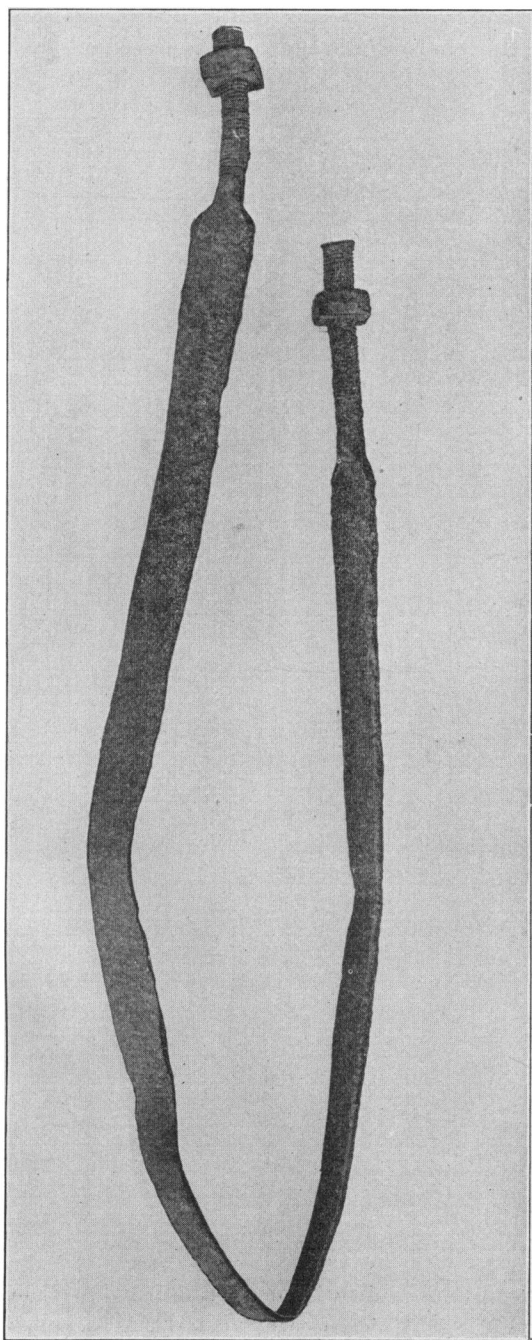


FIG. 4.

any further items which might be of interest for this paper, and workmen were found engaged in removing the rails of this very terminal.

Information was therefore obtained as to the results of electrolytic action on these rails (they having been positive). An impression was taken on paper of the exact size and shape of the

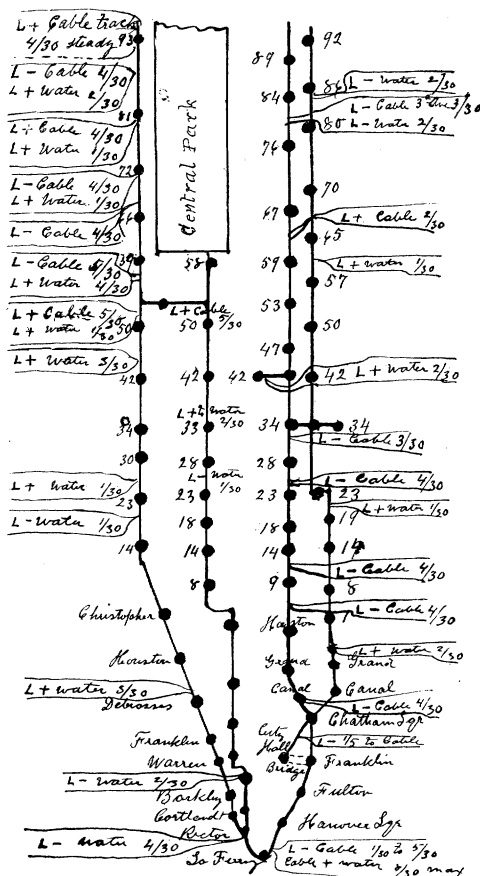


FIG. 5.

end of one of the four rails which composed that terminal switch, the ends of the other rails all being in just about the same condition. Fig. 3 shows a comparison of the size and shape of the rail when new and its present condition; the position of the out-lines as to each other being about as shown. From the condition of these rails now, it is quite plain that a large amount of metal

has been removed from them by electrolysis. The original size of the rails was furnished by the company supplying the rails, they being 70 lbs. to the yard; furthermore, the bottom sides of all these rails were cut by the current down to knife edges for several feet back from the ends. These edges were irregular in shape and somewhat jagged in appearance.

Another feature of interest is the condition of the cross-bars or tie-rods which keep the rails in position. These bars, which were originally  $1\frac{1}{2}$ " wide by  $\frac{3}{8}$ " thick, were nearly all so eaten away that the middle portion was missing, the ends protruding from the rails at from 6" to 12". Fig. 4 gives a view of one of these bars which was conveniently left behind when the other materials were removed. It is the only one I saw which was intact, and is in a much better state of preservation than the others, consequently not an average sample.

This specimen is on the table for inspection by those who care to examine it, as well as some small pieces, broken off by hand which were protruding from the rails. Your attention is called to a feature not shown in the cut and that is the sharp knife-edge of the side that was deepest in the ground from where the current passed out, somewhat similar in appearance to the sides of the rails above referred to; the ridges and pitting characteristics of electrolysis are also plainly visible in this, and in a lesser degree in the smaller specimens.

Further tests were made in this part of the city, but being not specially important, are omitted until 93d street is reached, from which point to the Battery a plan is given, showing the locations where tests have been made, their voltage and polarity. These tests refer mostly, as you will notice, to the incandescent current, passing at low voltage, ranging from  $\frac{1}{30}$  to  $\frac{1}{5}$  of a volt. One feature worthy of attention is the lowest reading being generally found at the "L" stations, between pillars under the stations and water pipes. This is accounted for by the fact that as there are water pipes supplied to most if not all the "L" stations they would make a fairly good electrical connection with the structure itself, and, therefore, not much difference of potential could be expected. This point also suggests a method for remedying this condition of affairs. Coming down the west side of the city, I was surprised to encounter a full fledged trolley current in the extreme lower part of the city. The first intimation was found at Rector and Greenwich streets,

it became more pronounced in the vicinity of South ferry where in testing between the rails of the Metropolitan cable road and an "L" pillar, a variation of from  $\frac{1}{30}$  to  $\frac{8}{30}$  volt was found, the rails positive, and the same reading between the rails and water pipes.

Just why there should be indications of a trolley current in this part of Manhattan Island was difficult to understand, but after making further tests coming up on the east side, this current was found to come from the Brooklyn bridge. Having pointed out how an overhead trolley, using the water pipes and incidentally the rails as a return, such as is operated on 135th street, can spread its influence, so to speak, for a distance of over 20 blocks in either direction north and south, through various pipes, railway structures, etc., the existence of this current from the bridge permeating underground metals through a large portion of the lower part of the city, is accounted for.

The tests were continued at the New York entrance of the bridge, and at the pillars which stand in the street just west of the Third avenue cable railway, I found the readings as follows: At one pillar a maximum of three volts, average  $1\frac{1}{2}$  volts, pillar positive to Third avenue cable rails. At another practically the same reading. Further up Park Row at the corner of Chambers street, pillar positive to cable rails, 1 volt maximum; water positive to cable rails  $\frac{1}{2}$  volt; pillar positive to water  $\frac{1}{3}$  of a volt.

All of these tests were made nearly a year and a half ago. A few days ago, tests were made over this same ground, and at places where a difference of potential of three volts maximum existed at that time, it is now found to be  $3\frac{1}{3}$  volts, pillars positive as before to rails of Third avenue cable and also to water pipes, showing in all probability that this current has been during all this time actively and unceasingly passing down the pillars which support the "L" station at this place, as well as the bridge crossing the street, and out from their foundations to other metals as stated, with now a fifth of a volt more for good measure.

In the light of present knowledge on this subject the very serious question presents itself to any practical mind here present, in what condition would we expect to find the anchor bolts and iron foundations of these pillars, if excavations were made at their bases?



track 4, where the voltage was found to be  $2\frac{1}{3}$  maximum. Previous to any use of electricity for operating cars on the bridge it had been known that currents were escaping to that structure from trolley lines in Brooklyn, and passing over would find their way through the city by underground pipes, etc., and thence crossing the river arrive back to the power-station in Kent avenue.

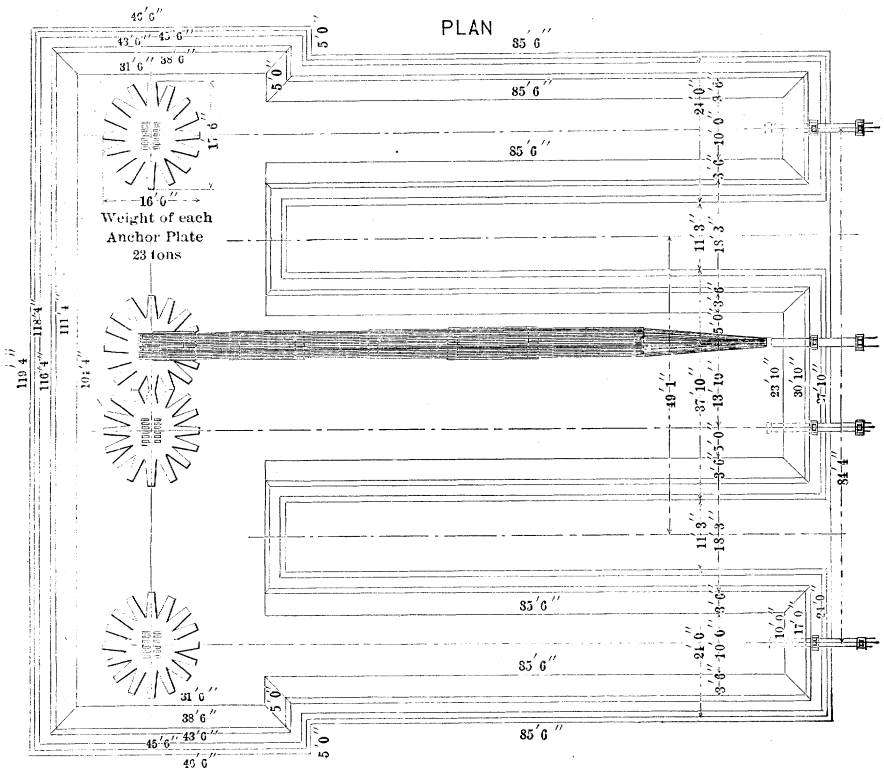


FIG. 7.

The polarity of both of these railway systems now operated on the bridge, indicates that these currents escape from their lines, but it is also quite likely that currents are even now coming over the bridge as they were a year ago. Only an extended investigation would determine these points, even if it were desirable that they should be known.

Let us now take up the investigation made on the bridge to deter-

mine if possible the movements of straying trolley currents and their possible effect on the cable terminals. In view of the importance of this matter I regret not being able to make it more thorough than here stated, as it would involve not only a fortnight's work at least, but the shutting down of the bridge plant for a time, which could hardly be expected under the circumstances. Such facts are represented however as it was practicable to obtain. Recognizing the necessity of having every detail as to the construction, location, etc., of these terminals before being able to intelligently consider the matter, plans prepared by the bridge engineers were obtained which are given in Figs. 6 and 7. These show the exact construction of the cable terminals and anchor plates, besides other information regarding construction, all of which is from an official source.

In regard to the construction of the cable terminals; as most of us know, the main cables are made up of eighteen strands, or smaller cables, which are practically continuous, the wire running back and forth from New York to Brooklyn, passing through the holes at the ends of heavy steel bars or links at each place, and the ends of the single wire being finally fastened by a rigid screw coupling. These two rows of steel bars of nine each, which are attached to the cable strands, one row placed over the other, as shown in Fig. 6, pass down with a graceful curve into solid stone masonry to the anchor-plates, and are secured to them by heavy steel bolts passing through the eyes at the ends, as shown in the figure. The anchor-plates are in shape somewhat longer one way than the other (see plan), each being a single piece of cast-iron, weighing twenty-three tons.

Coming now to the tests, it will be noticed that there is no possibility of reaching the anchor-plates other than by connection through the cables themselves, and they being firmly attached to the structure, cables and all are practically one conductor; and a connection on the structure would mean connection with the cables, and consequently with the anchor-plates.

This point therefore being settled, the next thing was to obtain a suitable ground, and on the suggestion of Mr. C. B. Martin, the electrician of the bridge, one of the railway cables was used during that portion of the day when it was not in operation for hauling a bridge train. This was a convenient as well as a good ground, the cable surface being polished bright through friction in passing over the pulleys, it



was possible to obtain a good contact, and as it passed over the large drums in the engine room which were on foundations connecting with engines, water-pipes, etc., it was probably the best ground independent of the structure obtainable. The connection to the structure was made by the use of a two-inch screw-clamp, the wire to the voltmeter being attached to it by the simple means of a screw and washer. Two of these clamps were generally used in nearly all of the previous tests, as they were found very convenient for attaching and detaching quickly to and from hydrants, pillars, etc. The first test under these conditions was made just over the Brooklyn anchorage, where the structure was found to be positive to the ground, with a difference of potential of  $2\frac{3}{4}$  volts maximum, estimated average  $1\frac{3}{4}$  volts.

At the Brooklyn tower another ground connection was made to a water-pipe, which ran down the side of the tower, and is intended for use in case of fire on the bridge. At this point the reading was  $3\frac{3}{4}$  volts maximum, average  $2\frac{3}{4}$ , bridge structure was as before positive. At center of span, structure positive at first, with  $2\frac{1}{4}$  volts maximum, but during the readings there were two reversals, one of them only remaining long enough to obtain a reading, which was  $1\frac{1}{4}$  volts maximum, structure negative. At the New York tower: structure positive to cable ground, with trolley variations ranging from  $\frac{3}{4}$ ths to 3 volts, average 2 volts. At New York anchorage: maximum  $2\frac{3}{4}$  volts, average 2 volts, structure positive, to ground.

Other tests were made to determine the polarity of the rails of the bridge trains, and they were found positive to the structure, the same as the rails of the trolley road heretofore tested. Let us now consider the question of the electrolytical conditions of the cable anchorages, as this point appears to be of high importance in this matter, if not the key to the whole situation in determining whether or not electrolytic action is going on. First: These anchorages are composed of solid stone masonry and are put together with the highest quality of cement; there is no brickwork or mortar in their construction.

2d. The 23 tons of iron composing the plates are set about 80 feet below the top of the anchorage. The distance from the bottom of the plates to mean high water is 3 feet 8 inches at the New York end, 5 feet at the Brooklyn end; there is no earthy matter, salts or alkalies, such as is found prevalent in the streets which go to make up an electrolyte, so I am informed, in any part of this structure.

I was at first apprehensive that on account of the comparatively short distance between mean high water and the plates at both anchorages there might be opportunity for salt water to reach the plates through seepage or capillary attraction and thereby produce such an electrolyte as to cause corrosion, but have been informed that it is not possible for salt water to reach these terminal plates on account of the distance from the river, the anchorages being over 900 feet from the towers which stand at each side of the river. Even allowing 100 feet for the salt water to work back, there is still ample margin as to distance before salt water can reach these plates; besides this, one of the bridge engineers showed me a plan of the construction of the foundation under each anchorage, which consists of heavy timbers 10' x 10' and some 12' x 12' arranged in 4 to 7 layers, placed a short distance apart, and the intervening spaces filled in with concrete cement.

In view of the tests therefore that have been made showing the structure and cables to be positive at both ends, it is quite possible that a portion of the currents straying from the trolley lines, and possibly from the bridge service, find their way out of the anchor plates through the dampness of the stone-work of these anchorages. The construction of these anchorages however is such, as I have endeavored to set forth, that it seems reasonable from the general construction of these piers that the mass of stone and concrete surrounding these plates will not constitute an electrolyte such as would favor electrolysis, and thereby cause corrosive action on them.

One of the bridge officials informed me that a certain authority had reported that electrolysis would not attack cast-iron, consequently their cast-iron anchor-plates were exempt from such danger. In the light of recent experience in other cities, that theory is now untenable; for instance, I will quote a few extracts from a pamphlet, giving the reports of four experts, besides that of the Secretary of the Water Board of the City of Dayton, Ohio, embodying an estimate of cost for repairing the damage.

Mr. E. E. Brownell, E. E., states: "To my surprise I have found in this city a six-inch water main that was corroded to the depth of one-quarter of an inch where the voltage did not average over 1.5 to 2 volts positive to the rails, therefore it is impossible to establish a certain voltage that will cover all cases for low readings."

The following extracts are quoted from the report of Mr. J. H. Shaffer, metallurgist :

He says : "In accordance with instructions from the Board, I have made a careful inspection of the cast-iron water mains at fifteen different locations in the city," and then gives the results of excavations, etc., two of which I will quote.

1st. "This excavation was made at the corner of Washington and Mound streets. It exposed a six-inch main and a ten-inch tee; the pipe was laid in 1874, and the tee in 1888, both were subjected to electrolytic action for about ten years. Both pipe and tee showed great evidence of electrolytic corrosion, the pipe being damaged to an alarming degree, with holes pitted from one-eighth to five-sixteenths of an inch in depth, and covering a large portion of the same.....The lead caulking was found to be in bad condition, and showed perceptible evidence of leaking. The pipes at this point were nine volts positive to the rails.

"2d. This excavation was made on Germantown street, near Krug. It uncovered a six-inch pipe. This pipe was electrolytically corroded in about the same proportion, with other conditions identical. A lead service pipe was also exposed at this point, and was found to be entirely destroyed."

A quotation from the report of the secretary on an approximate estimate of the cost of replacing water-pipes damaged by electrolysis caused by electric railway currents may also be interesting.

He says : "In calculating the cost of replacing the pipes in the whole affected territory, it is estimated at \$77,208.80.

"There is 17,513 feet of pipe that shows a voltage of from two to nine volts positive, and from pieces of pipe removed where electrically charged to this extent, it is found that they have deteriorated fifty per cent. in four years.

"Where they were required, when laid, to withstand a hydrostatic pressure of over 300 pounds per square inch, when tested by J. H. Shaffer, iron expert, after being subjected to 4.5 volts for four years, leaked at 150 pounds pressure."

He also states the following : "At 4.5 volts it has been shown that a six inch pipe can certainly become useless in 5 years."

I have quoted thus freely from this pamphlet for two reasons, one to show that it is a mistake to suppose that cast-iron is not subject to corrosion by electrolysis produced by railway currents, and also to show the penalty to which a city is subjected through permitting such conditions to exist so long that they cause such heavy damages to its property. In the light, therefore, of what has been shown to be the state of affairs in the upper part of this city due to escaping railway currents, as well as the experience

at Dayton, O., it appears to be the duty of engineers to exercise every possible precaution against the effects of this invisible element of destruction, which if left to itself will certainly shorten the life of valuable city property.

In the cases found to exist up town, it is true that the rails of the road referred to are apparently the principal metals damaged, for the reason that they happen to be positive to the water pipes, but as the escaping current goes into the pipes at one place it must come out at others, and at these places damage may be looked for.

The damages already done and threatened to public works in England by electrolysis has led to the establishment of regulations to prevent such action in the future, and similar legislation may be expected in this country should these conditions be allowed to continue. One of the provisions in the regulations prescribed by the British Board of Trade may be of interest just here. It is to the effect that if the pipe is negative to the rails the potential difference shall not exceed 4.5 volts, and if the pipe is positive to the rails the potential difference shall not exceed 1.5 volts. This appears to be very liberal for the railways, in view of the experience in cities on this side of the water; it is probable however they will be made more stringent as future experience in this direction dictates.

I have purposely avoided elaborating in this paper, any particular scheme for preventing damage by stray railway currents for the reason that methods are perfectly well known to railway companies for confining currents to their proper conductors, such as efficient bonding, and providing a return that will leave no inducement for the current to seek underground pipes, in preference to a legitimate conductor. It is simply a question of additional expense. Referring to the incandescent light current which was found prevailing everywhere in this part of the city from the Harlem river to the Battery, passing between all kinds of underground metals, and some on the surface, I do not consider these currents as particularly dangerous at the moment on account of their low voltage, but as before stated, it having been established that a fraction of a volt difference of potential will cause electrolytic action, it then comes down simply to a question of time, when those straying incandescent currents will have to be seriously considered.

In conclusion, I wish to say that these remarks regard-

ing possible damage to public structures through the action of electrolysis, have been made with no desire on my part to appear as an alarmist, but to present simple facts as found in these investigations. I believe that too little attention has heretofore been paid to this matter by any of us; perhaps for the reason that electrolytic action being invisible, as well as noiseless, it has thus escaped attention, and its baneful effects not fully appreciated. It is my opinion, however, that ordinary caution would suggest, that periodical tests should be made in every city by competent parties where a trolley road using a ground return is in operation, and the reports placed before those having authority to deal with the matter. In this way threatened damage by electrolysis to water and other pipes, as well as bridges, might be arrested and finally controlled.