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FOR OFFICIAL USE

H 9

P W—H 9

Post Office Engineering Department

TECHNICAL PAMPHLETS FOR WORKMEN

Subject

Electrolytic Action on Cable Sheaths,

etc.

ENGINEER-IN-CHIEF'S OFFICE
1919

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14. Maintenance of Manual Telephone Exchanges.
15. Telephone Testing Equipment.
16. Routine Testing for Manual Telephone Exchanges.
17. Internal Cabling and Wiring.

[*Continued on page iii of Cover.*

CORRECTION SLIP TABLE

The month and year of issue is printed at the end of each amendment in the Correction Slips, and the number of the slip in which any particular amendment is issued can, therefore, be traced from the date. In the case of short corrections made in manuscript, the date of issue of the slip should be noted against the correction.

The Summary portions of the Correction Slips should be completed and affixed below in numerical order.

FOR OFFICIAL USE

ELECTROLYTIC ACTION ON CABLE SHEATHS, etc

(H.9)

The following pamphlets in this series are of kindred interest :

H.4 Underground Construction. Part I—Conduits.

H.5 Underground Construction. Part II—Cables.

H.6 Underground Maintenance.

H.8 Power Circuit Guarding.

ELECTROLYTIC ACTION ON CABLE SHEATHS, ETC.

TABLE OF CONTENTS.

ELECTROLYTIC ACTION ON CABLE SHEATHS

1.—ACTION OF ELECTROLYSIS.

An electric current is conducted in two ways—either through a " metal " or through an " electrolyte." In the former case, which is called " metallic conduction," there is no chemical change in the composition of the conductor owing to the passage of the current, the material being heated only. A current in a telegraph or telephone circuit passes by " metallic conduction."

" Electrolytic " conduction occurs when a current passes through an acid, alkali or salt, or any liquid capable of being decomposed by the passage of an electric current. Certain liquids, such as petroleum and turpentine are non-conductors of electricity, and others, such as mercury and molten metals, are incapable of decomposition by the passage of a current. Current passing through the soil is found to pass almost wholly by electrolytic conduction. Solutions which are decomposed by the passage of an electric current are called **" electrolytes, "** and the conductors or terminals at which the current enters or leaves the solution are called **" electrodes."** The electrode, where the current enters the electrolyte, is called the **" anode,"** and the one at which it leaves, the **" cathode."** When a current is conducted electrolytically, chemical changes take place in the electrolyte and in one or both of the electrodes. Briefly, the molecules of the electrolyte are split up into positive and negative ions—the former flowing to the cathode and the latter to the anode. The anode also decomposes as a result of the electro-negative ions attacking the metal and reducing it to a metallic salt, whilst the cathode has deposited upon it the positive ions, which are usually innocuous. In commerce this process is employed for the electroplating of goods and refining of metals.

Electrolysis, however, is a possible source of harm to all metallic substances which are in the ground, as they are liable to be corroded by the action set up by stray currents from electric tramways, electric railways, and D.C. light and power systems. The corrosion will take place at all points where the current leaves the metal for an electrolyte, that is, at the anode. The fact that corrosion takes place at the point where the current leaves a metal is a most important point to remember. It should be mentioned, however, that in certain soils which contain salts of the alkali metals, corrosion of lead may also take place at the cathode, *i.e.*, at the point where the current *enters* the metal.

The Department's extensive system of underground pipes, pneumatic tubes, and lead-covered cables is thus liable to be harmed by stray currents which they may be carrying. If these stray currents leave the cables, etc., by " metallic " conduction, no harm is done, but where they leave *via* an electrolyte, corrosion ensues. It can be taken that all liquids and moisture found in the soil and in the ducts and pipes are electrolytes. The amount of corrosion which takes place—that is, the amount of metal eaten away—will depend upon three things:—

i. the strength of current;
ii. the time the current is flowing; and
iii. the kind of metal concerned.

Expressed as an equation—

W (weight of metal eaten away) = C × T × Z grammes where—

C = strength of current in ampères;

T = time in seconds;

Z = electro-chemical equivalent of the metal concerned.

Lead and iron are the only metals used by the Department for its underground works, and Z for those two metals is respectively ·0010716 and ·0002902 gramme. It will be observed that, as the amount of metal decomposed depends upon the current × time, the same effect may be produced by a large current flowing for a short time as by a small current flowing for a long time. For instance, 1 ampère flowing for one year will corrode, roughly, 75 lbs. of lead, so that ·5 ampères flowing for two years will corrode the same amount. Under favourable circumstances about 20 lbs. of iron will be eaten away by a current of 1 ampère flowing for one year. 453·6 grammes = 1 lb. avoirdupois.

It will be seen that the amount of metal that can be eaten away in a year is considerable even with a comparatively small current, and as but a small amount of lead taken away from a cable or pneumatic tube may involve the replacing of a long length of cable or tube at considerable expense, the prevention or mitigation of the effects is of considerable importance.

The prevention or mitigation of the effects of electrolysis by stray currents can be dealt with in two ways:—(i) by controlling the power system so as to limit the amount of current which can pass through the earth and the materials therein, and (ii) by taking steps to ensure that the telegraph and telephone plant suffers the least possible damage from the stray currents that may be picked up. (i) is the more important of the two, as, apart from the obvious desirability of preventing trouble developing at the source, the steps that can be taken under (ii), even after careful investigation and consideration, may involve changes which react adversely upon the Department's plant, and may merely shift the trouble to some other locality.

2.—THE CONTROL OF POWER SYSTEMS.

Overhead Electric Tramway Systems.—When the installation of electric tramways using uninsulated rails for the return of the current was first proposed in the United Kingdom it was recognized that there would be considerable danger to gas, water, and other pipes, and cables laid in the ground if the unrestricted use of the earth for the return of the current were agreed to. It was therefore enacted that such systems must comply with regulations made by the Ministry of Transport for the purpose of "preventing fusion or injurious electrolytic action of or on gas or water pipes or other metallic pipes, structures, or substances." In every Act of Parliament or Order authorizing the installation of a tramway, or light railway, or electric railway, powers are given to the Ministry of Transport to formulate regulations having these objects in view which must be complied with by the undertakers.

Before these regulations are detailed, it is desirable to describe briefly the ordinary **tramway systems** which are most concerned.

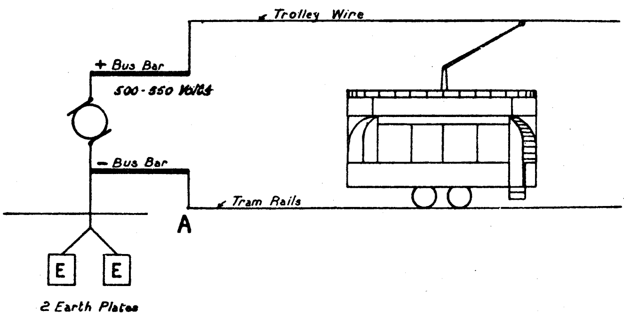

Fig. 1.

If the system is not very extensive, the current is supplied to the overhead trolley wire from the power station as indicated in Fig. 1, the feeding being at that one point only. The generator keeps a constant pressure between the bus bars of from 500 to 550 volts according to the extent of the system, the trolley wire being connected to the positive bus bar and the uninsulated rails to the negative bus bar. In accordance with the Ministry of Transport Regulations, the negative bus bar is connected to two earth plates, which must not have a resistance of more than 2 ohms between them. If the negative bus bar is some distance from the rail, an insulated cable is used for the connection between the rail and the bus bar, and in that case the two earth connections are made at the junction of the insulated cables and the uninsulated rail—that is at "A" in

Fig. 1. If suitable earth connections cannot be made owing to the nature of the soil, connections with water mains will be accepted by the Ministry of Transport.

When the system is extensive, insulated positive feeders are run beside the track, and the trolley wires are fed from these. The trolley wires are divided into half-mile sections, as in Fig. 2.

If the system is very extensive, the load requirements frequently necessitate sub-stations, each helping in the general supply, but the principles are the same as here described above.

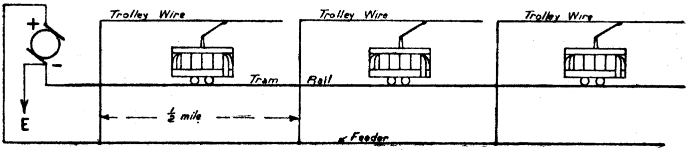

Fig. 2.

It will be seen that the motor on the tramway car obtains its current from the positively charged trolley wire, which is kept at constant pressure, the current returning to the negative bus bar *via* the rails. The rails, however, are in more or less intimate contact with the soil, and the result is that the whole of the current is not confined to the rails. Indeed, it is found in practice that from 15 to 20 per cent. of the total current strays from the rails. On one system it was found that as much as 60 per cent. returned *via* the earth.

The proportion of current that strays from the rails depends upon the conductivity of the rails, the conductivity of the earth, and the resistance between the rails and the earth. The conductivity of the rails depends upon the size of the rails, the effectiveness of the bonding between consecutive rails, and the length of the track. If the track is well drained with dry soil, the leakage will be less than with damp ground. Where rails are laid on a sound concrete foundation, there is high resistance between them and the general mass of the earth, and the leakage of current will be reduced accordingly. Fig. 3 shows the distribu-

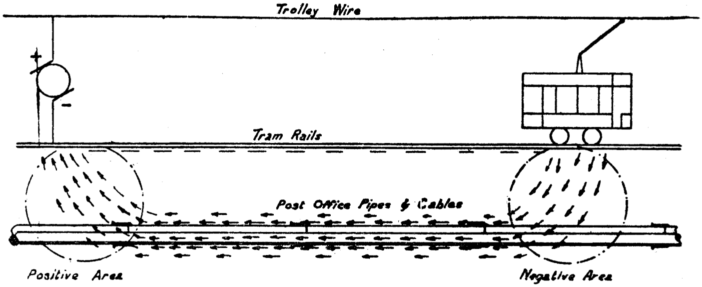

Fig 3.

tion of the return current between the rails, earth, and pipe and cable adjacent to the track. The last can be taken as representative also of a lead-covered cable in a duct. It should be noted in passing that the current leaves the track for the pipe in the area farthest from the negative feeding point and returns from the pipe in the area near the return feeder. The former is called the "negative" area and the latter the "positive" area. The latter is the danger area. The Ministry of Transport Regulations, previously referred to, take these matters into consideration, and the two following extracted regulations are those which most concern the Department.

The indicator connections, etc., referred to under 6 (1) are for measuring the current returning to the negative bus bar *via* the two earth connections shown in Figs. 1 and 2.

"6. When the return is partly, or entirely uninsulated, the Company shall in the construction and maintenance of the tramway (a) so separate the uninsulated return from the general mass of earth, and from any pipe in the vicinity; (b) so connect together the several lengths of the rails; (c) adopt such means for reducing the difference produced by the current between the potential of the uninsulated return at any one point and the potential of the uninsulated return at any other point; (d) so maintain the efficiency of the earth connections specified in the preceding regulations as to fulfil the following conditions, viz.:—

"(1) That the current passing from the earth connections through the indicator to the generator or through the resistance to the insulated return shall not at any time exceed either two ampères per mile of single tramway line or five per cent. of the total current output of the station.

"(2) That if at any time and at any place a test be made by connecting a galvanometer or other current indicator to the uninsulated return and to any pipe in the vicinity, it shall always be possible to reverse the direction of any current indicated by interposing a battery of three Leclanché cells connected in series if the direction of the current is from the return to the pipe, or by interposing one Leclanché cell if the direction of current is from the pipe to the return.

"In order to provide a continuous indication that the condition (1) is complied with, the Company shall place in a conspicuous position a suitable, properly connected, and correctly marked current indicator, and shall keep it connected during the whole time that the line is charged.

"The owner of any such pipe may require the Company to permit him, at reasonable times and intervals, to ascertain by test that the conditions specified in (2) are complied with as regards his pipe."

"7. When the return is partly or entirely uninsulated, a continuous record shall be kept by the Company of the difference of potential during the working of the tramway between points on the uninsulated return. If at any time such difference of potential between any two points exceeds the limit of seven volts, the Company shall take immediate steps to reduce it below that limit."

The penultimate paragraph of Reg. 6 referring to the provision of a " continuous indication " of leakage current being picked up by the earthplates, was deleted from the Ministry of Transport Regulations in 1910. This was because, at that time the Regulations were modified as far as they affected those systems in which the negative bus bar was connected to the rails only by negative feeders of considerable length. In such systems, instead of connecting the negative bus bar to earthplates, the earthplates are placed at the point where the negative feeder joins the rails. The modified Regulations permit the fixing of a Maximum Demand Indicator in the leads from such earthplates as an alternative to running special wires back to the Power Station to a continuous recorder. The Maximum Demand Indicator should be read weekly.

Briefly restated, the undertakers have to provide a dry track for the rails, efficiently to bond the rails together, adopt any other means for reducing the potential drop in the rails, and maintain efficiently the rail bonds and the earth connections on the bus bar. This is to ensure (*a*) that only a small portion of the current returns to the negative bus bars *via* the earth plates (2 ampères per mile of single track, or 5 per cent. of the total output of the station); (*b*) that the voltage between any pipe or cable sheath and the rails shall not exceed the voltage of 1 Leclanché cell if the cable is positive, or 3 Leclanché cells if the cable is negative; and (*c*) that the voltage drop between any two points on the rails does not exceed 7 volts. Continuous records have to be kept for (*c*).

In practice, the Leclanché cell tests in 6 (2) are not carried out, as it is simpler to use a voltmeter, and ascertain directly whether the difference of potential exceeds 1·5 volts when the cable or pipe is positive to the rails, or 4·5 volts when it is negative to the rails. When the regulations were drawn up, electrical measuring instruments of precision were not so common as now, hence the use of a Leclanché cell as a measure of voltage. In case of dispute it is an easy matter to carry out the actual test prescribed in the regulation.

The tests indicated in 6 (2) are of importance, as they indicate the area and places where the Department's plant is likely to be damaged, that is, where the pipe or cable is positive to the rails.

It should not be taken, however, that wherever there is a comparatively high positive potential between the P.O. plant and the rail, damage is taking place at that point, as it is possible for a test to show a high difference of potential, while there is a little current on the cable sheath in question. This occurs where there is a high resistance between the rail and the cable. The conditions, however, are likely to become dangerous at such a point should the resistance decrease—say, with dampness during wet weather—and then heavy currents may flow which are not in evidence during dry weather. In connection with this test, therefore, the question of strength of current in the sheathing is important.

The maximum of 7 volt drop allowed on the rail is the most important regulation, as this decides the amount of current circulating in the rails and earth, and consequently the amount of stray current which will be picked up by neighbouring pipes and cables—*i.e.*, it is the drop of potential between points on the sheathing of the cable which decides the strength of current flowing in the sheathing. To keep within this regulation, where tramway systems have heavy loads the authorities have to supplement the rail return in some cases by negative feeders, and on very large systems by "negative boosters," or by dividing the system into small areas and serving each by a sub-station.

Fig. 4 indicates, in diagrammatic form, the negative feeder system. It will be seen from this that the current is tapped at a number of points on the track and returns *via* insulated

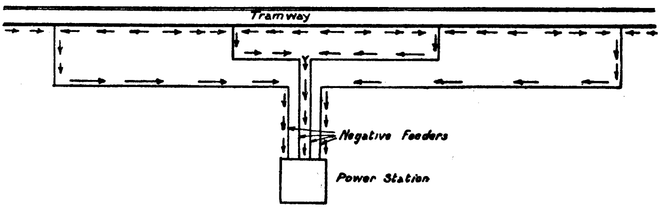

Fig. 4.

cables. By this arrangement, the drop on any section is kept within the regulation if the points and size of cable are suitably chosen.

It is possible, however, to bring the apparent resistance down to zero, or below zero, by placing in the conductor an electro-motive force varying with the current flowing, and in such a direction as to assist the current to flow. This is done by the use of a "booster," which is a dynamo driven by an electric motor, and having its armature connected in series with the circuit in which it is desired to alter the pressure, while its field magnets are excited in various ways.

Fig. 5 shows the application of this method to a tramway system. One return feeder is shown. The negative bus bar N is connected to the track at *a*, another feeder being run to a distant part of the track, *b*. The difference of potential between *a* and *b* is found to be, say, 10 volts when full current is flowing—*i.e.*, *b* is + to *a*. The "booster" armature is connected in series with the return feeder, and its magnets in series with the line feeder. When driven at a constant speed by a suitable motor, it will give a pressure in almost direct proportion to the current flowing into the line, and therefore to the current flowing through the return feeder also. It can thus be made to counterbalance almost exactly the fall of pressure in the return feeder, so that the two ends of the return feeder, *N* and *b*, and therefore the two points of the track *a* and *b*, are kept at almost the same potential and the resistance of the return feeder made practically negligible. In effect, the "booster" sucks back the current *via* the "booster" cable, and the drop of potential between *a* and *b* is reduced.

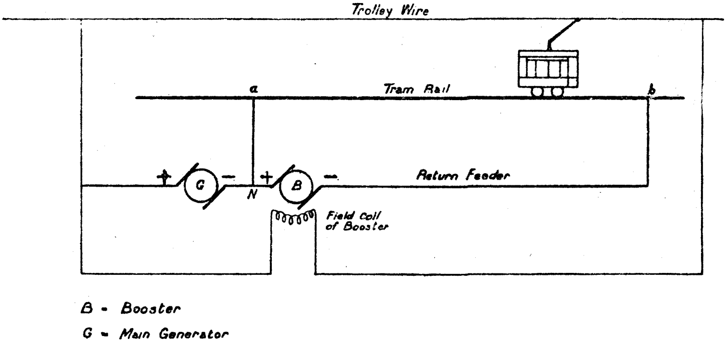

Fig. 5.

Conduit Tramway Systems.—Considerable space has been given to the overhead electric tramway system, as that is the system mostly concerned with the question of electrolysis. On conduit systems, both the positive and negative conductors are insulated, and leakage currents due to insulation defects only are concerned.

Electric Railways are usually situated some distance from the Department's plant, and consequently there should be little trouble from such systems where uninsulated rails are used for the return of the current as with the "third rail system." Both the negative and positive rails are insulated when the fourth rail system is used. The principal regulations imposed by the Ministry of Transport for electric railways in metal-lined tunnels insist upon a maximum of 10 volts between the running rails (if used for the return) and the metal tube, and a maximum drop on the uninsulated rail returns of 7 volts, the same as with tramway systems. A daily record of the voltage drop has to be kept.

D.C. Electric Lighting Systems should not give much trouble by electrolytic action set up by stray currents, as only one earth connection is allowed on any distinct circuit, and the leakage current must not exceed 1-1000th part of the maximum supply. Burn-outs and definite faults on such systems may, however, produce electrolytic corrosion.

Alternating Current Systems, both railway and electric lighting and power, are not likely to cause damage by electrolytic action, as the effect of one half cycle is largely wiped out by the succeeding half cycle. Experiments show that electrolytic action with A.C. varies with the frequency of the alternating current, and is usually not more than from ·5 to 2 per cent. of the effect which would be produced by a continuous current of the same strength.

8.—PRECAUTIONS TO BE TAKEN WITH TELEGRAPH AND TELEPHONE PLANT, ETC.

In the following notes reference to pipes or lead covered cables are usually interchangeable. It should be remarked, however, that the damage to an iron pipe as used by the Department is not so serious as in the case of pipes belonging to gas and water undertakings.

It has been said that a large proportion of the current used with electric tramways leaves the rails for the earth, and it is found, even if the system is worked strictly in accordance with the Ministry of Transport Regulations previously dealt with, that in pipes and cables adjacent to such systems currents of varying strengths are circulating. Certain investigators have contended that at a distance of 3 feet from a tramway rail the current in the soil is of such low density that a pipe or cable would be practically unaffected, and that it is only when a metallic connection is made directly or indirectly to the rails that appreciable currents are picked up. This contention has been disputed, however, and does not appear to be borne out in fact, but it is certainly desirable that the Department's underground plant should be kept at the greatest distance from the rails that can reasonably be arranged. This is particularly desirable at crossings of tramway tracks, as at those points electrolytic action is most likely to occur.

Care should be taken to avoid contacts with **tramway standards.** In many cases the standards are bonded to the rails in connection with the earthing of the guard wires, and in such cases where pipes are concerned the leakage current to the cable will be increased.

As shown in Fig. 8, the current leaves the tramway system at the point farthest from the negative feeder, and returns to the rail in the neighbourhood of the negative feeder. If voltage tests are made between an adjacent cable and the rails over a section of tramway track, it will be found at the farthest point that the rail is + to the cable, and this will hold good for a certain distance, when an area will be found where the voltage alternates in direction, after which an area is reached where the cable is + to the rails. This latter area is the danger section, and is called the "positive" area, as it is in this area that current, if present, will leave the cable for the rails, and, as pointed out previously, it is at the point at which the current leaves that electrolytic action occurs. Although electrolytic damage will not usually take place in the "negative" area, that is in the area where the rails are positive, the condition of the plant in this area is important, as it is here that the stray current is taken on to the sheathing. Cables should not usually be specially earthed in this area, and extra care should be taken to avoid direct or indirect connections with the rails.

It has been the practice in some places in America to put insulating joints in cables with the object of preventing current flowing along the sheathing of the cable, but unless the points are very carefully chosen after thorough investigation, the only result is to shift the point at which damage occurs.

Where cables are laid in iron pipes, these latter should be bonded or joined together, where a break occurs in the route, at a box or manhole. This to a large extent prevents the redistribution of the current carried by the pipes and cables. Where a cable is carried in a pipe, the two must be regarded as independent conductors touching at intervals, and a current traversing the route will divide between them in proportion to the resistance between any two points of contact. It follows, therefore, that anything tending to vary the resistance of either one or other—a pipe coupling or a cable joint—will cause a portion of the current to leave one medium for the other, and if an electrolyte is present, electrolytic action is liable to take place. Ensuring the continuity of the pipe lines by bonding at boxes is the best thing to be done, but it does not give immunity from damage.

With cable in stoneware and earthenware ducts the damage will usually only take place at the point where the current is definitely leaving the cable system for the soil, but it may occur at other points if the soil has a variable conductivity and the joints in the ducts are not waterproof. These conditions may result in redistribution of the current between the earth and cable.

The importance of dry conduits cannot be overrated, as the amount of electrolyte present will largely determine the extent of the corrosion.

Care should be taken in seeing that all cables are clear of water in boxes and manholes. The composition of fluid and fluid matter that comes in contact with cables is significant, but this can be determined only by chemical analysis. For instance, if carbonic acid gas is present and electrolytic action has been started, the corrosion of the lead will go on automatically by chemical means, even though the current may have ceased. Liberal use should be made of petroleum jelly when drawing in lead-covered cables. Petroleum jelly is practically an inert material which is of assistance in protecting the sheathing from corrosion.

In making tests in connection with cases of electrolytic damage, voltage tests are of use in indicating the points at which danger is likely to occur. They do not necessarily, however, give a true indication of what is happening. It is quite possible to have a large current flowing in the cable sheathing and yet a voltmeter will show little or no potential difference between the cable or pipe and earth, and, of course, current strength is the principal factor. Voltage tests between cable and tramway rails and between cable and earth are taken to ascertain the danger area and the working conditions on the tramway system. A lead plate or a lead sleeve filled with damp sponge, held against the side of the joint box close to the duct or placed on the floor of the manhole is the best earth connection for tests of p.d. to earth. Tests to a pipe or earth plate which is possibly polarized due to the flow of vagabond currents, should be avoided. As pointed out previously, a comparatively high positive p.d. between a cable and a tramrail does not necessarily mean there is a strong current flowing in the cable sheath, although it always shows that a heavy current might flow if the resistance between the rail and the cable were reduced. The strength of current flowing in the sheathing of a cable can be measured by various means without cutting the sheathing, but such tests cannot be described here. The simplest method is to slip back a sleeve or cut a complete strip out of the sheathing and read the current on a milliammeter bridged across the gap. A milliammeter has, however, a high resistance when compared with the small piece of lead it has displaced, and the conditions are therefore not the same. It is best, therefore, to use an instrument of very low resistance and shunt it. A Detector No. 2, joined up for reading 500 milliampères and shunted with 4 yds. 4 in. of flame-proof wire 1/12½, will have a resistance of about ·146 Ω, and will read 1/10th of the value of the current—*i.e.*, the reading should be multiplied by 10 to give the full current.

Submission of samples in cases of suspected electrolytic and chemical corrosion. Valuable evidence as to the cause of corrosion is usually given by a chemical analysis of a sample of the damaged sheathing and of water and soil from the neighbourhood of the point where the corrosion has occurred. In the case of samples of sheathing care should be taken to choose those which exhibit clearly the type of corrosion which has occurred, and if possible to include the portion of sheath which has actually given rise to the fault. The type of corrosion is largely determined by examination of deposits of various lead compounds formed in the corrosion pits, and the greatest care should be taken not to remove these deposits. The value of a specimen is often completely destroyed by cleaning before submission.

Before collecting a sample of fluid the bottle (Winchester Quart size, if possible) should be carefully washed and thereafter rinsed with the fluid. The fluid used for rinsing purposes should be thrown away where it cannot mingle again with the remainder of the fluid from which the sample is being taken. Glass stoppers should be used if possible. Should corks have to be employed they ought to be quite new and well washed with the water before insertion into the bottle.

Where damage has been done to cables, endeavours should be made to find the point at which the current is leaving. Tests at successive boxes will indicate where the current strength is reduced. Earth plates to which the cables (and pipes if concerned) should be connected, should then be sunk at the nearest boxes. The object of this connection is to provide a direct path for the current to leave by metallic conduction and so prevent the effects of the current leaving by "electrolytic" conduction. It should be pointed out that it is sometimes found that a current leaves over a very small area in which case the action may be severe and rapid owing to a high density current, whilst in other cases the current will leave over a wide area when a longer length of cable may be involved, but the action at any point may not be very marked.

It has been the practice in America to connect the sheathing of telephone cables directly to the negative bus bar of the tramway system, or to the rails, but this has been found to have objectionable features. It considerably increases the currents on the sheathings, and frequently causes trouble by intensifying interchange of leakage currents between the telephone cables and water pipes. It also introduces serious risks in the event of short circuits on the power systems, or of failure of rail bonds, as very heavy currents then circulate which may damage the cables.

Summing up, it can be said that the things to bear in mind **are** :—

(a) Cables should be kept as far away as reasonably practical from tramway lines.

(b) Contact with the rails either directly or indirectly must be avoided in the "negative" area. Connections in the positive area may be allowed in special cases after careful investigation as an alternative to (h).

(c) Pipes should not be laid in contact with tramway standards.

(d) Cables should be kept clear of water in boxes and manholes, and dry duct lines are desirable.

(e) Chemical composition of fluid and soil has important bearing. Cables should be liberally covered with petroleum jelly when being drawn in.

(f) Voltage tests indicate danger points.

(g) Measurement of strength of current in the sheathing is of great importance.

(h) Earth plates should be sunk to which cables (and pipe if concerned) should be connected, at boxes near the points where the current leaves the cables.

(j) Iron pipes should be bonded across boxes and manholes.

(k) At the junction of routes, the cables and pipes should be joined together by lead strips soldered to the sheathing.

4.—OTHER TYPES OF CORROSION.

The question of the effects of currents set up by local action, due to presence of dissimilar metals, should be referred to. Such action will be set up with suitable soil conditions, but as lead and iron are concerned it will normally be iron which will be eaten away. To be extensive, the action also requires a good supply of electrolyte, and generally speaking, although local action cannot be ignored, it is not likely to be of frequent occurrence. If currents are due to local action—voltage readings usually die away owing to polarisation. This is not the case with foreign currents. All cases have to be considered in relation to the existing electrical conditions before it can be decided whether the action is due to local currents, but it should be borne in mind that in cases where there are no evidences of stray currents, the damage may have been caused some time previously, and that conditions on the power system may have altered in the meantime.

Corrosion by purely chemical action may occur in certain soils or where organic acids are present from the decomposition of wood or vegetable matter. Similarly, cables may be affected in made up ground especially where ashes or clinkers abound. In the latter case local currents may also be set up. Analysis of the soil, etc., is necessary in these cases, and will usually throw light on the cause of the damage.

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LIST OF
Technical Pamphlets for Workmen
(Continued)

GROUP D—*continued.*

18. Distribution Cases, M.D.F. and I.D.F.
19. Cord Repairs.
20. Superposed Circuits. Transformers. Bridging Coils and Retardation Coils.
21. Call Offices.
22. Units, Amplifying. (*Not on Sale.*)

GROUP E.

1. Automatic Telephony: Step by Step Systems.
2. Automatic Telephony: Coded Call Indicator (C.C.I.) Working.
3. Automatic Telephony: Keysending "B" positions.

GROUP F.

1. Subscribers' Apparatus. Common Battery System
2. Subscribers' Apparatus, C.B.S. Part I—C.B.S. No. 1 System.
3. Subscribers' Apparatus. Magneto.
4. Private Branch Exchanges—Common Battery System.
5. Private Branch Exchange—C.B. Multiple No. 9.
6. Private Branch Exchanges—Magneto.
7. House Telephone Systems.
8. Wiring of Subscribers' Premises.

GROUP G.

1. Maintenance of Secondary Cells.
2. Power Plant for Telegraph and Telephone Purposes.
3. Maintenance of Power Plant for Telegraph and Telephone Purposes.
4. Telegraph Battery Power Distribution Boards.

GROUP H.

1. Open Line Construction, Part I.
2. Open Line Construction, Part II.
3. Open Line Maintenance.
4. Underground Construction, Part I—Conduits.
5. Underground Construction, Part II—Cables.
6. Underground Maintenance.
7. Cable Balancing.
8. Power Circuit Guarding.
9. Electrolytic Action on Cable Sheaths, etc.
10. Constants of Conductors used for Telegraph and Telephone Purposes.

GROUP I.

1. Submarine Cables.

GROUP K.

1. Electric Lighting.
2. Lifts.
3. Heating Systems.
4. Pneumatic Tube Systems.
5. Gas and Petrol Engines.