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# SURFACE INSULATION OF PIPES AS A MEANS OF PREVENTING ELECTROLYSIS

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## I. INTRODUCTION

One of the methods first resorted to as a possible means of preventing damage to buried water pipes and gas pipes by electrolysis and soil corrosion, and one which is still in use to a considerable extent, consists in covering the surface of the pipes with a coating intended to insulate them from the surrounding earth. In numerous instances in practice, pipes have been protected

against soil corrosion by such coatings, which appeared to remain in good condition for a number of years; but it is still doubtful whether there is any instance on record where damage by electrolysis has been effectually prevented in this way if the voltage conditions were at all severe. On the contrary, there have been cases where efforts to prevent electrolysis of pipes by this means have undoubtedly done actual harm. The causes of this are brought out later in this paper; in general, it may be said to be due to peculiarities of the coatings used, which cause them to fail in spots and thus allow greatly aggravated cases of local damage to occur, in place of the more distributed trouble which would take place if the pipes were not coated, assuming the voltage conditions to be the same in both cases.

At the present time there are a great many paints and waterproofing materials on the market which might appear to be suitable for insulating coatings on underground pipes, and which are, in fact, often recommended by their makers as being well adapted for the purpose. Since these coatings are commercially available, and are used occasionally as insulating coatings with the view of reducing damage from electrolysis, the Bureau of Standards has undertaken, in connection with a general investigation of the subject of electrolysis, to test a large number of these coatings with the special view to determining their value as preventives of electrolytic damage.

## II. WORK OF PREVIOUS INVESTIGATORS

A considerable amount of work along this line has been done by previous investigators, the most extensive of which was reported by R. B. Harper before the Illinois Gas Association in March, 1909. In this investigation more than 38 different compounds, including paints, dips, and wrappings, were tested. The conclusions given in the report state that no insulating coating was found that would resist the attacks of electrolysis for any considerable length of time. Against the results of these tests, however, there has been directed the criticism that the voltage used on the coatings (110 volts) was abnormally high. Since the voltages to which a pipe coating would be subjected under most

practical conditions would not exceed a few volts, tests made on 110 volts would not appear to furnish altogether reliable data as to the value of the coating as a protection against electrolysis.

In addition to the work just mentioned, that of various other investigators also points to the fact that at least a large proportion of the paints sold for the purpose of preserving metals from corrosion are not impervious to water. From the standpoint of soil corrosion the access of water to the protected iron may not be a serious matter, provided the paint is an inhibitor of corrosion, or at least does not form a galvanic couple with the iron; but if there is a difference of potential of several volts between the pipes and soil the results may be very serious, as shown by the experimental data presented later in this paper.

## III. MATERIALS AVAILABLE FOR INSULATION PURPOSES

The materials which are practicable commercially for insulating coverings for underground pipes may be divided into six general classes:

(*a*) Paints, or compounds which are to be applied at ordinary temperatures, depending on oxidation or other chemical action, drying, etc., for their setting properties.

(*b*) Dips or compounds intended to be melted at a high temperature and the iron immersed and left until bath and iron are at the same temperature, when the iron is removed and allowed to cool, the compound hardening with decreasing temperature. These dips include asphalts, coal-tar pitches, and their allied products.

(*c*) Wrappings, which consist of alternate layers of compound and fabric. The compounds used include the classes mentioned under both (*a*) and (*b*) while the fabric may be either felt, cloth, or paper. The latter may be treated or untreated, according to the ideas of the manufacturer or the person making the test. There are a great many subdivisions of these three classes, but since it is the object of this work to determine the value of the various materials as preventives of electrolysis when applied according to the specifications of the manufacturer, it does not seem to be necessary to go into them here. A short description of each material in the record of the results of the tests appears to be sufficient.

(*d*) Fiber conduit, in which pipe can be laid quite conveniently. This conduit can be used with or without pitch filling and can be made up with screw joints. In point of cost of materials and labor of putting in place it compares quite favorably with the best wrappings.

(*e*) Enamels, or those coatings of glass of peculiar toughness with which iron can be covered and which are quite impervious to moisture. They will stand a considerable amount of rough usage, but crush under a pipe wrench, and will crack when the metal underneath them is bent. The durability of these enamel coatings is well shown in the cases of enameled iron washbowls, bathtubs, and cooking utensils.

(*f*) Cement mortar and concrete coatings have been used to a considerable extent as protective coatings for pipes, and in this paragraph it may be well to set forth briefly the results of certain tests on these coatings which have been made at the Bureau of Standards. It has been shown in these tests that cement and concrete are insulating only when perfectly dry. The addition of a slight amount of moisture reduces the resistance to such a low value that the protective power, through insulation, of a mortar coating when damp would be of no moment whatever. Cement mortar absorbs water quite readily and the mortar coating of a pipe laid in damp ground would therefore be a conductor of electricity at all times, and thus no reliance could be placed upon protection through insulation in this way. The following table gives the resistivities of various samples of mortar and concrete which had been soaked in water at room temperature and under atmospheric pressure until no further increase in weight was noted:

Resistivity of Concrete [1]

| Proportions of concrete. | Resistivity. | Proportions of concrete. | Resistivity. |
|---|---|---|---|
| Neat cement | 3500 | 1:2½:4 concrete | 8000 |
| 1:2 mortar | 2300 | 1:3:5 concrete | 8200 |
| 1:4 mortar | 2100 | 1:4:7 concrete | 9900 |
| 1:2:3 concrete | 6300 | | |

[1] The resistivity of concrete will, of course, vary greatly with the aggregate, method of making, etc., and the above values are indicative only of the order of magnitudes of resistivities that may be expected.

It may also be well to state here that in the course of the work on electrolysis in concrete, which is described in Technologic Paper No. 18 of the Bureau of Standards, no waterproofing compound or paint was found which would permanently render concrete a nonconductor of electricity when subjected to the action of moisture.

When concrete is new and contains a large amount of calcium hydroxide there is a considerable passivating action which allows current to leave a pipe coated with cement mortar with comparatively little corrosion of the iron, but with age the calcium hydroxide is carbonated and the passivating action is destroyed, with the result that the pipe corrodes quite rapidly. Tests carried out at the Bureau of Standards on cement-coated pipes with lead joints showed that in less than two years cracking of the mortar coating and pitting of the pipe occurred to a marked degree, even with low voltages applied.

The conclusion to be drawn from these results is that a cement or mortar coating is of no practical value as a preventive of electrolysis of underground pipes.

Tests have been carried out on various paints, dips, and wrappings, and these tests are described below. The tests on fiber conduits and enamels have not progressed far enough at present to give conclusions as to their values as preventives of electrolysis, but they will be reported on later.

## IV. TESTS OF PAINTS

### 1. GENERAL OUTLINE OF TESTS

In the process of formulating a series of tests to accomplish the object outlined at the end of Section I, the following facts were considered as having an important bearing:

(*a*) That the effectiveness of an insulating coating as a preventive of electrolysis depends primarily upon its continuity.

(*b*) That in practice electrolytic corrosion takes place in the presence of soil water or other water containing various chemicals in more or less dilute solution.

(*c*) That air and the above-mentioned water alternate to a greater or less degree in coming in contact with the coating.

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(*d*) That the potential differences encountered are usually low.

(*e*) That an insulating coating which is unable to withstand the combined action of water, air, and a low electric stress can not reasonably be expected to make a better showing when the water in contact with it contains an active chemical in solution.

With these in mind a series of tests was outlined which was calculated to determine the effectiveness of each insulating coating under voltage conditions approximating those which measurements had shown to be common in practice. The severity of these conditions was modified to suit the different classes of coatings, the idea being that a coating suited to mild conditions should be tested under such conditions, while for the more rugged coatings the conditions should be made more severe. The object of such a series of tests was to avoid all undue acceleration and to give to each coating every advantage to which it seemed entitled. The test itself consisted in causing water and air to alternate in coming in contact with a continuous coating of each substance while a low potential difference was applied across the coating from the water to the metal surface upon which the coating had been placed. In the case of each coating the metal was made positive in some specimens and negative in others, while as a check on the effect of the electric stress on the paints certain specimens were subjected to the alternate action of water and air with no difference of potential applied.

## 2. PREPARATION OF SPECIMENS

In preparing specimens for the tests the first difficulty encountered was that of obtaining a continuous coating of a paint. The only way by which this could be overcome was by applying a sufficient number of coats to completely eliminate all pinholes and flaws. Four coats, when carefully put on, were usually found sufficient to give the best results of which a paint is capable. The procedure in preparing painted specimens which was formulated during the early progress of the work and adhered to quite closely thereafter was as follows: It was found to be preferable that the paint be applied to a smooth, flat, or nearly flat, surface having no projections or rough spots, and care was taken to see that the surface was free from grease, scale, or rust, especially grease. In brushing on quick-drying paints the brush was not passed over the

surface after the paint had gained its initial set, which usually took but two or three minutes. It was found essential that the paint be thinned until it would spread well, and the coating was never applied so thickly that it would run in ridges and dry or leave blisters. The thinning agents used were those recommended by the manufacturers of the paints and included turpentine, benzine, and gasoline. Each coat was thoroughly dried before the application of the next. In cleaning brushes, while passing from one paint to another, great care was taken that no gasoline, alcohol, or other cleaning agent was retained by the brushes, as some paints are extremely sensitive to them.

### 3. FORM OF SPECIMENS

To obtain a smooth, nearly flat surface, and, at the same time, other distinct advantages, specimens were made of a form shown

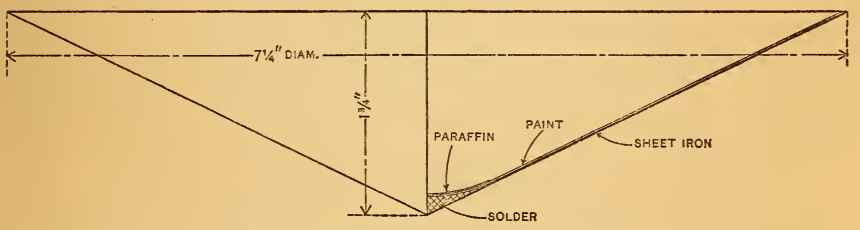


Fig. 1.—*Sheet-iron cone used in paint tests*

in Fig. 1. These consisted of sheet-iron cones of about 7 inches diameter of base and 1¾ inches altitude. The interior of the apex of each cone was filled with solder and the overlapping joint soldered to a smooth surface, in order to do away with the sharp corners which would be hard to paint or otherwise coat. The interior surface of the cone was coated. When the coating was completed a portion of the surface a little more than covering the area of the solder at the apex was strongly reinforced against dampness and electrical stress, in order to do away with the effect of any chance roughness of surface which might be present. This reinforcing was done with a coat of warm paraffin. Trial was made of several substitutes for paraffin, one of which consisted of paint and muslin, but they were all found to be quite unsatisfactory. It may be said, without exception, that no painted cone

failed in or around the edge of the paraffined portion of the surface during the progress of the tests.

The cone presents marked advantages for the purpose of testing insulating coatings of the character of those under consideration. The surface of the cone being smooth, and nearly flat, it is easy to coat uniformly. There are no ends or corners where defects may appear. After they are coated they may be laid down anywhere to dry or set, and no ordinary handling is likely to damage the coat. The cone also forms the containing vessel for the liquid used in the tests.

### 4. PERIOD REQUIRED FOR DRYING OF PAINTS

When the tests were first begun a total of 10 days drying for the whole number of coats was thought to be a sufficient preparation for testing a paint, but later results showed that two months was hardly time enough for the greater number of the paints to attain their full power as waterproofers. Many paints depend upon the action of oxygen from the air for their setting properties, and as this action is comparatively slow it is not complete when the paints are dry enough for handling.

### 5. PRELIMINARY TEST

The first test to which the painted specimens were subjected after the paint had dried was the test for pinholes and flaws. This test consisted at first in filling the cone to about one-half inch from the rim with mercury and applying a 60-cycle alternating difference of potential of 80 volts (effective) with the mercury and the sheet iron of the cone as contact pieces. Eighty volts was settled upon as a test voltage which would not immediately break down even a thin coating of a paint if dry and flawless and still would give an unmistakable indication if the coating were not perfectly continuous. This test was later modified by using a 10 per cent NaCl solution in the place of mercury. The salt solution was not only more convenient to handle, but it seemed to search out flaws in the coating more readily than mercury. An alternating current milliammeter of 831 ohms resistance and 0.050 ampere full-scale deflection was put in series with the cone, and a kick of the needle when the circuit was closed indicated a defect in the coating. The potential was applied for

30 seconds, and if no deflection of the needle occurred, the coating was considered perfect. Specimens which did not pass this test were rejected and others made and tested until a set of five perfect specimens was obtained of each paint. The effect of the length of the drying period was the most evident in the results of this test. Out of a number of tests at the end of 10 days drying and of others at two months the percentage of defective coatings for the shorter period was four or five times as great as for the longer period.

### 6. RESISTANCE MEASUREMENTS

This test (as well as those following) was carried out on the specimens surviving the first test, and consisted in measuring the electrical resistance of the paint coatings in ohms per square centimeter. This was done by filling each cone with salt water, as in the first test, placing it in parallel with a resistance of 25 000 ohms and measuring the resistance of the parallel circuit with a Wheatstone bridge, using direct current. The resistances of the coatings were very high, and this procedure was necessary in order to bring the resistances to be measured within the limits of the capacity of the bridge. A very sensitive galvanometer was used, and if placing the cone in or out of parallel with the known resistance made a change of 0.5 ohm, it could easily be detected. After calculating the resistance of the whole area of the coating by the method of parallel circuits the area of the cone multiplied by the value obtained gave the resistance of the coating in ohms per square centimeter. A great many of the paint coatings were of such high resistance that balancing the bridge on the 25 000-ohm resistance and then putting the cone in parallel with it caused no deflection of the galvanometer. Calculations and trial showed that if a paint coating had a resistance of more than $2 \times 10^{11}$ ohms per square centimeter this would be the case and in the table of results the resistance of such paints is designated as greater than this value. Those paints having a resistance lower than the above value showed an action resembling polarization, in that the resistance increased very rapidly while the cone was in the bridge circuit. The method is not highly accurate, but gives the order of magnitude of the resistances of the paint coatings, which is about all that is required.

## 7. FINAL TEST OF PAINT COATINGS

In the final test each painted cone was filled to one-half inch from the rim with water from the city water mains (or other electrolyte, as the case required) and placed in a rack made and wired especially for the purpose of the test. The one-half inch strip of dry paint around the rim was left in order to prevent leakage of current over the edge as much as possible. Two cones of each set of five mentioned above were connected up electrically with the sheet iron of the cone anode and the negative terminal in the form of a couple of turns of bare copper wire brought into the tap water. Another cone was connected with the sheet-iron cathode and the positive terminal brought into the tap water. (See Fig. 2.) The two remaining cones were not subjected to

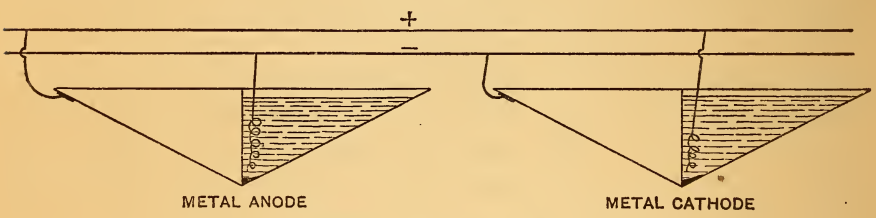


Fig. 2.—*Connections of specimens to electrical circuit*

electrical stress but the electrical connections were made available for current readings, when the potential was applied long enough for the reading to be taken. A direct-current difference of potential of 4 volts was impressed upon the circuit continuously, a storage battery being used for the purpose. This potential difference was assumed to represent the mean rather than an extreme of those found in practice under conditions favorable to electrolysis where a paint might be expected to act with success as a preventive. During a period of about two weeks, under normal atmospheric conditions, almost complete evaporation of water from the cones would occur. They would then be refilled and two days later current readings would be taken. In this way any error which might be caused by leakage of current over the damp edges of the cones immediately after refilling was eliminated; the current reading included the flow through all of the painted surface upon which the water and air had acted, and the conditions of the test as outlined above

were fulfilled with a minimum of labor and expenditure of time. The first appearance of current flow is indicated by the number of hours to failure in Table 1, and is to be taken as meaning the end of the insulating power of the paint. After the first appearance of current flow the life of a paint coating with continuously applied potential is very short. Specimens were left in circuit until failure was complete and the current became 1.5 milliamperes or more.

TABLE 1

Tests of Metal-Preservative Paints as Insulating Coatings

| Paint No. | Name of paint | Specimen | Coats | Resis., ohms per cm.[2] | Electrolyte | Voltage of time test | Polarity of cone | Hours to failure | | | Weeks of drying |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Pos. | Neg. | Neut. | |
| 1 | Antakwa, heavy..... | 1 | 4 | $2.0 \times 10^{11}$ | 2% $Na_2CO_3$... | 4 | Pos... | 312 | ..... | ..... | 2 |
| | | 2 | 4 | $2.0 \times 10^{11}$ | Water..... | 4 | Pos... | 384 | ..... | ..... | 2 |
| | | 3 | 4 | $>2.0 \times 10^{11}$ | .....do..... | 4 | Neg... | ..... | 2000 | ..... | 8 |
| | | 4 | 4 | $>2.0 \times 10^{11}$ | .....do..... | 0 | Neut.. | ..... | ..... | 1400 | 8 |
| | | 5 | 4 | $>2.0 \times 10^{11}$ | .....do..... | 0 | Neut.. | ..... | ..... | 1400 | 8 |
| 2 | Antakwa, metal protection. | 1 | 4 | $2.0 \times 10^{11}$ | 2% $Na_2CO_3$... | 4 | Pos... | 192 | ..... | ..... | 2 |
| | | 2 | 4 | $1.6 \times 10^{9}$ | Water..... | 4 | Pos... | 0 | ..... | ..... | 2 |
| | | 3 | 4 | $>2.0 \times 10^{11}$ | .....do..... | 4 | Neg... | ..... | 2000 | ..... | 8 |
| | | 4 | 4 | $>2.0 \times 10^{11}$ | .....do..... | 0 | Neut.. | ..... | ..... | 1400 | 8 |
| | | 5 | 4 | $>2.0 \times 10^{11}$ | .....do..... | 0 | Neut.. | ..... | ..... | 1400 | 8 |
| 3 | R. I. W., number not known. | 1 | 4 | $2.0 \times 10^{11}$ | ½% $H_2SO_4$..... | 4 | Pos... | 312 | ..... | ..... | 2 |
| | | 2 | 4 | $>2.0 \times 10^{11}$ | Water..... | 4 | Pos... | 5000 | ..... | ..... | 2 |
| | | 3 | 4 | $>2.0 \times 10^{11}$ | .....do..... | 4 | Neg... | ..... | 600 | ..... | 8 |
| | | 4 | 4 | $>2.0 \times 10^{11}$ | .....do..... | 0 | Neut.. | ..... | ..... | 600 | 8 |
| | | 5 | 4 | $>2.0 \times 10^{11}$ | .....do..... | 0 | Neut.. | ..... | ..... | 1350 | 8 |
| 4 | Carbonkote, interior | 1 | 4 | $3.0 \times 10^{10}$ | ½% $H_2SO_4$..... | 4 | Pos... | 528 | ..... | ..... | 2 |
| | | 2 | 5 | $3.6 \times 10^{10}$ | Water..... | 4 | Pos... | ([2]) | ..... | ..... | 2 |
| | | 3 | 4 | $>2.0 \times 10^{11}$ | .....do..... | 4 | Neg... | ..... | ([2]) | ..... | 8 |
| | | 4 | 4 | $>2.0 \times 10^{11}$ | .....do..... | 0 | Neut.. | ..... | ..... | ([2]) | 8 |
| | | 5 | 4 | $>2.0 \times 10^{11}$ | .....do..... | 0 | Neut.. | ..... | ..... | ([2]) | 8 |
| 5 | Mindura, brine-resisting finish. | 1 | 5 | $7.0 \times 10^{9}$ | 3% NaCl..... | 4 | Pos... | 840 | ..... | ..... | 2 |
| | | 2 | 5 | $3.2 \times 10^{9}$ | Water..... | 4 | Pos... | 120 | ..... | ..... | 2 |
| | | 3 | 5 | $>2.0 \times 10^{11}$ | .....do..... | 4 | Neg... | ..... | 760 | ..... | 8 |
| | | 4 | 5 | $>2.0 \times 10^{11}$ | .....do..... | 0 | Neut.. | ..... | ..... | 570 | 8 |
| | | 5 | 5 | $>2.0 \times 10^{11}$ | .....do..... | 0 | Neut.. | ..... | ..... | 570 | 8 |
| 6 | Mindura, ordinary finish. | 1 | 5 | $10.8 \times 10^{9}$ | 2% $Na_2CO_3$... | 4 | Pos... | 5 | ..... | ..... | 2 |
| | | 2 | 5 | $3.2 \times 10^{9}$ | Water..... | 4 | Pos... | 7 | ..... | ..... | 2 |
| | | 3 | 5 | $>2.0 \times 10^{11}$ | .....do..... | 4 | Neg... | ..... | 2000 | ..... | 8 |
| | | 4 | 5 | $>2.0 \times 10^{11}$ | .....do..... | 0 | Neut.. | ..... | ..... | 2800 | 8 |
| | | 5 | 5 | $>2.0 \times 10^{11}$ | .....do..... | 0 | Neut.. | ..... | ..... | 2800 | 8 |
| 7 | Nev-a-Rust..... | 1 | 4 | $1.7 \times 10^{9}$ | 2% $Na_2CO_3$... | 4 | Pos... | 5 | ..... | ..... | 2 |
| | | 2 | 4 | $7.7 \times 10^{8}$ | Water..... | 4 | Pos... | 240 | ..... | ..... | 2 |
| | | 3 | 4 | $1.6 \times 10^{9}$ | .....do..... | 4 | Neg... | ..... | 120 | ..... | 8 |
| | | 4 | 4 | $1.6 \times 10^{9}$ | .....do..... | 0 | Neut.. | ..... | ..... | 336 | 8 |
| | | 5 | 4 | $2.1 \times 10^{9}$ | .....do..... | 0 | Neut.. | ..... | ..... | 902 | 8 |
| 8 | Carbonall, No. 10... | 1 | 4 | $2.0 \times 10^{10}$ | ½% $H_2SO_4$..... | 4 | Pos... | 5 | ..... | ..... | 2 |
| | | 2 | 4 | $5.5 \times 10^{10}$ | Water..... | 4 | Pos... | 552 | ..... | ..... | 2 |
| | | 3 | 4 | $>2.0 \times 10^{11}$ | .....do..... | 4 | Neg... | ..... | 3144 | ..... | 8 |
| | | 4 | 4 | $>2.0 \times 10^{11}$ | .....do..... | 0 | Neut.. | ..... | ..... | 1100 | 8 |
| | | 5 | 4 | $>2.0 \times 10^{11}$ | .....do..... | 0 | Neut.. | ..... | ..... | 1100 | 8 |

[2] No sign of current after 10 000 hours.

TABLE 1—Continued

Tests of Metal-Preservative Paints as Insulating Coatings—Continued

| Paint No. | Name of paint | Specimen | Coats | Resis., ohms per cm.² | Electrolyte | Voltage of time test | Polarity of cone | Hours to failure | | | Weeks of drying |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Pos. | Neg. | Neut. | |
| 9 | Carbonkote, No. 100 | 1 | 4 | $3.0 \times 10^{9}$ | 2% $Na_2CO_3$ | 4 | Pos | 72 | | | 2 |
| | | 2 | 5 | $1.6 \times 10^{9}$ | Water | 4 | Pos | 1368 | | | 8 |
| | | 3 | 4 | $1.1 \times 10^{11}$ | do | 4 | Neg | | 6000 | | 8 |
| | | 4 | 4 | $1.1 \times 10^{11}$ | do | 0 | Neut | | | 2800 | 8 |
| | | 5 | 4 | $5.5 \times 10^{10}$ | do | 0 | Neut | | | 2800 | 8 |
| 10 | Sarco | 1 | 4 | $2.0 \times 10^{11}$ | ½% $H_2SO_4$ | 4 | Pos | 312 | | | 2 |
| | | 2 | 4 | $3.4 \times 10^{7}$ | Water | 4 | Pos | 0 | | | 8 |
| | | 3 | 4 | $9.2 \times 10^{6}$ | do | 4 | Neg | | 1752 | | 8 |
| | | 4 | 4 | $1.2 \times 10^{8}$ | do | 0 | Neut | | | 336 | 8 |
| | | 5 | 4 | $1.0 \times 10^{6}$ | do | 0 | Neut | | | 336 | 8 |
| 11 | AeOnite, preservative paint. | 1 | 4 | $4.5 \times 10^{8}$ | do | 4 | Pos | 5 | | | 2 |
| | | 2 | 4 | $3.6 \times 10^{8}$ | do | 4 | Pos | 0 | | | 2 |
| | | 3 | 4 | $6.2 \times 10^{9}$ | do | 4 | Neg | | 2952 | | 8 |
| | | 4 | 4 | $5.4 \times 10^{9}$ | do | 0 | Neut | | | 336 | 8 |
| | | 5 | 4 | $5.6 \times 10^{9}$ | do | 0 | Neut | | | 1208 | 8 |
| 12 | Crysolite, No. 10 | 1 | 4 | $1.0 \times 10^{9}$ | do | 4 | Pos | 0 | | | 2 |
| | | 2 | 4 | $6.6 \times 10^{9}$ | do | 4 | Pos | 240 | | | 2 |
| | | 3 | 4 | $>2.0 \times 10^{11}$ | do | 4 | Neg | | 860 | | 8 |
| | | 4 | 4 | $1.1 \times 10^{11}$ | do | 0 | Neut | | | 1300 | 8 |
| | | 5 | 4 | $1.1 \times 10^{11}$ | do | 0 | Neut | | | 600 | 8 |
| 13 | Neponset, Waterdyke paint. | 1 | 4 | $1.2 \times 10^{9}$ | do | 4 | Pos | 0 | | | 2 |
| | | 2 | 5 | $>2.0 \times 10^{11}$ | do | 4 | Pos | 2800 | | | 2 |
| | | 3 | 4 | $1.1 \times 10^{9}$ | do | 4 | Neg | | 10000 | | 8 |
| | | 4 | 4 | $3.5 \times 10^{7}$ | do | 0 | Neut | | | 1752 | 8 |
| | | 5 | 4 | $9.2 \times 10^{8}$ | do | 0 | Neut | | | 2376 | 8 |
| 14 | No. 107, H. F. Scott | 1 | 4 | $1.0 \times 10^{10}$ | do | 4 | Pos | 5 | | | 2 |
| | | 2 | 4 | $2.2 \times 10^{9}$ | do | 4 | Pos | 6500 | | | 8 |
| | | 3 | 4 | $1.8 \times 10^{8}$ | do | 4 | Neg | | 912 | | 8 |
| | | 4 | 4 | $6.8 \times 10^{9}$ | do | 0 | Neut | | | 912 | 8 |
| | | 5 | 4 | $2.0 \times 10^{7}$ | do | 0 | Neut | | | 3200 | 8 |
| 15 | Insulite | 1 | 4 | $1.0 \times 10^{6}$ | do | 4 | Pos | 10000 | | | 8 |
| | | 2 | 5 | $2.2 \times 10^{9}$ | do | 4 | Pos | 48 | | | 2 |
| | | 3 | 4 | $>2.0 \times 10^{11}$ | do | 4 | Neg | | 2700 | | 2 |
| | | 4 | 4 | $4.2 \times 10^{7}$ | do | 0 | Neut | | | 336 | 8 |
| | | 5 | 4 | $1.8 \times 10^{7}$ | do | 0 | Neut | | | 336 | 8 |
| 16 | Bar-OX | 1 | 4 | $1.5 \times 10^{9}$ | do | 4 | Pos | 3300 | | | 8 |
| | | 2 | 4 | $1.6 \times 10^{9}$ | do | 4 | Pos | 816 | | | 8 |
| | | 3 | 4 | $1.6 \times 10^{9}$ | do | 4 | Neg | | 206 | | 8 |
| | | 4 | 4 | $3.7 \times 10^{10}$ | do | 0 | Neut | | | 700 | 8 |
| | | 5 | 4 | $3.7 \times 10^{10}$ | do | 0 | Neut | | | 1400 | 8 |
| 17 | R. I. W., No. 5 | 1 | 4 | $5.0 \times 10^{10}$ | do | 4 | Pos | 1320 | | | 8 |
| | | 2 | 4 | $5.6 \times 10^{9}$ | do | 4 | Pos | 480 | | | 8 |
| | | 3 | 4 | $3.9 \times 10^{9}$ | do | 4 | Neg | | 3900 | | 8 |
| | | 4 | 4 | $>2.0 \times 10^{11}$ | do | 0 | Neut | | | 1400 | 8 |
| | | 5 | 4 | $>2.0 \times 10^{11}$ | do | 0 | Neut | | | 1400 | 8 |
| 18 | Gliddens, acid proof and graphite acid proof. | 1 | 4 | $5.0 \times 10^{10}$ | do | 4 | Pos | 4500 | | | 8 |
| | | 2 | 4 | $2.5 \times 10^{10}$ | do | 4 | Pos | 5300 | | | 8 |
| | | 3 | 4 | $2.5 \times 10^{10}$ | do | 4 | Neg | | 2800 | | 8 |
| | | 4 | 4 | $8.5 \times 10^{10}$ | do | 0 | Neut | | | 2880 | 8 |
| | | 5 | 4 | $1.0 \times 10^{5}$ | do | 0 | Neut | | | 2800 | 8 |
| 19 | Hydrex, preservative paint. | 1 | 4 | $4.6 \times 10^{9}$ | do | 4 | Pos | 2600 | | | 8 |
| | | 2 | 4 | $8.4 \times 10^{9}$ | do | 4 | Pos | 816 | | | 8 |
| | | 3 | 4 | $>2.0 \times 10^{11}$ | do | 4 | Neg | | 2600 | | 8 |
| | | 4 | 4 | $2.5 \times 10^{7}$ | do | 0 | Neut | | | 912 | 8 |
| | | 5 | 4 | $4.3 \times 10^{7}$ | do | 0 | Neut | | | 912 | 8 |

TABLE 1—Continued

Tests of Metal-Preservative Paints as Insulating Coatings—Continued

| Paint No. | Name of paint | Specimen | Coats | Resis., ohms per cm.[2] | Electrolyte | Voltage of time test | Polarity of cone | Hours to failure | | | Weeks of drying |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Pos. | Neg. | Neut. | |
| 20 | R. I. W., No. 49, over Tockolith. | 1 | 3 | $7.2 \times 10^{9}$ | Water | 4 | Pos | 192 | | | 8 |
| | | 2 | 3 | $7.2 \times 10^{9}$ | do | 4 | Pos | 192 | | | 8 |
| | | 3 | 3 | $5.6 \times 10^{9}$ | do | 4 | Neg | | 100 | | 8 |
| | | 4 | 3 | $>2.0 \times 10^{11}$ | do | 0 | Neut | | | 1600 | 8 |
| | | 5 | 3 | $>2.0 \times 10^{11}$ | do | 0 | Neut | | | 2000 | 8 |
| 21 | Insulate | 1 | 4 | $>2.0 \times 10^{11}$ | do | 4 | Pos | 100 | | | 8 |
| | | 2 | 4 | $>2.0 \times 10^{11}$ | do | 4 | Pos | 1586 | | | 8 |
| | | 3 | 4 | $3.1 \times 10^{9}$ | do | 4 | Neg | | 2800 | | 8 |
| | | 4 | 4 | $>2.0 \times 10^{11}$ | do | 0 | Neut | | | 1200 | 8 |
| | | 5 | 4 | $4.2 \times 10^{9}$ | do | 0 | Neut | | | 900 | 8 |
| [3]22 | Insulator, Carman | [4] 1 | 4 | $4.0 \times 10^{6}$ | do | 4 | | | | | |
| | | 2 | 4 | | do | | | | | | |
| | | 3 | 4 | | do | | | | | | |
| | | 4 | 4 | | do | | | | | | |
| | | 5 | 4 | | do | | | | | | |
| [5]23 | Damp-proofer, Carman. | [4] 1 | 4 | $1.2 \times 10^{8}$ | do | | | | | | |
| | | 2 | 4 | | do | | | | | | |
| | | 3 | 4 | | do | | | | | | |
| | | 4 | 4 | | do | | | | | | |
| | | 5 | 4 | | do | | | | | | |
| 24 | Crysolite, No. 8 | 1 | 4 | $>2.0 \times 10^{11}$ | do | 4 | Pos | 150 | | | 8 |
| | | 2 | 4 | $7.0 \times 10^{8}$ | do | 4 | Pos | 1032 | | | 8 |
| | | 3 | 4 | $1.0 \times 10^{6}$ | do | 4 | Neg | | 120 | | 8 |
| | | 4 | 4 | $1.0 \times 10^{6}$ | do | 0 | Neut | | | 1032 | 8 |
| | | 5 | 4 | $1.0 \times 10^{6}$ | do | 0 | Neut | | | 1032 | 8 |
| 25 | Dixon's graphite | 1 | 5 | $9.0 \times 10^{7}$ | do | 4 | Pos | 48 | | | 2 |
| | | 2 | 4 | $3.3 \times 10^{8}$ | do | 4 | Pos | 2800 | | | 2 |
| | | 3 | 4 | $1.6 \times 10^{9}$ | do | 4 | Neg | | 120 | | 8 |
| | | 4 | 4 | $1.6 \times 10^{9}$ | do | 0 | Neut | | | 120 | 8 |
| | | 5 | 4 | $1.8 \times 10^{8}$ | do | 0 | Neut | | | 120 | 8 |
| 26 | S. P. C., flexible iron paint. | 1 | 4 | $1.2 \times 10^{8}$ | do | 4 | Pos | 96 | | | 8 |
| | | 2 | 4 | $2.3 \times 10^{7}$ | do | 4 | Pos | 0 | | | 8 |
| | | 3 | 4 | $1.8 \times 10^{8}$ | do | 4 | Neg | | 10000 | | 8 |
| | | 4 | 4 | $1.0 \times 10^{8}$ | do | 0 | Neut | | | 672 | 8 |
| | | 5 | 4 | $2.2 \times 10^{8}$ | do | 0 | Neut | | | 672 | 8 |
| 27 | P & B, No. 2 | 1 | 4 | $9.8 \times 10^{7}$ | do | 4 | Pos | 6500 | | | 8 |
| | | 2 | 4 | $2.0 \times 10^{8}$ | do | 4 | Pos | 912 | | | 8 |
| | | 3 | 4 | $2.0 \times 10^{7}$ | do | 4 | Neg | | 288 | | 8 |
| | | 4 | 4 | $2.9 \times 10^{8}$ | do | 0 | Neut | | | 912 | 8 |
| | | 5 | 4 | $1.0 \times 10^{4}$ | do | 0 | Neut | | | 912 | 8 |
| [6]28 | P & B, black, air-drying varnish. | 1 | 4 | | do | 4 | Pos | 96 | | | 8 |
| | | 2 | 4 | | do | 4 | Pos | 96 | | | 8 |
| | | 3 | 4 | | do | 4 | Neg | | 96 | | 8 |
| | | 4 | 4 | | do | 0 | Neut | | | 6500 | 8 |
| | | 5 | 4 | | do | 0 | Neut | | | 6500 | 8 |
| 29 | National, double K natural graphite paint. | 1 | 4 | $4.0 \times 10^{8}$ | do | 4 | Pos | 10000 | | | 8 |
| | | 2 | 4 | $3.4 \times 10^{8}$ | do | 4 | Pos | 10000 | | | 8 |
| | | 3 | 4 | $3.4 \times 10^{8}$ | do | 4 | Neg | | 912 | | 8 |
| | | 4 | 4 | $3.4 \times 10^{8}$ | do | 0 | Neut | | | 912 | 8 |
| | | 5 | 4 | $3.4 \times 10^{8}$ | do | 0 | Neut | | | 912 | 8 |

[3] Four holes eaten through cone in 48 hours. Ten specimens in all were required to obtain one which would withstand the first test. All were carefully treated and dried 8 weeks.
[4] Nos. 2 to 5 failed on 80 volts.
[5] Five holes eaten through cone in 48 hours. Ten specimens in all were required to obtain one which would withstand the first test. All were carefully treated and dried 8 weeks.
[6] Resistance very low, about 1,000 ohms.

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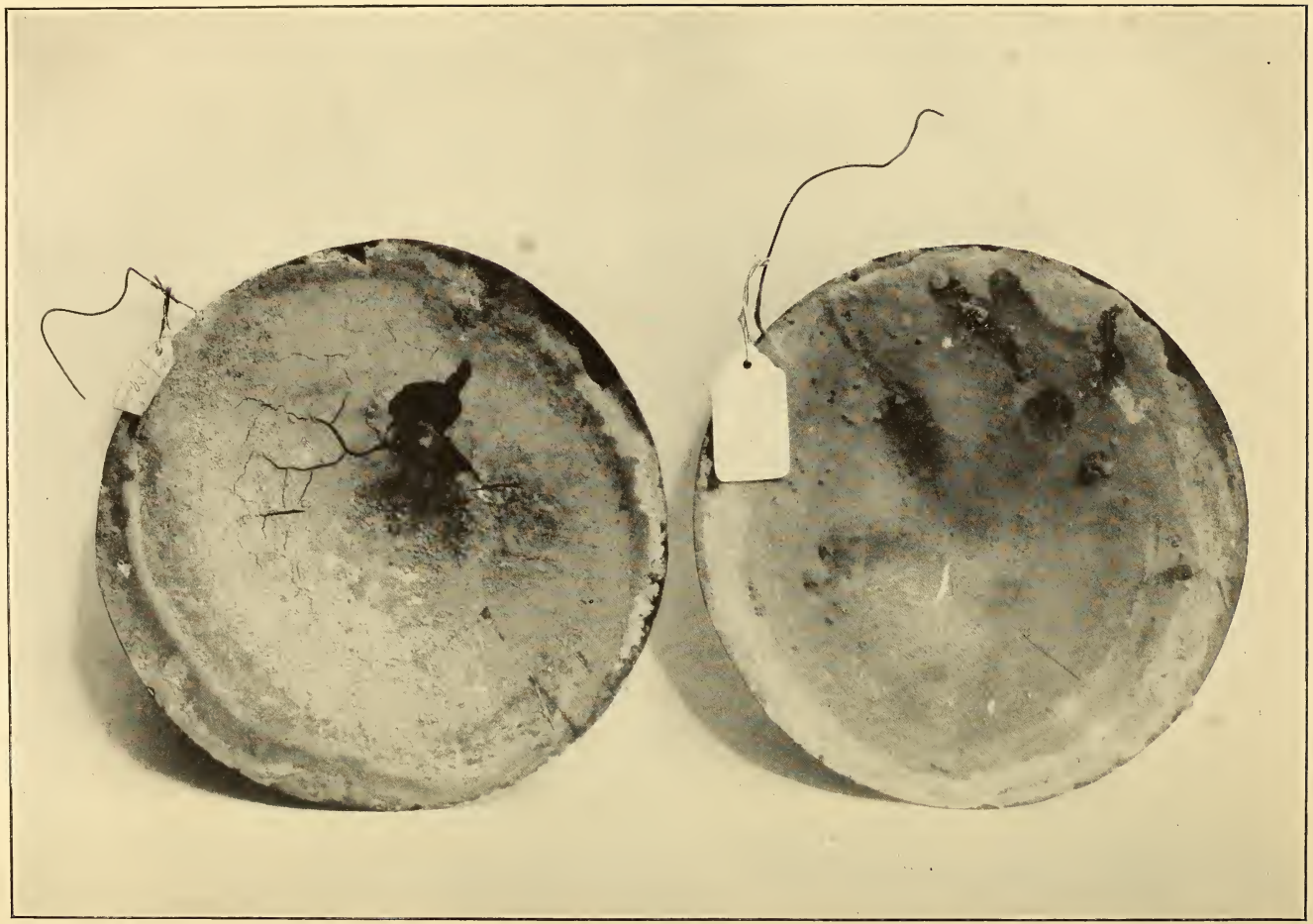
TABLE 1—Continued

Tests of Metal-Preservative Paints as Insulating Coatings—Continued

| Paint No. | Name of paint | Specimen | Coats | Resis., ohms per cm.² | Electrolyte | Voltage of time test | Polarity of cone | Hours to failure | | | Weeks of drying |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Pos. | Neg. | Neut. | |
| 30 | Des Moines, elaterite, No. 40. | 1 | 4 | $2.7 \times 10^8$ | Water | 4 | Pos | 10000 | | | 8 |
| | | 2 | 4 | $2.2 \times 10^8$ | do | 4 | Pos | 10000 | | | 8 |
| | | 3 | 4 | $1.8 \times 10^8$ | do | 4 | Neg | | 120 | | 8 |
| | | 4 | 4 | $6.0 \times 10^7$ | do | 0 | Neut | | | 2440 | 8 |
| | | 5 | 4 | $4.0 \times 10^8$ | do | 0 | Neut | | | 2000 | 8 |
| 31 | Des Moines, elaterite, No. 10. | 1 | 4 | $9.7 \times 10^6$ | do | 4 | Pos | 120 | | | 8 |
| | | 2 | 4 | $2.1 \times 10^7$ | do | 4 | Pos | 3300 | | | 8 |
| | | 3 | 4 | $4.0 \times 10^6$ | do | 4 | Neg | | 120 | | 8 |
| | | 4 | 4 | $1.8 \times 10^7$ | do | 0 | Neut | | | 96 | 8 |
| | | 5 | 4 | $9.7 \times 10^6$ | do | 0 | Neut | | | 96 | 8 |
| 32 | I.D.P., steel paint | 1 | 4 | $4.0 \times 10^6$ | do | 4 | Pos | 120 | | | 8 |
| | | 2 | 4 | $6.5 \times 10^7$ | do | 4 | Pos | 120 | | | 8 |
| | | 3 | 4 | $6.0 \times 10^7$ | do | 4 | Neg | | 120 | | 8 |
| | | 4 | 4 | $5.7 \times 10^7$ | do | 0 | Neut | | | 96 | 8 |
| | | 5 | 4 | $1.0 \times 10^6$ | do | 0 | Neut | | | 96 | 8 |
| | | | | | | | Av.= | 1647 | —2900 | 3112 | |

## 8. DISCUSSION OF RESULTS OF PAINT TESTS

Table 1 gives the condensed data of the tests, indicating the number of coats given each specimen, the resistance in ohms per square centimeter before the test was started, the electrolyte used (which in most cases was water from the city mains), the voltage of the time test, the polarity of the iron of the cone, the hours elapsing before the first appearance of current flow in positive, negative, and neutral specimens, and the weeks of drying in each case. The general appearance of the data under the three columns headed "Hours to failure" which, of course, is the most important, shows that none of these paints is to be depended upon as a preventive of electrolysis in the presence of moisture even though the voltage between pipes and earth be only 4 volts. Here and there individual specimens appear which seem to have withstood the action of the water for a considerable period of time, and in No. 4 only one of the four specimens has failed after a little more than a year. It may be said of No. 4, therefore, that it gives far greater promise of good results in practice than any



CATHODE SPECIMEN ANODE SPECIMEN

Fig. 3.—*Specimens showing manner of failure of anode and cathode specimens*

of the others, although the fact that one of these coatings has already failed indicates that the useful life of the coatings is not to be depended on for any great length of time. The averages of the hours to failure seem to indicate that positive specimens lose their insulating power first, with negative specimens second, and those not subjected to a difference of potential third. That this should be the order does not seem unlikely, but the differences between the averages are too small to be conclusive in this respect. On the contrary, an examination of the data specimen by specimen shows quite clearly that the low electrical stress applied had no apparent effect at all toward reducing the insulating power of the paint. The time of failure evidently depends on the characteristics of the individual specimens and the action of the water.

The manner in which failure of the coatings occurred was distinctive of the direction of current flow. The anode specimens would show rust spots at the places where failure first took place. These rust spots would grow to craters in some cases if the paint coating was brittle and easily broken, or bubbles would form if the coating was elastic. The removal of this crater or bubble would reveal a pit filled with iron rust, the pit sometimes extending through the sheet iron. The cathode specimens failed in an entirely different way. No rusting of the iron occurred under the paint coating but gas was liberated which lifted the paint film until a blister was formed which would sometimes break and leave a large area of the iron exposed. These forms of failure are illustrated in Fig. 3, the specimen on the right being an anode specimen, while the one on the left is a cathode specimen. The specimens having no potential applied showed no deterioration of the coatings which was visible to the eye, except in one or two cases where the paint blistered somewhat as it did when the specimens were made cathode. No. 6 showed this type of failure in the greatest degree.

## V. TESTS OF PIPE WRAPPINGS AND DIPS

### 1. GENERAL FEATURES OF THE TEST

The tests of pipe wrappings were conducted in much the same manner as the tests on the paints. Sheet-iron cones were used, and the interiors of the cones were lined with the material to be tested. The preliminary test to determine whether the coatings were continuous or not was omitted, and also the measurement of the electrical resistances of the coatings. These omissions were made after experimenting with a number of specimens and finding that the electrical resistances were invariably greater than $2 \times 10^{11}$ ohms per square centimeter, while the test for pinholes and flaws showed no defective specimens. This is not extraordinary, in view of the thickness of the coatings (three thirty-seconds to one-fourth of an inch). The two measurements above mentioned were therefore omitted, on the assumption that all specimens of this character would probably respond to these two tests in a similar manner. The specimens with no potential applied were also omitted, because there seemed to be no reason to believe that the low electrical stress used in testing these wrappings (15 volts) would act on them in a different manner from that shown in the results of the paint tests, where it is seen that the electrical stress had very little apparent effect in hastening the initial breakdown of the coatings.

Four specimens constituted a set. A number of sets were made up with each material, however, the object of the several sets being to test different thicknesses of the coating. Several of the compounds were intended for both wrappings and dips, and a number of cones were dipped in order to determine whether it is practicable to coat a pipe effectively in this way.

### 2. PREPARATION OF SPECIMENS

The materials tested included asphalts, pitches, and a few paints which were especially recommended for pipe-wrapping purposes. These were used in various combinations with felts, cloths, and papers. In preparing the various materials for lining the cones a circular piece of the fabric used was first cut out and slit from center to circumference, after which the edges of the slit

were lapped until the circular piece of fabric assumed a conical shape corresponding to the shape of the cone in which it was to fit. If the compound to be tested was an asphalt or a pitch, the interior of the cone was then swabbed with the hot compound and the conical piece of fabric pressed into it. This was immediately followed by another swabbing with the compound and another layer of fabric, and so on until the desired number of layers had been placed. The last layer of fabric was always thoroughly swabbed with the compound and formed as nearly a perfect union with it as could be expected.

In preparing specimens in which paints were used, the interior of the cone was first painted and allowed to dry thoroughly. This was followed by another light coat of paint and a layer of fabric (muslin), into which a coat of paint had been well brushed. When this had dried the performance was repeated until the desired number of layers had been placed. This process was rather tedious, because paints in general do not dry readily when applied in this way.

In preparing dipped specimens the cones were immersed in the melted compound and manipulated until all air bubbles beneath the coating and been eliminated. The specimens were then removed and allowed to cool, after which they were dipped again rather quickly, in order to give a thicker coat. The first coat was very thin, because the iron and bath were at the same temperature and there was a great tendency for the compound to run off when the specimen was removed. The thicknesses of the coatings when finished were from one thirty-second to one-sixteenth of an inch.

In melting the compounds enough heat was applied to render the material quite liquid, but overheating and burning was carefully avoided.

### 3. FINAL TEST OF PIPE WRAPPINGS

In this test the cones were filled with water from the city mains and placed in a rack in a manner similar to that described in connection with the paint tests. Two of the four specimens in each set were connected up electrically with the sheet iron of the cone positive and the other two with the iron negative. In the case of the cones lined with compound and fabric a voltage of 15 volts

was impressed continuously. The dipped specimens had 4 volts impressed upon them. The higher voltage was used in the case of the wrappings because such coatings would be expected to withstand rather severe electrolysis conditions, and in fact their use would as a rule be justified only where electrolysis conditions were unusually bad.

The water was allowed to evaporate from the cones after which they were refilled. This was followed on occasions by the taking of current readings. The current readings were taken as often as seemed necessary. At first the readings were taken on alternate days, but this period of time was gradually extended to two months, because of later developments which showed that the life of the wrappings was such as to make more frequent readings unnecessary.

The first appearance of current flow was taken as an indication that the insulating power of the coatings had ended. Specimens were usually left in circuit until there was abundant evidence of failure, or at least until the current became 2 or 3 milliamperes.

### 4. DISCUSSION OF RESULTS

Table 2 gives the condensed data of the tests, showing the number of layers or dippings in each case, the polarity of the iron, and the hours to the first appearance of current flow. From this data it is seen that 82 per cent of the total number of specimens under test have failed to date. Sets Nos. 25, 26, and 33, seem to remain intact, but they were of the last ones put in circuit, so their behavior is not yet definitely determined. Set No. 27, however, which is of the same material as 25 and 26, shows two individual specimens to have failed. These are of one layer of compound and burlap and it seems reasonable to say that they forecast the future behavior of the others of the same material. There is no indication at present as to the ultimate effect on set No. 33. The results taken as a whole do not indicate that the life, as an insulator, of a coating of this character can be expected to be more than two or three years even when put in place on the pipes and buried in perfect condition, and in most cases failure may be expected within a few months. The attempt to dip specimens is seen to have yielded very poor results, and it is questionable whether coating pipes in this way is any better than painting them, so far as protection against electrolysis is concerned.

## TABLE 2

### Tests of Pipe Wrappings, Dips, Etc., as Insulating Coatings

[Water served as electrolyte in all cases. Voltage=15 except in 1-1 and 4-1 where V=4, and also 206 to 225.]

| Coating | Material | Layers or dippings | Specimen | Polarity of cone | Hours to failure | |
|---|---|---|---|---|---|---|
| | | | | | Positive | Negative |
| 1 | Neponset water-dyke felt and compound | 3 layers | 1 | Positive | 9200 | |
| | | | 2 | do | 5040 | |
| | | | 3 | do | 6000 | |
| | | | 4 | Negative | | 2160 |
| | | | 5 | do | | 9200 |
| 2 | do | 2 layers | 9 | Positive | 7600 | |
| | | | 10 | do | 4200 | |
| | | | 11 | Negative | | 3600 |
| | | | 12 | do | | 10000 |
| 3 | do | 1 layer | 17 | Positive | 10000 | |
| | | | 18 | do | 10000 | |
| | | | 19 | Negative | | 3100 |
| | | | 20 | do | | 4200 |
| 4 | Hydrex felt and compound | 3 layers | 25 | Positive | 16000 | |
| | | | 26 | do | 14700 | |
| | | | 27 | do | [7] 14000 | |
| | | | 28 | Negative | | 3200 |
| | | | 29 | do | | 5000 |
| 5 | do | 2 layers | 33 | do | | 2000 |
| | | | 34 | do | | 2900 |
| | | | 35 | Positive | 10000 | |
| | | | 36 | do | 10000 | |
| 6 | do | 1 layer | 41 | Negative | | 3040 |
| | | | 42 | do | | 2000 |
| | | | 43 | Positive | 10000 | |
| | | | 44 | do | 3800 | |
| 7 | Pitch and burlap | 3 layers | 49 | do | 14700 | |
| | | | 50 | Negative | | 4300 |
| 8 | do | 2 layers | 51 | Positive | 5700 | |
| | | | 52 | Negative | | 5000 |
| 9 | Barrett specification pitch and tar paper | 3 layers | 57 | Positive | 3500 | |
| | | | 58 | do | 4800 | |
| | | | 59 | Negative | | 3900 |
| | | | 60 | do | | 2100 |
| 10 | do | 2 layers | 65 | Positive | 2100 | |
| | | | 66 | do | 2100 | |
| | | | 67 | Negative | | 720 |
| | | | 68 | do | | 720 |
| 11 | do | 1 layer | 73 | Positive | 3400 | |
| | | | 74 | do | 3400 | |
| | | | 75 | Negative | | 552 |
| | | | 76 | do | | 48 |

[7] No breakdown after the given number of hours.

TABLE 2—Continued

Tests of Pipe Wrappings, Dips, Etc., as Insulating Coatings—Continued

| Coating | Material | Layers or dippings | Specimen | Polarity of cone | Hours to failure | |
|---|---|---|---|---|---|---|
| | | | | | Positive | Negative |
| 12 | Barrett pitch (sample 1) and muslin | 3 layers | 81 | Positive | 12500 | |
| | | | 82 | do | 3400 | |
| | | | 83 | Negative | | 3900 |
| | | | 84 | do | | 3900 |
| 13 | Barrett pitch (sample 2) and muslin | do | 89 | Positive | 12500 | |
| | | | 90 | do | 12500 | |
| | | | 91 | Negative | | 5500 |
| | | | 92 | do | | 3400 |
| 14 | Barrett pitch (sample 3) and muslin | do | 97 | Positive | 4400 | |
| | | | 98 | do | 4400 | |
| | | | 99 | Negative | | 1400 |
| | | | 100 | do | | 3000 |
| 15 | Barrett pitch (sample 4) and muslin | do | 105 | Positive | 12000 | |
| | | | 106 | do | [7] 12000 | |
| | | | 107 | Negative | | [7] 12000 |
| | | | 108 | do | | 12000 |
| 16 | Sarco-mineral rubber-pipe dip and muslin | 4 layers | 113 | do | | 2100 |
| | | | 114 | do | | 2100 |
| | | | 115 | Positive | 10000 | |
| | | | 116 | do | 10000 | |
| 17 | do | 3 layers | 121 | Negative | | 1400 |
| | | | 122 | do | | 336 |
| | | | 123 | Positive | 10000 | |
| | | | 124 | do | 2100 | |
| 18 | do | 2 layers | 129 | Negative | | 1200 |
| | | | 130 | do | | 300 |
| | | | 131 | Positive | 300 | |
| | | | 132 | do | 2900 | |
| 19 | do | 1 layer | 137 | Negative | | 2100 |
| | | | 138 | do | | 300 |
| | | | 139 | Positive | 300 | |
| | | | 140 | do | 2100 | |
| 20 | Mogul repairing compound and muslin | 2 layers | 145 | do | 1600 | |
| | | | 146 | do | 1600 | |
| | | | 147 | Negative | | 1600 |
| | | | 148 | do | | 1000 |
| 21 | do | 1 layer | 154 | Positive | 768 | |
| | | | 155 | do | 1600 | |
| | | | 156 | Negative | | 1600 |
| | | | 157 | do | | 1000 |
| 22 | S. P. Co. cold cementing compound and treated burlap | 3 layers | 162 | Positive | 7200 | |
| | | | 163 | do | [7] 7200 | |
| | | | 164 | Negative | | 7200 |
| | | | 165 | do | | 7200 |

[7] No breakdown after the given number of hours.

TABLE 2—Continued

Tests of Pipe Wrappings, Dips, Etc., as Insulating Coatings—Continued

| Coating | Material | Layers or dippings | Specimen | Polarity of cone | Hours to failure | |
|---|---|---|---|---|---|---|
| | | | | | Positive | Negative |
| 23 | S. P. Co. cold cementing compound and treated burlap | 2 layers | 170 | Positive | [7] 7200 | |
| | | | 171 | do | 7200 | |
| | | | 172 | Negative | | 480 |
| | | | 173 | do | | 7200 |
| 24 | do | 1 layer | 178 | Positive | [7] 7200 | |
| | | | 179 | do | [7] 7200 | |
| | | | 180 | Negative | | 7200 |
| | | | 181 | do | | [7] 7200 |
| 25 | S. P. Co. cementing compound (grade A) and treated burlap | 3 layers | 186 | Positive | [7] 7200 | |
| | | | 187 | do | [7] 7200 | |
| | | | 188 | Negative | | [7] 7200 |
| | | | 189 | do | | [7] 7200 |
| 26 | do | 2 layers | 194 | Positive | [7] 7200 | |
| | | | 195 | do | [7] 7200 | |
| | | | 196 | Negative | | [7] 7200 |
| | | | 197 | do | | [7] 7200 |
| 27 | do | 1 layer | 202 | Positive | [7] 7200 | |
| | | | 203 | do | 7200 | |
| | | | 204 | Negative | | [7] 7200 |
| | | | 205 | do | | 7200 |
| 28 | Sarco-mineral rubber-pipe dip | 2 dippings | 206 | Positive | 24 | |
| | | | 207 | do | 5 | |
| | | | 208 | do | 96 | |
| | | | 209 | do | 9000 | |
| 29 | Barrett pitch (sample 1) | do | 210 | do | 0 | |
| | | | 211 | do | 0 | |
| | | | 212 | Negative | | 360 |
| | | | 213 | do | | 0 |
| 30 | Barrett pitch (sample 2) | do | 214 | Positive | 336 | |
| | | | 215 | do | 0 | |
| | | | 216 | Negative | | 0 |
| | | | 217 | do | | 1056 |
| 31 | Barrett pitch (sample 3) | do | 218 | Positive | 672 | |
| | | | 219 | do | 4400 | |
| | | | 220 | Negative | | 1680 |
| | | | 221 | do | | 4400 |
| 32 | Barrett pitch (sample 4) | do | 222 | Positive | 0 | |
| | | | 223 | do | 6000 | |
| | | | 224 | Negative | | 672 |
| | | | 225 | do | | 336 |
| 33 | Minwax and cloth | 2 layers | 226 | Positive | [7] 3192 | |
| | | | 227 | do | [7] 3192 | |
| | | | 228 | Negative | | [7] 3192 |
| | | | 229 | do | | [7] 3192 |

[7] No breakdown after the given number of hours.

The manner of failure of the coatings was similar to that of the paint coatings, i. e., craters of rust formed at points in anode specimens if they were allowed to run long enough, while cathode specimens showed large blisters. The failure of these coatings was, however, much slower than the paint coatings after the first appearance of current flow. This is probably due to the thickness and rigidity of the coatings.

## VI. TESTS OF WRAPPED PIPES BURIED IN EARTH

In view of the fact that the laboratory tests might be open to criticism on account of the continual presence of moisture in contact with the coatings, whereas if the specimens were buried in earth they might be partially dry at times and their useful life thus be greatly increased, it was deemed advisable to conduct a few tests under conditions such as would be met with in actual practice. To this end a number of specimens of wrapped pipe were obtained and a test carried out, as described below.

### 1. GENERAL DESCRIPTION OF SPECIMENS

In this test 26 specimens of wrapped pipe were used, 24 of which were furnished by commercial firms. Twelve of these 24 specimens were of 4-inch wrought-iron pipe, 5 feet in length, which had been wrapped with two alternate layers of pitch and burlap. The other 12 were of 1½-inch wrought-iron pipe, 5 feet in length, which had been covered with 4 alternate layers of tar and paper. This paper was not impregnated with tar before being applied, but consisted of what appeared to be rather heavy wrapping paper wound on spirally over a coat of tar while the tar was still hot, the tar containing 3 or 4 per cent lime. The finished coating in this case was about one-eighth of an inch in thickness. This coating is of the type known as the Nichols coating and has been used to a considerable extent in actual service. The pipes described above were covered and supplied to the Bureau by a large gas company that has been using this type of coating for several years. The burlap and pitch coating was a little thicker than the pitch and paper coating, or about three-sixteenths of an inch. In preparing the specimens for burying in the earth,

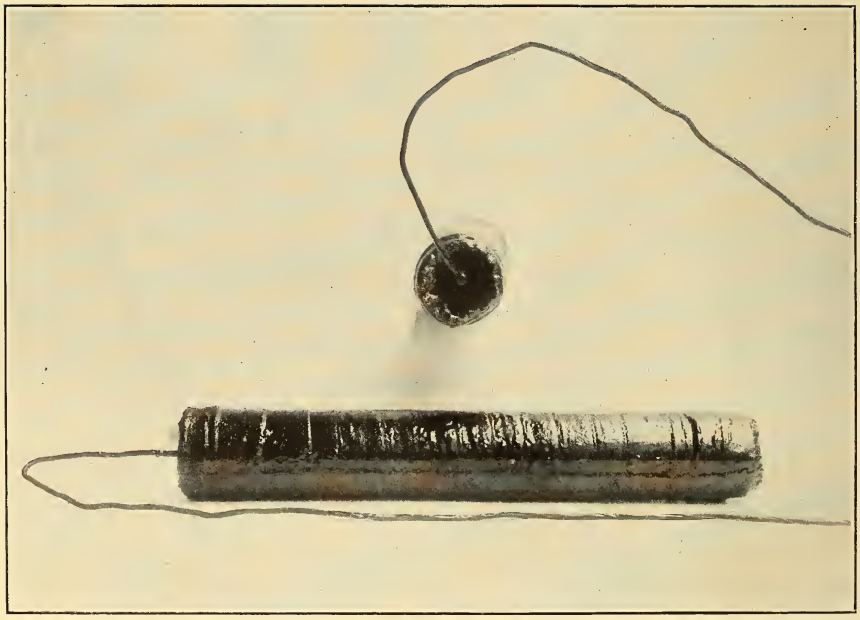


Fig. 4.—*Specimens of pipe with muslin and paint covering*

leads of rubber-covered copper wire were first soldered to the inside of the pipes and the ends of the pipes closed with wooden plugs, the wire leads being drawn out through small holes made in the plugs. The ends of the pipes were then capped with several thicknesses of tarred paper and pitch, this cap extending about 4 inches over the end of the pipe. The ends of the pipe were thus thoroughly reenforced against dampness by a cap which made a good union with the wrapping itself. This made it certain that the wrapping would show current leakage first, as the thickness of the cap was several times that of the wrapping.

The two remaining specimens of wrapped pipe spoken of above were made up with muslin and the paint given under numbers 21 and 22 in Table 2. These specimens were very carefully prepared in the laboratory, the coating being placed on pieces of clean iron pipe 1½ inches in diameter and 18 inches long after having plugged their ends and arranged the leads as described in the preceding paragraph. The coating was applied as follows: Two coats of paint were brushed on 3 days apart and allowed to dry. A third coat was then put on. Whenth is third coat had become tacky, a strip of muslin which had been painted and allowed to dry was wound on spirally over the tacky coat so as to make two layers, the muslin being painted a second coat as it was wound on. This was given 10 days in which to dry, at the end of which time the specimens were given two more coats of paint about three days apart, as was done in the case of the first two coats. The specimens were then allowed to dry for another month before placing them in the ground. Fig. 4 shows the appearance of the finished specimens.

## 2. DESCRIPTION OF TEST

The specimens were buried in earth and connected up to the positive side of a 15-volt direct-current circuit in such a way that the pipes were about 4.5 volts positive to the surrounding earth. Current readings were taken at intervals of about one month. The ground was quite wet during the spring and fairly moist during the rest of the year. The temperature ranged from about 0° C in winter to 17° or 18° in summer.

### 3. DISCUSSION OF RESULTS

Table 3 gives the results of the tests. As before, the data in the column headed "Time to failure" indicates the time to the first appearance of current flow.

TABLE 3

Tests of Wrapped Pipes Buried in Earth

| Specimen | Wrapping used | Time to failure | Total time of test | Current in milliamps. at end of test |
|---|---|---|---|---|
| | | Days | Months | |
| 1 | Pitch and burlap | 10 | 18 | 10.0 |
| 2 | do | 7 | 18 | 12.0 |
| 3 | do | 7 | 18 | 13.0 |
| 4 | do | 10 | 18 | 8.0 |
| 5 | do | 10 | 18 | 9.0 |
| 6 | do | 10 | 18 | 8.0 |
| 7 | do | 13 | 18 | 9.0 |
| 8 | do | 13 | 18 | 8.0 |
| 9 | do | 13 | 18 | 8.0 |
| 10 | do | 56 | 18 | 4.0 |
| 11 | do | 56 | 18 | 5.0 |
| 12 | do | 56 | 18 | 5.0 |
| 13 | Tar and paper | 29 | 10 | 2.0 |
| 14 | do | 29 | 10 | 2.0 |
| 15 | do | 29 | 10 | 1.5 |
| 16 | do | 29 | 10 | 1.5 |
| 17 | do | 29 | 10 | 2.0 |
| 18 | do | 29 | 10 | 2.0 |
| 19 | do | 29 | 10 | 1.5 |
| 20 | do | 75 | 10 | 1.5 |
| 21 | do | 2 | 10 | 1.5 |
| 22 | do | 29 | 10 | 4.0 |
| 23 | do | 29 | 10 | 2.0 |
| 24 | do | 29 | 10 | 2.0 |
| 25 | Paint and muslin | 63 | 13 | 1.4 |
| 26 | do | 63 | 13 | 1.0 |

The total time of the test and the current at the time the specimens were dug up are also given.

When the pipes were removed from the earth and the wrapping stripped off they were found to be covered with rust spots, and here and there were pits of considerable depth. An illustration of these pits is given in Fig. 5. The pipes longest in the ground

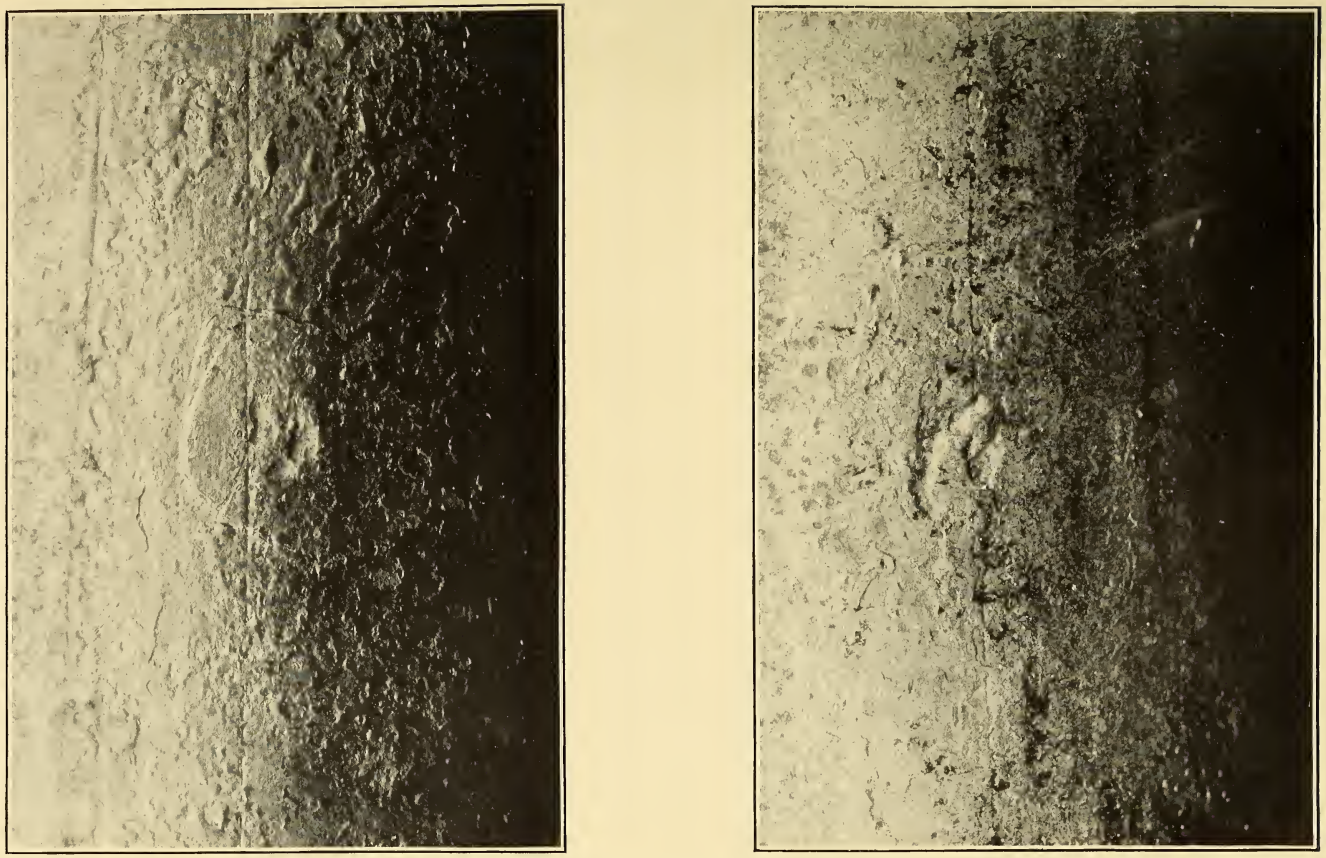


Fig. 5.—*Pits in surface of wrapped pipe after removal from the ground*

were buried about one and one-half years, and in that time pits were formed extending almost through the iron. The currents were not large, but the high-current density resulting from local failure of the coating resulted in very rapid corrosion of the iron wherever breakdown occurred. The longest period during which any specimen of the lot remained insulated is seen to be 75 days, which is very insignificant, indeed, compared with the total life of a pipe under normal conditions.

## VII. CAUSE OF THE FAILURE OF THE COATINGS

A careful study of the conditions under which the failure of insulating coatings under electric stress takes place shows that it is due to the combined action of the moisture and electric stress. Repeated experiments have shown that if any paints or membranes herein referred to are carefully weighed when dry and then immersed in water they will markedly increase in weight, showing that they all absorb moisture in greater or less degree. This is also borne out by the electrolytic measurements already described in this paper. The failure of the coating has been found to be invariably preceded by a slight flow of electric current, which in itself is proof that a slight amount of moisture has penetrated through the coat to the surface of the coated metal.

The actual rupture of the coating is due to the fact that when the water once penetrates through to the surface of the metal a slight flow of electric current first takes place, and this results in a small amount of electrolysis, which invariably produces more or less gas. This gas being confined soon develops sufficient pressure to rupture the coating, giving rise to the peculiar appearances illustrated in Fig. 3. While in the experiments above described the failure of the coating has usually taken place only locally, this is undoubtedly due to the fact that the experiments were distinued as soon as rapid pitting of the covered pipes had taken place. If the coatings were to be left in service, as they would be in any practical case, moisture would undoubtedly continue to penetrate the coating at many points, which would in time give rise to a continued increase in the number and size of the blisters, so that ultimately the coating would be entirely destroyed.

The time required for such destruction would, of course, depend upon the thickness of the coating. But coatings of the thickness commonly used for covering service pipes and similar structures can hardly be expected to last more than a few years. At most, under ordinarily severe electrolysis conditions a majority of the paints and coatings which we have tested would undoubtedly fail within a short time, their useful life probably not exceeding a year in the majority of cases.

There remain two other classes of surface insulations which we have not discussed in this paper, for the reason that the experimental work in regard to them has not yet progressed far enough to justify us in making definite statements as to their value. These are the methods already referred to in the introduction of this paper, viz, inclosing the pipes within some sort of fiber conduit either with or without pitch filler, or covering the pipe with some sort of insulating enamel similar to those used in the manufacture of numerous kinds of enameled ironware that are now on the market for a great variety of purposes.

Experiments relating to the effectiveness and value of both of these methods of protection of pipe are now in progress and will be reported on as soon as conclusive results have been obtained.

## VIII. CONCLUSIONS

Summing up the results of the foregoing experiments it is evident that they indicate that such pipe paints, dips, and wrappings as have been brought to our attention are, with practically no exception, of no value whatever for protecting pipes from electrolysis when applied in the positive areas near the power houses. If, however, they are applied in negative areas they may be of considerable temporary value in reducing the current picked up by the pipe, and in that way indirectly they may reduce damage in positive areas.

We wish to emphasize the fact that the results of these tests are not to be considered as throwing light on the value of these coatings for protecting various metals from natural soil corrosion, as the tests were designed solely for the purpose of testing their value as a means for protecting against electrolysis from stray currents, where the forces tending to corrode the pipes

are of much greater magnitude than those producing galvanic action, which is largely responsible for slow corrosion of iron in soil. Whatever use may be made of such coatings in the negative areas for reducing the amount of current flow in the pipes it should always be looked upon as a secondary means of mitigation only and not depended upon as a chief means of protecting pipes.

In any case, where electrolytic action becomes serious, the first and most important step to be taken is to provide a proper negative return for the stray railway currents so that the potential drop in the rail will be reduced to so low a value that there will be no serious tendency for stray currents to pass in transit from the tracks on to the pipes. When adequate measures are taken in this direction it will, as a rule, not be necessary to go to great expense in providing exterior protection on the pipe systems themselves; were such protection necessary, we think that there are other and much more effective means available than surface insulation. It is not within the scope of the present paper, however, to discuss such methods, as they are discussed in considerable detail in Technologic Paper No. 27, by the Bureau of Standards, dealing with the general subject of electrolysis mitigation,

WASHINGTON, January 5, 1914.

# APPENDIX

## EXPERIENCE AND OPINIONS OF PIPE OWNING COMPANIES WITH REGARD TO THE PREVENTION OF ELECTROLYSIS AND SOIL CORROSION BY MEANS OF INSULATING COATINGS.

With a view to obtaining information as to the experiences of a large number of pipe-owning companies with insulating coatings for underground pipes 28 letters, each containing a list of questions, were addressed to as many companies in cities of importance throughout the United States. Replies were received from 19 of these companies. The list of questions was as follows:

(1) What kind of coatings have you used and what was the manner of their application?

(2) In what kind of soil was the pipe laid after coating?

(3) Was the coated pipe subjected to soil corrosion only, or to both soil and electrolytic corrosion?

(4) For what length of time did these coatings appear to successfully prevent corrosion?

(5) What was the character of the damage to the pipe and coating where damage occurred?

(6) What is your opinion of such coatings, in general, as preventives of either soil corrosion or electrolytic corrosion?

Table 4 shows the results of this correspondence in a brief manner. It is there seen that nine of the correspondents reported actual experience with insulating coatings used for the purpose of preventing damage to pipes by electrolysis. The substance of their replies is quoted verbatim below, the numbers showing answers corresponding to the questions given above.

TABLE 4

| Company from which letter was received | Coating used | Corrosion to which pipe was subjected | Soil in which pipe was laid | Nature of damage to pipe and coating |
|---|---|---|---|---|
| Water department, Atlantic City, N. J. | Pioneer mineral rubber as dip with burlap wrapping. | Principally soil corrosion, but tests showed some electrolytic action. | Sand soil and salt marsh | Blisters in coating and pits in pipe in marsh; slight damage in sandy soil. |
| Kingston Gas & Electric Co., Kingston, N. Y. | Coal-tar pitch as dip. Box filled with pitch around pipe for prevention of electrolytic corrosion. | Soil corrosion and electrolytic corrosion. | Variety of soils ranging from clay to clean sand. | Pitting of pipes with light coating. No trouble after 5 years with boxed pipes. |
| New York State Railways, Syracuse, N. Y. | Asphalt paint and tape much the same as friction tape. | Electrolytic corrosion | Dry soil, with gravel and some clay. | No trouble after 5 years of service. |
| Metropolitan water and sewerage board, Boston, Mass. | Burlap saturated with hot asphalt. Slaked lime and Portland cement mortar. | do | Made ground, ashes, gravel, etc., laid over marsh mud. | Burlap and asphalt did not stop pitting. No report of lime and mortar coating. |
| Philadelphia Suburban Gas & Electric Co., Chester, Pa. | Hickenlooper coating; pipe dipped and wrapped with muslin; 2 layers.[8] | do | Dry yellow clay | Pits and complete destruction of the coating in spots. |
| Water department, Springfield, Mass. | Tar and tar paper, 1 to 8 thicknesses. Coal-tar dip. | Electrolytic corrosion and soil corrosion. | Gravelly soil and also heavy soil in lowlands. | No damage of any kind after 3 years. |
| Elizabethtown Gas Light Co., Elizabeth, N. J. | Hickenlooper coating with a wrapping of muslin.[8] | Soil corrosion | Red clay, red sand, and a mixture of both. | No damage after 7 years. |
| Roaring Creek Water & Light Co., Shamokin, Pa. | Pipes dipped in coal-tar pitch | do | Coal dirt, coal ashes, clay, red shale, etc. | No damage after 20 years. |
| Counties Gas & Electric Co., Norristown, Pa. | Pipes dipped in coal tar mixed with a small percentage of lime or cement. | Soil corrosion in most instances; in some instances to soil and electrolytic corrosion. | Red clay, red shale, and gray sand. | Complete destruction of the pipes after 3 to 7 years. |
| Humphreys & Miller, 165 Broadway, New York, N. Y. | Hickenlooper coating; also others[8]. | Soil corrosion in some cases; some cases both soil and electrolytic corrosion. | No data as to kind of soil | No damage by soil corrosion. |
| Mohawk Gas Co., Schenectady, N. Y. | Pipes painted with Hickenlooper's coating.[8] | Soil corrosion | Sand and clay soil | Very little damage after 20 years. |
| The Chuctunda Gas Light Co., Amsterdam, N. Y. | Coal-tar pitch, coal tar over a coating of graphite paint, pitch painted on hot. | Soil and electrolytic corrosion | Blasted rock, gravel, sand, hardpan, and loam. | No damage after 10 years. |

[8] The Hickenlooper coating is described in letter E, from the Philadelphia Gas & Electric Co.

TABLE 4—Continued

| Company from which letter was received | Coating used | Corrosion to which pipe was subjected | Soil in which pipe was laid | Nature of damage to pipe and coating |
|---|---|---|---|---|
| Board of water commissioners, Binghamton, N. Y. | Pipes dipped in hot asphaltum | Soil corrosion | Clay, gravel, etc | Pipes rusted out in about 10 years, even when kept out of contact with coal cinders. |
| The Peoples Gas Light & Coke Co., Chicago, Ill. | Cremo and coal tar | Soil and electrolytic | Gravel, sand, blue and yellow clay loam, cinders, and refuse. | Deep localized pittings. |
| Newburgh City Water Works, Newburgh, N. Y. | Tar coating—dipped | Soil corrosion | All kinds | No serious trouble. |
| The City of New York department of water supply, gas, and electricity, New York, N. Y. | Coal tar, mineral-rubber asphalt coating. | Soil and electrolytic | Cast iron in soil of all kinds, wet and dry; steel pipe in sand soil. | Corrosion of cast-iron pipe in form of tubercles with small pits beneath. Very little damage to steel pipe. |
| Transit Development Co., Brooklyn, N. Y. | No experience with insulating coatings. | | | |
| New Rochelle Water Co., New Rochelle, N. Y. | do | | | |
| The Davenport Water Co., Davenport, Iowa. | Coatings as specified by New England Waterworks Association (tar coating). | Soil corrosion | Kind of soil not mentioned | No damage to cast-iron pipe, even after 40 years. |

### A. METROPOLITAN WATER AND SEWERAGE BOARD, BOSTON, MASS.

Wm. E. Foss

(1): "Burlap saturated with hot asphalt; and slaked lime and Portland cement mortar. Both of these coverings were applied after the pipes were laid.

[The burlap and asphalt covering was applied to a forty-eight inch water main at points where it was thought that considerable damage by electrolysis was being done. One section 26 feet long, another 77 feet long and another 39 feet long were treated in the following manner: The pipes were first thoroughly cleaned with scrapers and wire brushes. A coat of asphalt paint was then applied and over this a layer of Warren's "Kiola rock asphalt wire composition" was applied hot. A sheet of burlap was then wrapped around the pipe, and over this another layer of the hot asphalt was put on. The insulation was applied in short sections, which overlapped about 6 inches at the junction lines, and when completed was from ¼ inch to ½ inch in thickness. As the trench was refilled, three lines of old tram rails were laid in the trench parallel with the axes of the pipes, and about 6 inches from the bells at the nearest point. These rails were connected to the pipe line by means of "0000" copper bonds soldered to the pipe bells near the ends of each insulated section. The rails were also connected at the ends with similar copper bonds. Where the pipe line was located under the car tracks, the rails were placed in a horizontal plane directly over the pipes, and opposite the power station where there are no tracks in the street they were placed in a vertical plane. Arrangements have been made so that the amount of electricity flowing off from the rails can be measured, and also the amount flowing on the pipes. All of the pipes insulated show the effects of the electrolytic action, and some of them have been very badly damaged. On one pipe there were about 80 pittings, varying in size from circles ¼ of an inch to 1½ inches in width, and from $\frac{1}{16}$ of an inch to $\frac{9}{16}$ of an inch in depth. Extract from second annual report of metropolitan water and sewerage board, Jan. 1, 1903.]

"The lime and cement covering was first used last fall (1912). A ½ inch coat of slaked lime was applied to the outside of the pipe and over this a 1½ inch protective coating of mortar, composed of equal parts of Portland cement and sand, was applied.

(2): "The soil in which the 48-inch pipes covered with burlap and asphalt were laid was partially made ground containing miscellaneous materials, including some ashes and clayey gravel, which had been filled over the original marsh mud. The ground water usually stood 3 or 4 feet below the surface of the ground. The 24-inch pipes covered with lime and cement mortar were laid in a brick lined tunnel 6 feet in diameter, located under an arm of Boston Harbor. The coated pipes are surrounded by salt water which leaks into and fills the tunnel.

(3): "The pipes covered with burlap and asphalt were probably subjected to electrolytic corrosion only, as they were laid near a large power station where the street railway return current flowed through the soil at all times. The pipes covered with lime and mortar have been insulated from the remainder of the pipe system by a wooden joint at each end of the tunnel, in order to prevent electrolytic corrosion as far as possible.

(4) and (5): "The condition of the pipes coated with lime and cement mortar has not been determined since the recent application of the coating.

[On April 6, 1904, the burlap and asphalt covering which was applied in November, 1902, was removed from one length of 48-inch pipe for the purpose of examination. Before the covering was applied the pipe was carefully cleaned and the pits dug out and located. Upon removing the covering many new pits were found, and in some cases one large pit was found where there were two or three separate pits before the covering was put on. The number of pits in the pipe had increased from 80 in 1902 to 496 in 1904.

The railway engineers suggested that possibly the pits were not all dug out before the pipe was covered, and therefore re-covered it for a further test. They have since made the following experimental tests, which indicate that the covering has little if any value under some circumstances.

A short piece of 4-inch pipe, covered in the same manner as the large pipe, was buried in dry earth in a box, and a cast iron plate was buried 1.25 feet from the pipe. In one test tar was used in the covering, and in another asphaltum. The pipe and plate were connected in the regular trolley circuit of 500 volts. While the earth was dry the resistance between the pipe and plate with the tar covering was 700 megohms, and with the asphaltum covering 34 megohms. The earth was then saturated with salt water, and the resistance quickly diminished, and after seven to ten days disappeared. Extract from report of metropolitan water and sewerage board, Jan. 1, 1905.]

(6): "Our experience would indicate that it is not practicable to successfully apply and maintain protective coatings to underground pipes in general. Whether or not the lime and mortar covering will be successful under the special conditions where it has been applied on our work has not yet been determined."

The conditions of the tests of the covering used on the 48-inch pipe seem to be fair enough, but the voltage used in the tests on the 4-inch pipe is abnormally high. It is unsafe to draw conclusions from the results of such forced tests. The coatings were presumably put on with considerable care, but inasmuch as the coating of the 48-inch pipe was probably put on while the pipe was full of water, it would be very difficult to obtain a continuous coating of the asphalt. That is, the rapid cooling would tend to leave the coating full of pinholes instead of allowing the asphalt to run together after it had been brushed on and thus form an impervious layer.

### B. NEW YORK STATE RAILWAYS, SYRACUSE, N. Y.

A. N. Brown

(1): "The pipe in question was a 6-inch gas main, cast iron, leaded joints, and at this particular intersection had been giving considerable trouble; in fact every two years this pipe would fail. In 1908 it became necessary to make a renewal of some 100 feet of pipe, and before putting it in the ground each length was given a

good thick coating of asphalt paint and then served with an insulating tape about 6 inches in width and in make-up very much like the ordinary friction tape. Another coat of asphalt paint was then applied and this was allowed to set before being installed in the ground. The joints were made up and a similar application was then made around each joint as on the pipe itself.

(2): "The soil was not damp and contained considerable gravel and some clay.

(3): "The pipe at this location was subject to electrolytic corrosion only, there being nothing about the soil which would lead one to believe that soil corrosion was taking place.

(4): "The pipe, coated as outlined above, has been in service five years and has given no trouble.

(5): "There has been no damage observed on either pipe or coating.

(6): "To prevent electrolytic action on pipes by such a method and make it applicable to a whole system is out of the question on account of the excessive expense. The approximate cost to cover this 100 feet of pipe, including labor and material was 30 cents per foot."

The principal objection to be brought against the coating described above at present is its first cost, as stated under (6). Five years is also too short a time to judge of its ultimate behavior under the conditions of the test, because the soil in which the pipe was laid is described as being not damp, which would have a tendency to lengthen the life of the coating over what it would be in a damp soil. In view of the excessive cost of covering the pipe in this way it seems that the life of the pipe ought to be at least doubled over that under ordinary conditions where not subjected to electrolysis, because there are a number of comparatively inexpensive ways in which the damage by electrolysis could be prevented, or at least very much reduced.

C. KINGSTON GAS & ELECTRIC CO., 611 BROADWAY, KINGSTON, N. Y.

F. TOBEY, Jr.

(1): "The coating used was coal tar pitch. For ordinary purposes the tar is applied by dipping the hot pipes into a trough containing the melted tar. On larger pipes it is applied with brushes to the steam heated pipe.

(2): "These pipes are laid in a variety of soils, ranging from clay to clean sand.

(3): "When coated as above, the pipe was not intentionally subjected to electrolysis. Where electrolysis is suspected the pipe is encased by a wooden box, and the box is filled with hard

pitch, which forms a coating at least one inch in thickness at the thinnest part.

(4): "We have had some experience of electrolysis on the light coated pipes, sometimes within two years. Those with the box covering have not been affected after an exposure of five years, so far as we can learn.

(5): "The damage generally took the form of deep pitting, often involving the whole thickness of the pipes, and causing leakage. In appearance these pits could not be distinguished from rust spots.

(6): "We would say that the first mentioned coating has considerable value in preventing ordinary corrosion, but very little if any value in the prevention of electrolysis. The box coating appears to be of value for the latter purpose.

"In addition I would say that this matter of pipe coating has not been taken up by our company, until within the last ten or twelve years, and in passing I will state that we still have in use a number of miles of pipes, both cast and wrought iron, which have been in the earth for fifty years, and occasional removals have shown that some of these were still in condition to last some years longer. These old pipes were put into the ground with no treatment whatever, and I am inclined to believe that in the absence of electric currents, and in sandy soil, neither cast nor wrought iron pipes require any protective covering."

The box covering described above is evidently of such a character that it would last for a long time. There are no threads of fabric to form a path for water to creep through the pitch mass, and if trouble does not develop by the pitch flowing into the manholes or down inclines and leaving portions of the pipe exposed, the protection ought to be very good. No mention is made of cost but it would probably be approximately 35 cents per foot for a 6-inch pipe for materials. This would almost make it out of the question as a means of preventing electrolysis, but in the light of the results described previously in this paper it seems that the only hope of permanent protection by an insulating coating is to be found in coatings approaching in thickness that of the one described above.

### D. WATER DEPARTMENT OF ATLANTIC CITY, N. J.

LINCOLN VAN GILDER

(1): "Pioneer Mineral Rubber used as a hot dip on 30-inch steel pipe over which a wrapping of burlap was placed. A brand of asphaltum rubber called 'Marco' was used on ⅝-inch wrought iron bonds for a wood stave pipe. The latter received two hot dippings and in both cases a cold brush coat was applied to all abraded places.

(2): "These pipes were both laid in a sandy field and across salt marsh, partly under the surface of the latter, the exposed portion being backfilled with a meadow sod.

(3): "Principally soil corrosion. Various tests show slight electrolytic action.

(4): "Both brands have given good service to date in the sandy soil and both were but partially satisfactory in salt marsh. The steel pipe coated with Pioneer Rubber began to fail within two years and is today, after 12 years, nearly worn out. The wrought iron bands on the wood pipe are now about 3 years old. They have not seriously deteriorated. The coating, where intact, appears to have considerable elasticity but some has flaked off.

(5): "On the steel pipe, blisters would appear in the coating and the pipe would pit under the blisters. The burlap covering did not appear to be beneficial.

"A section of this pipe recently examined by the writer shows the coating of the top and sides to be valueless and the pipe badly pitted. The bottom third of this section is in fairly good condition. The burlap is destroyed but the mineral rubber adheres well, has considerable elasticity and the pipe shows but slight pitting. At this point the bottom part of pipe lies in solid meadow that is constantly saturated.

"At some points on this line the worst pitting occurs at the bottom of the pipe, at others the top pits and the bottom rarely shows a leak, the latter condition occurring nearest the thoroughfare where the marsh is subject to overflow with very salt water. The bottom pitting occurs nearer the shore where the soil is fresher but fairly salt. The 'Marco' coating has not been on long enough to give an authoritative opinion.

(6): "For soil corrosion, the writer's experience with protective coatings has been rather unsatisfactory. For the prevention of electrolysis his experience has not been sufficient to warrant an opinion."

### E. PHILADELPHIA SUBURBAN GAS & ELECTRIC CO.

CHARLES WILDE.

(1): "During the last five years we have used two coatings for protecting our pipe. The formula of the first of these coatings is as follows: Five gallons of coal tar boiled from 4 to 5 hours at a temperature not exceeding 550° F, this boiling to continue until the tar is sticky but is not brittle when dropped into cold water.

"To the tar which is being boiled add for every gallon of tar one pound of quicklime which has been slacked to a powder; also $\frac{1}{5}$ pound of tallow and $\frac{1}{20}$ pound of powdered resin.

"The lime, resin and tallow may be added at any time before or during the boiling.

"After the boiling is finished 13 ounces of a solution of crude rubber in turpentine is added to every gallon of tar. This solution is made by dissolving two pounds of rubber in 7 gallons of turpentine. The rubber should not be added until the tar is almost cool, as it will not do to boil the rubber. The rubber may be added after the mixture is heated ready to go on the pipe.

"The other coating which we have been using later is simply 600° F coal tar pitch, or in other words, nothing more nor less than a coal tar boiled to 600° F, in order to drive off the acids and as much oil as possible without making the pitch brittle.

"We apply these coatings as follows: First, see that the pipe is thoroughly clean and free from rust, and also remove any burrs or projections of metal.

"Put the coating in a trough with a steam coil in the bottom. Pass steam through the pipe from ten to thirty seconds until the pipe is thoroughly heated and dry. The pipe is then to be dipped in the coating and allowed to remain in long enough to completely coat the pipe, after which it is taken out and wrapped with muslin or manila paper which has been torn or cut into strips five inches wide. After being wrapped the pipe is again dipped and wrapped as before, thus securing a quite heavy coating, and if it is known that the pipe is to be used in a district particularly affected by electrolytic conditions, it would be advisable to give it a third treatment as above outlined.

(2): "Our pipe is, as a rule, laid in a dry yellow clay, but we have nearly all soil conditions to contend with. When laying pipe in a fill where cinders or any other material has been used that would prove destructive to our pipe, the pipe is protected by placing in the ditch below the pipe, and also over the pipe, a sufficient covering of good earth to prevent the corrosive materials from coming in contact with the pipe.

(3): "Our pipe has been principally subjected to electrolytic corrosion.

(4): "In answering this question I would say that in some instances where we have been formerly in constant trouble, we have not up to the present time (on service pipe renewed about five years ago) had any further trouble. In some other localities, it does not seem to have been so efficient, as we have had in some instances service pipe to be destroyed in a period of a little over one year, even with the pipe coated as above specified.

(5): "The character of the damage to the pipe has always been in the nature of pits, which in some cases are in clusters and in others may be in one deep pit, in very many instances leaving a

deposit in the pits of hard carbon. The damage to the coating is always a complete destruction of the coating at the place where the trouble occurs. At other parts of the pipe, possibly not more than a foot distant, the coating may be in perfect condition.

(6): "Our opinion is that with either of these coatings applied to the pipes as above specified we have secured a much longer average life to our pipe than would otherwise be the case. We do not hesitate to say that either of the coatings as above outlined is an absolute necessity where any steel or wrought iron pipe is exposed to soil or electrolytic corrosion, and believe that the pipe thus protected should show an average life at least 50 per cent longer than pipes which are not coated."

### F. THE CHUCTUNDA GAS LIGHT CO., AMSTERDAM, N. Y.

GEO. D. CONLEE

(1): "The coatings used were coal tar pitch—coal tar pitch over a coating of graphite paint—and pitch painted on hot. All service pipes laid in the last twelve years have been coated.

(2): "Services have been laid in all sorts of ground, including blasted rock, gravel, sand, hard pan and loam.

(3): "In a number of cases there were stray currents shown in the pipes by test.

(4): "Pipes have lately been exposed after being in the ground for more than ten years with no signs of corrosion.

(5): "We have not found any coated pipe that has been seriously damaged.

(6): "We coat all wrought iron pipe that we put under ground as we consider that the increased life of the pipe pays the increased cost several times over.

"In July 1909 we made some tests for Mr. A. F. Ganz of Stevens Institute on a six-inch line coated with tar and having a Dresser coupling every three hundred feet. This pipe passes the substation which supplies the street railway current. It was dug up after having been in the ground for about ten years and found to be in good condition, the coating being perfect and without signs of rust under it.

"We coat with hot pitch at the present time, the first coat of graphite paint having been discontinued."

### G. THE PEOPLES GAS LIGHT & COKE CO., CHICAGO, ILL.

J. H. EUSTACE

(1): "Experimentally we have used about 40 coatings for the prevention of soil and electrolytic corrosion of underground iron pipe. A complete description of these tests, their results and

conclusions drawn appears in the Proceedings of the Illinois Gas Association for 1909, p. 108 to 192, in a paper entitled 'The Comparative Values of Various Coatings and Coverings for the Prevention of Soil and Electrolytic Corrosion of Iron Pipe,' by R. B. Harper.

"Prior to 1909 we used a coating known as 'Cremo.' This preparation was based upon the formula of Mr. Hickenlooper and was similar in many respects to the Hickenlooper coating used by many gas companies at that time. The preparation of that coating as made by us prior to 1909 was as follows (description given in Illinois Gas Association Proceedings for 1909):

A 50-gallon barrel of clean, water free, coal tar is placed in an ordinary portable tar kettle and gradually heated up by a slow fire. When sufficiently fluid, 25 pounds of freshly slaked lime are sifted over the top and well stirred into the tar, which is now brought to a boil. When the mixture shows a consistency of a soft pitch upon cooling a sample to ordinary temperature, the fire is drawn and the whole allowed to cool somewhat. The maximum temperature of the mixture when the fires are drawn is usually 500° F. The hot pitch is transferred to settling and cooling tanks. As the mixture cools to about 350° F, 3 pounds of powdered resin and about 8 pounds of tallow are added and worked in until well dissolved and incorporated with the pitch. When a temperature of about 200° F is reached, 5 gallons of rubber cement (containing rubber and turpentine in the ratio of 4 pounds of pure rubber to 7 gallons of turpentine) are added and stirred in until a thoroughly homogeneous mixture results.

Cremo, when fresh, is a brownish-black, soft material that possesses tenacity, and, when stretched by pulling apart two surfaces to which it is attached, presents a fibrous or ropy appearance. Even when made with the greatest care, it contains particles of rubber which appear as minute lumps. It has a specific gravity of from 1.2 to 1.25 and often contains over 3% by weight of lime. It becomes fluid at about 180° F.

Cremo remains soft for a considerable time, but gradually hardens, apparently by volatilization and oxidation of some of its constituents.

"Owing to numerous examples of failure of pipe coated by 'Cremo,' tests were started in 1907 on the protective values of this and other coatings. As a result of nearly two years of testing, the conclusion was reached that, all things considered, a clean coal tar pitch with requisite physical properties was vastly superior as regards cost, durability, etc., to 'Cremo' or Hickenlooper coating and to many of the paints or dips on the market. Therefore, since 1909, a clean coal tar pitch free from water, acids or soluble mineral matter has been in use by us.

"At present we prepare our pipe covering as follows:

"A 50-gallon barrel of clean, water free, coal tar is placed in an ordinary portable tar kettle and gradually heated by a slow fire, as was done in making 'Cremo.' This is done under a special draft hood, so that the distilling vapors are drawn from the kettles, through an exhaust fan, into a brick stack which acts as a condenser. In this way objectionable vapors are not breathed by the workmen and danger of fires is reduced to a minimum.

"The tar is then gradually boiled until the hot liquid residual pitch shows temperatures of from about 525 to 550° F. The

temperature reached depends upon the consistency of the pitch at that time. Pitch coating of the proper consistency has a specific gravity at 60° F of about 1.28. When a small sample taken from the kettle and chilled in water at ordinary temperature may be rolled into a ball which will not stick to the fingers, the material is about finished. A final test, by coating a small piece of pipe, cooling same to ordinary temperature and examining for adherence of coating, lack of undue tackiness and freedom from brittleness, is considered the best indicator of a finished preparation. When the pitch meets the foregoing requirements, the fires are at once withdrawn from the kettles and the hot pitch transferred to galvanized iron cooling tanks. When cooled to about 300° F the pipe covering is poured into 50-gallon barrels, in which it is shipped to the various pipe covering sheds throughout the city.

"At these shops the pipe covering is placed in a long wooden trough having a cross section of a symmetrical trapezium. At the bottom of this trough, which is about 12 inches wide and 8 inches deep, are several lengths of pipe constituting a steam coil for keeping the pipe covering liquid during application. One end of the trough is provided with a crank and geared device for revolving the pipe in the trough.

"The process of covering the service pipe in sizes from 1½ inch to 4 inches is preceded by a thorough cleaning, so that all mill scale, rust, foreign material, moisture, etc., is removed prior to placing the pipe in the bath of pitch.

"After heating the clean pipe by means of a steam jet placed in one end and the allowing of steam to blow through, the hot pipe is capped at one end and fastened to the revolving device at the other. It is then let down into the bath of liquid pitch and, as it slowly revolves, a spindle carrying a roll of muslin 4 inches wide is moved parallel with the pipe, wrapping it snugly with an overlap of about 1 inch. In this manner the entire pipe is wrapped with muslin which is saturated with coal tar pitch. The excess pitch is removed by a block which follows the winding device.

"The whole operation occupies but a few minutes.

"The completed pipe is then removed and laid on a rack to cool and allow the covering to harden.

(2): "Our pipes have been buried in almost every conceivable type of soil as much of this city is built on filled ground. The soils include gravel, sand, blue and yellow clays, loam, cinders, plaster, brick, refuse of all kinds and mixtures of any of those mentioned with one another. In many cases it would be most difficult to classify the soil surrounding a given pipe.

(3): "Our underground coated pipes have been subjected to both soil and electrolytic corrosion.

(4): "The protective life of our coatings is quite variable. In some cases the coating shows destruction in spots after a few months and in others no deterioration is noticeable after years. Cases of failure are usually found in ground under electrolytic conditions. Whether these failures are due to some poorly saturated spots in the covering which are initially permeable to soil waters and hence readily corroded, or are attributable to excessively destructive conditions existing in the surrounding soil, we are unable to state.

(5): "In most cases of damage to coated pipe, the corrosion localizes itself in several spots where the cloth appears to be more or less rotted and the pitch disintegrated or melted away by the heat at the surface corroded. The pipe itself usually shows deep and localized pittings which in numerous cases have resulted in large holes or perforations to the interior.

(6): "In general, we feel that while the coating which we have adopted as the best shows failures from time to time, due doubtless to the practical impossibility of covering each and every pipe in an absolute perfect manner, yet much protection is afforded our service pipes from ordinary soil corrosion and mild conditions of stray electric currents."

### H. THE CITY OF NEW YORK DEPARTMENT OF WATER SUPPLY, GAS, AND ELECTRICITY

I. M. DE VERONA

(1): "*Cast-iron pipe.*—The coating used upon cast-iron pipe is the customary dead oil of coal tar coating, and generally in accordance with the following specifications:

38. After such inspection and examination by the engineer, both as to cleaning and rust, all pipes and special castings shall be heated in an oven to a temperature of about 300 degrees Fahrenheit, and shall then, and at this temperature, be coated inside and out by dipping into a tank filled with coal tar pitch as hereinafter specified.

Every casting shall be entirely free from rust when the coating is applied. If the casting can not be heated and coated immediately after being cleaned, the surface shall be covered with linseed oil to prevent rusting until such time as it may be coated.

39. The coal-tar pitch shall be made from coal tar, distilled until the naptha is entirely removed and the material mixed with oil so as to make a smooth, tough and tenacious coating, neither sufficiently soft to flow when exposed to the summer sun nor brittle enough to crack and scale off when exposed to temperature below freezing. The pitch shall be carefully heated in a suitable vessel to a temperature of 300 degrees Fahrenheit, and shall be maintained at this temperature during the time of dipping the pipe. Should this pitch thicken and deteriorate after a number of pipes have been dipped, fresh pitch or some of its original ingredients shall be added to maintain the qualities of the dip. The vessel shall be entirely emptied of its old contents and refilled with fresh pitch, when deemed necessary by the Engineer. Every casting shall remain in the pitch for such time as the Engineer may direct, and shall then be slowly removed and laid on skids to drip.

"*Steel pipe.*—The only steel pipe laid by this Department which has been laid for a reasonable length of time, and which has been

at all examined since laying, is coated in accordance with the following specifications:

85. After such tests, the pipes, after being heated and cleaned, are to be coated by dipping vertically in a bath of Mineral Rubber Asphalt Pipe Coating, equal to that manufactured by the American Asphalt and Rubber Company of Chicago. The pipe must remain in the dipping tank until it shall have attained the temperature of the bath. The coating must be durable, smooth, glossy, hard, tough, perfectly waterproof and strongly adhesive to the metal, and must show no tendency to flow when exposed to the sun in summer or become so brittle as to scale in winter. All pipe must be thoroughly covered and protected by the coating. The dipping material must be kept pure and free from sand, grit or any other foreign material. To attain this the Contractor must, as often as is necessary, in the opinion of the Engineer, empty the tanks of their contents, clean and refill them with pure material. The consistency of the material must also be kept uniform by the addition from time to time of suitable flux.

(2): "*Cast-iron pipe.*—Cast-iron pipe has been laid by this Department in soil of practically every nature, both wet and dry; and has been subject in some cases to the action of sewage and of salt water.

"*Steel pipe.*—The steel pipe in question, amounting to about 25 miles in length, was laid mostly in sandy soil and generally above the ground water table.

(3): "*Cast-iron pipe.*—The cast-iron pipe in this city has been only slightly affected by electrolysis, so far as this Department has information. The only places noted where cast-iron pipe has been acted upon electrolytically have been in the vicinity of electric power stations, and there the action has not been serious.

"*Steel pipe.*—The steel pipe in question has not been subject to electrolytic action as far as we know.

(4): "*Cast-iron pipe.*—The minimum age at which tuberculation and marked corrosion occur is generally about ten years, and the protection of the pipe by the coating is of more or less value up to 50 years or more.

"In Brooklyn, a comparison of the condition of uncoated pipe laid in 1858–9 with coated pipe laid in 1860–5 shows that the corrosion of the uncoated pipe is several times as great in area and amount as that of the coated pipe. But in Manhattan there is some pipe which has been in service for about 70 years, and remains in good condition, although it probably was never coated.

"*Steel pipe.*—The steel pipe in question, part of which was laid in 1907 and the remainder in 1909, was uncovered in several places during the past year. The coating in all places was found to be intact, except in a few cases on the under side of the pipe at field joints where settlement had occurred, and the consequent leakage had produced incipient rusting over small areas.

(5): "*Cast-iron pipe.*—The corrosion of cast-iron pipe, especially in the interior, takes the form of tubercles, beneath which small pits are formed in the iron.

(6): "*Cast-iron water pipe.*—The purpose of coating cast-iron pipe is not so much to prevent soil and electrolytic corrosion as to prevent the corrosion of the interior of the pipe and thus preserve a smooth and unobstructed waterway. The application of a preservative coating such as above described prevents to a large degree corrosion due to the action of the soil for a period of ten years or more. Such few observations as we have tend to show that the coating is also of some slight advantage in resisting electrolytic corrosion.

"*Steel pipe.*—We have no information regarding the action of steel pipe coating other than that given above.

"It is impossible for us to answer your questions in detail, as no systematic observations have been made by this Department with regard to the effect of protective coatings in preventing corrosion."

### I. WATER DEPARTMENT, CITY OF SPRINGFIELD, MASS.

E. E. Lockridge

This letter mentions a 42-inch steel main which was subjected to electrolysis at a certain portion of its length. In order to protect this part it was covered with from one to eight thicknesses of tar paper laid alternately with the same general kind of tar which was applied hot to the pipe as it lay in the trench. This coating has been in service since December, 1909, and in September, 1913, had shown no signs of failure or deterioration.

Eight of the remaining correspondents had used dips, consisting of hot tar and mixtures of hot tar, turpentine, rubber, and rosin, for the prevention of soil corrosion with a fair degree of success, but were generally of the opinion that an attempt to prevent electrolysis in any such manner would result in failure. Two correspondents had had no experience with insulating coatings in any way.

The results of these practical tests seem, in a general way, to bear out the results of the laboratory tests described in the foregoing paper. In one or two cases mentioned trouble from stray currents had not yet developed, but there is also some uncertainty as to whether the conditions were present which would develop trouble. From three to five years is also rather a short time for serious trouble to appear if coated pipe is buried in a rather dry soil, as mentioned in one or two of the letters. There appears to be nothing in the above replies to change the conclusions drawn from the laboratory tests previously described, which lead to the conclusion that insulating coatings heretofore used should not be depended on to protect pipes from corrosion by stray currents.