FOR OFFICIAL USE.

H.6.

P.W.—H.6.

Post Office Engineering Department

TECHNICAL PAMPHLETS FOR WORKMEN

Subject :

Underground Maintenance

ENGINEER-IN-CHIEF'S OFFICE,
1919.

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LIST OF
Technical Pamphlets for Workmen

GROUP A.

1. Magnetism and Electricity.
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3. Technical Terms.
4. Test Boards.
5. Protective Fittings.
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7. Sensitivity of Apparatus.
8. Terms and Definitions used in Telegraphy and Telephony.

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FOR OFFICIAL USE.

UNDERGROUND MAINTENANCE

(H.6).

The following pamphlets in this series are kindred interest :

A.6. Measuring and Testing Instruments.
H.4. Underground Construction. Part I.
H.5. Underground Construction. Part II.
H.7. Cable Balancing.
H.8. Power Circuit Guarding.
H.9. Electrolytic Action on Cable Sheaths, etc.

Also

P.O. Technical Instruction IV. "Maintenance Testing."

UNDERGROUND MAINTENANCE.

TABLE OF CONTENTS.

UNDERGROUND MAINTENANCE.

1. INSPECTION OF MANHOLES AND JOINTING CHAMBERS.

Systematic maintenance of manholes and jointing chambers is necessary in order to ensure that underground plant is kept in an efficient condition and that no defects are developing.

The lineman can make good small defects that arise and keep the boxes in a clean condition by periodical visits for this purpose, or on occasions when access to the boxes is required for the purpose of clearing faults, but in addition to the ordinary maintenance visits, detailed inspections are made at definite periods when the examination should be specially directed to the following items :—

STRUCTURAL WORK.

(a) The condition of the painting on the Boiler Plates, Rolled Steel Joists and Cable Bearers.

(b) Indications of excessive rust on or deterioration of the steelwork.

(c) Appearance of the brickwork, cement joints and concrete floor, and any signs of cracks or subsidence.

(d) Indication of distortion of the walls or roofing of reinforced concrete manholes.

(e) Position of grating on the sump-pit and freedom of the pipe itself from rubbish.

(f) Rigidity of the fixing of the Ring bolts to the floor, of the manhole steps and "Lewis Bolts" supporting cable bearers, of Cable Distribution Heads, etc.

FRAMES AND COVERS.

(g) Any difference in level between the rim of the frame of the cover and the surface of the roadway or footway.

(h) Any tendency of the cover to rock in the frame, requiring adjustment of the fitting strips, and the condition of the wood blocks or other "filling" of the cover.

CABLES.

(i) The condition of cables at the mouth of pipes entering manholes and boxes, at points where they are supported on bearers at the mouth of the pipes and also where any flattening or distortion of the sheathing has taken place.

(j) Indications of excessive sagging due to too long a length without support, and points where protection is required from men entering or working in the manhole.

(k) The position and legibility of the lead label on each cable on which the cable code is stamped and the identification of cables containing fire alarm wires by red painting on the sheathing.

(Each cable should be carefully inspected throughout the whole length exposed in the chamber. Where a direct view cannot be obtained it will be necessary to use a mirror.)

BONDING.

(l) The attachment of the lead strip to each pipe by means of either a bonding bolt or a bonding clip and the continuity of the lead strip between the pipes.

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(m) The soldered connection of the bonding strip to every cable and its connection to the earth plate in a manhole.

At least once a year an electrical test of the efficiency of the bonding is made in the following manner (Fig. 1) :—

The apparatus used consists of a Detector, one Dry Cell "Z" and a brass clamp made up into a small portable set.

To make the test the brass clamp is screwed to the lead bonding strip and the wire from the other terminal securely fixed to a knife or saw file with a wood handle. Connection

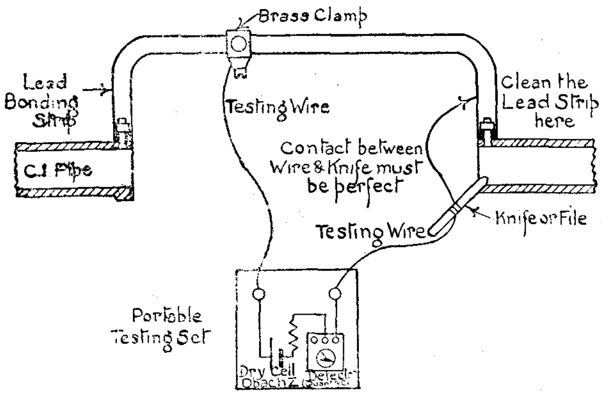


Fig. 1.

is made to the pipe by filing a notch on the inside of the spigot. The deflection in the "Q" coil of the Galvanometer is noted and a second connection is now made by a piece of wire between the file and the bonding strip, close to the clip, the first connection between the file and the pipe being maintained. If the bond is efficient there will be no change in the deflection when the second connection is made and broken.

The testing of the bond to the cables is similarly carried out, the knife or file being held on a cleaned portion of the sheath.

Presence of Water.—If any quantity of water is found in the chamber it should be ascertained if it is surface water which has entered around the cover, or water which has drained in from adjacent chambers or percolated through the brickwork. The first can be prevented by caulking the cover with plastic cement, but the two latter may be due to a leaky water main or to an undrained water source, and prevention in these cases is more difficult.

Presence of Gas.—The inspection of manholes should also take into consideration the presence of coal or other dangerous gases. Special precautions are necessary to guard against explosions and accidents from this cause, and methods have been adopted for ascertaining the presence of gas.

Coal gas can usually be detected by the smell. It is lighter than air and can easily be removed from a manhole by ventilation, the covers of the manhole and of adjoining chambers being removed. In bad cases fresh air can be pumped in from a desiccator. It is important to remember that a naked light must not be used if there is the least suspicion of the presence of coal gas.

Gases sometimes found in manholes are Carbon Dioxide (CO_2) and other gases heavier than air which cannot be ascertained by the sense of smell. Gases of this nature are not so readily removed from manholes, and as they settle close to the floor their effect is greatest on a man working low down where the air is foul. Higher up in the chamber the air may be comparatively pure.

To clear heavy gases from a manhole a pail should be used and the gas bailed out as if it were water. A desiccator should then be used to remove thoroughly all traces of the foul gas. The portable hand desiccator can be specially adapted for this purpose.

The instruments used for the detection of gas are the Gas Leak Indicator and the Safety Lamp. The former instrument gives a reading on a dial of the amount of gas present and discriminates between gases lighter or heavier than air. The Safety Lamp is lit and suspended in the chamber to be tested. If coal or other inflammable gas is present the interior of the lamp will be filled with a bluish flame. Non-inflammable gases such as Carbon Dioxide (CO_2) will cause the lamp to burn feebly or extinguish it if they are present in large proportions. When the candle in the lamp burns with a steady bright light the air is fit to breathe. If this is not the case it is unsafe to remain in the manhole, and the foul air requires to be removed.

Some manholes which are liable to flooding have a connection made to the sewage system by means of an ordinary drain trap. If owing to a period of dryness the water in the trap should evaporate, the manhole chamber will become directly accessible to gases from the sewer. Care should be taken in such cases to ensure that the drain trap is kept "sealed" by occasionally pouring slowly down a bucket of water.

2.—CABLE RECORDS.

Each cable is known by a code, which may consist of one or more letters or a letter and a number. Each pair of wires or single wire in the cable is numbered; the numbers being consecutive through the cable, commencing with one. The pair on which a particular circuit in a cable is working is therefore known by the designation of the cable code and the pair number.

for example A.B. 13 being pair No. 13 in a cable whose code is A.B.

The present practice is to give each main cable from an exchange a single letter code, the letters A to Z being used omitting I and Q. Where more than 24 cables enter an exchange double code letters are used, AA., AB., etc.

Distribution Cables are coded with the number of the Distribution Point to which they are connected.

Where Cables are led through Cable Distribution Heads the pairs are numbered on each side of the joints. Special coloured labels are provided to enable the numbers to be easily found; a different colour being used for each group of 50 wires.

All pairs are again numbered at the Distribution Point which they serve, and it is thus possible to identify a particular pair (1) at the Exchange Main Distribution frame, where the wires in each cable are arranged consecutively on the frame (2) at the Distribution Point (3) at intermediate points where the cable is led through a Cable Distribution Head.

Records are kept on Cards.

(a) **Main Cable Card.**—This shows the whole of the pairs in a main cable and the corresponding pairs at the Distribution Points to which they are connected.

(b) **Distribution Point Card.**—This card shows the whole of the pairs at a Distribution Point and the corresponding pairs in the Main Cable to which they are connected. The Subscriber's Exchange number and address for each circuit in use are also shown on this card.

(c) **An Index Card** is also kept which gives for each subscriber's number the relative number on the Main Frame, and the Distribution Point and the Distribution Point number to which the subscriber is connected.

From these particulars it is possible to identify easily any circuit at the points from which localization tests are made for faults, and between points where crosses are made to restore faulty circuits.

The layout of each main cable and its connections to the various branch cables and Distribution Points is also shown on a Cable Pair Distribution Diagram of which Fig. 2 is an example.

3. FAULTS ON CABLES.

Faults which occur in underground cables may be classified as Disconnections, Contacts, Definite Earth Faults, Low Insulation, and Overhearing Faults.

The largest proportion of these faults occurs at the terminations of the cable or in Cable Distribution Heads or Cable Connection Boxes or at the junction of the Loading Coil Stub and the Loading Coil. Occasionally a fault develops in a joint some considerable time after it has been made. It is seldom that a

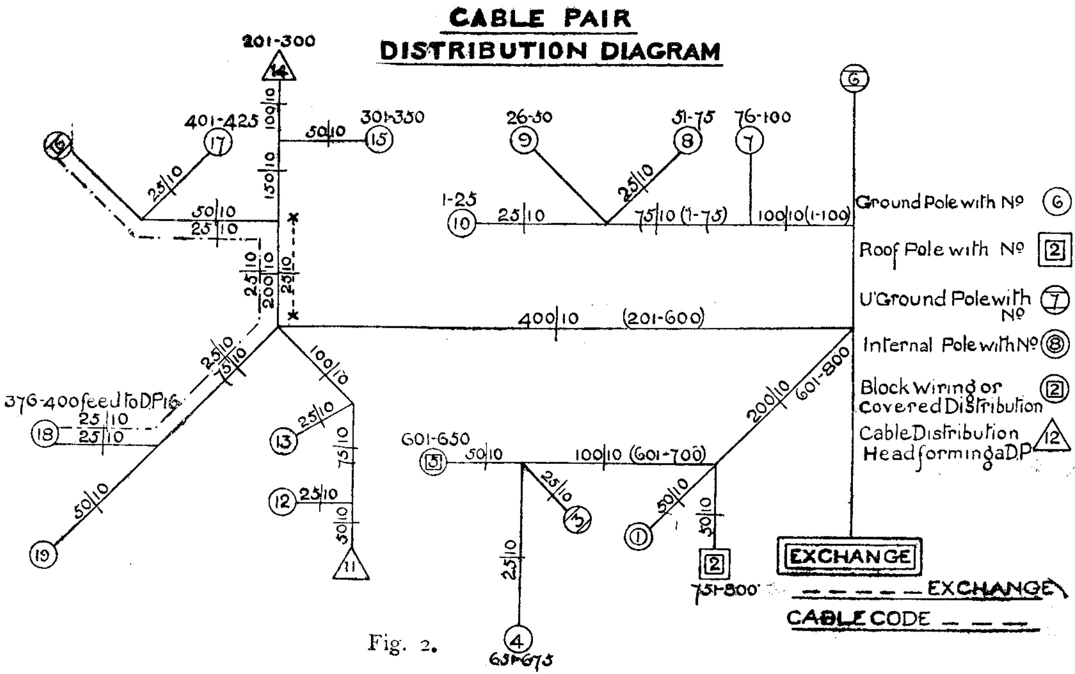

CABLE PAIR
DISTRIBUTION DIAGRAM
201-300
14
100|10
401-425
17
50|10
301-350
15
150|10
16
25|10
50|10
25|10
25|10
200|10
25|10
26-30
9
51-75
8
76-100
7
6
1-25
10
25|10
25|10
75|10 (1-75)
100|10(1-100)
Ground Pole with No 6
Roof Pole with No 2
U'Ground Pole with No 7
Internal Pole with No 8
Block Wiring or Covered Distribution 2
Cable Distribution Head forming a DP 12
400|10
(201-600)
25|10
75|10
100|10
376-400 feed to DP 16
25|10
18
25|10
25|10
13
75|10
12
25|10
50|10
11
50|10
19
601-650
5
50|10
100|10 (601-700)
200|10
601-800
25|10
3
50|10
1
50|10
2
751-800
25|10
4
651-675
EXCHANGE
EXCHANGE
CABLE CODE

Fig. 2.

fault will arise in a cable length unless the cable has been subjected to some severe and usually obvious mechanical injury.

The localization of faults is carried out at the Exchange in conjunction with the outside lineman, but when the fault has been proved to a definite section of the cable a localization test from an intermediate point may be necessary. Facilities are provided at Exchange Test Desks for rapidly testing lines as regards insulation resistance and continuity. The standard instrument now used for localization tests to determine the position of earths, contacts and low insulation faults, is the Megger or Bridge Megger. Localization of disconnections can be made by testing the capacity of the disconnected wire and comparing it with the capacity of a good wire in the same cable, but the best instrument for this purpose is the "Universal" Fault Locator, which is capable of determining the position of disconnections or earth and low insulation faults.

Simple tests to determine if a fault is in a particular section may be made by means of the Detector and a Battery as shown in Fig. 3.

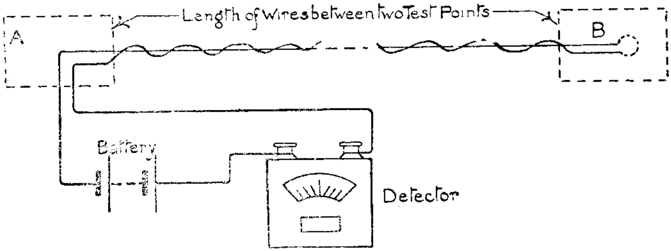


Fig. 3.

(a) **Test for a disconnection between A and B.**—The detector and battery are joined to the two wires at A, and at B the lines are looped together. If there is a disconnection there will be no deflection on the detector.

(b) **Test for a contact between two wires in the Section A to B.**—The detector and battery are joined to the two wires at A and the ends of the wires at B are left disconnected. If the wires are in contact there will be a deflection in the galvanometer.

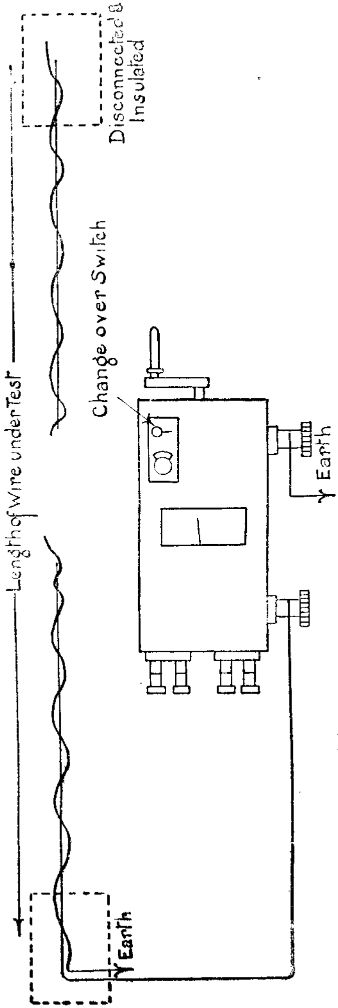
(c) **Test for an earth.**—One side of the battery is connected to earth, the other to the detector. The second terminal of the detector is connected to the cable wire. If the wire is earthing there will be a deflection on the galvanometer. The battery connections should then be reversed between earth and the detector. If the deflection on the scale is not the same in both cases, this will indicate that a current is leaking into the circuit from the point where it is making earth.

The following methods are adopted for **measuring insulation resistance and localising faults by the Megger or Bridge Megger.**

(a) **Measuring Insulation Resistance** (Fig. 4).

The megger must be placed on a steady and level base. The handle must always be turned in a clockwise direction and with an even motion, the speed being gradually increased until the clutch is felt to slip. Earth and Line are connected as shown on the diagram. The value of the insulation will be read directly by the position of the pointer on the scale. The change-over switch on the Bridge Megger should be turned to Megger.

(b) **Measuring Conductor Resistance.**—To measure the resistance of a conductor by means of the Bridge Megger, as, for example, the resistance of a pair of



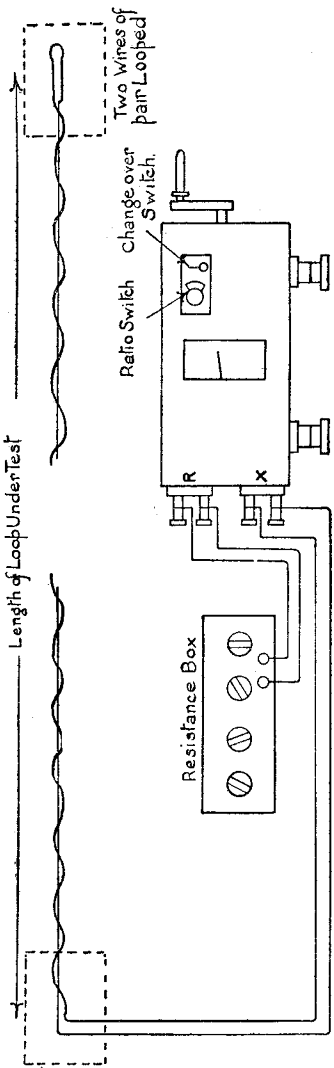
MEASURING INSULATION RESISTANCE
(ONE WIRE OF A PAIR)

Fig. 4

wires to a point where they are looped for test, the connections are made as shown in Fig. 5.

The change-over switch is set to bridge, and the ratio switch to 1. The resistance box is joined up as shown, and should be set to zero on all the dials. The generator handle should be turned slowly in a clockwise direction, when the needle will take up a position on the side of the line marked increase R. The resistance should now be slowly increased in the resistance box, commencing with the thousands, and then the hundreds, tens, and units, until a steady reading is obtained and the pointer rests exactly on the line marked G on the scale.

If the resistance is under 100 ohms it is better to move the ratio-switch to 10 or 100. The value of the resistance in that case will be 1/10th or 1/100th of the reading shown by the resistance box.



MEASURING CONDUCTOR RESISTANCE

Fig. 5.

If the conductor resistance of one wire is required and a second wire is not available to form a loop, the wire may be earthed at the distant end, and the end at the testing point connected to one of the X terminals, the other X terminal being joined to earth. The test is then made in the same way as before, and the reading obtained is the resistance of the wire with the addition of the earth resistance.

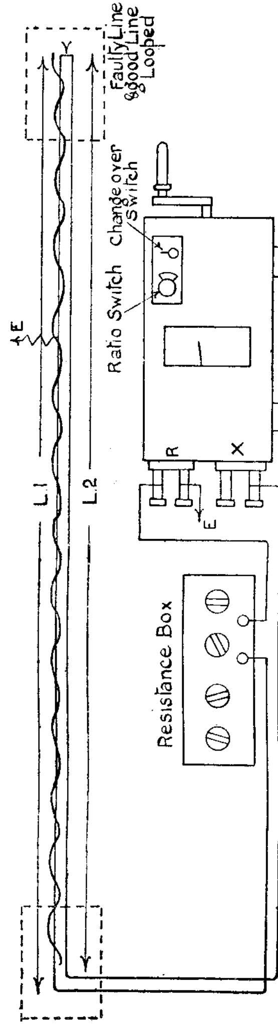
The most frequent localization test required when a fault develops on an underground cable is **to determine the position of an earth fault.**

An approximate test may be made in the manner last described by ascertaining the resistance of one conductor from the testing end to earth at the fault. This is only applicable if the fault is a pronounced earth fault and the wire used for test is in good condition as regards insulation except at the point where the definite fault exists.

If a second wire in good condition is available for use in testing and the Varley loop test applied with the Bridge Megger, a much better result is obtained.

(c) **Measuring the distance to an EARTH FAULT.**

The connections of the Megger are made as indicated in Fig. 6. The



MEASURING THE DISTANCE TO AN EARTH FAULT

Fig. 6.

good line and the faulty line are looped at the distant end. One terminal R is connected to earth and the other to the resistance box. The faulty line and the good line are connected to the resistance box and to the X (outer) terminal respectively. The ratio-switch is set to 1 and the resistance box dials to zero.

The generator handle should be turned and the value of the resistance in the resistance box raised step by step till a steady reading of the pointer is obtained on the mark G of the scale—let this resistance be R. The resistance of the loop, *i.e.*, L_1 and L_2, should now be obtained in the manner previously described for measuring the conductor resistance of a lop. This will give the value of $L_1 + L_2$. Then the resistance of the wire in ohms between the testing point and fault will be equal to $\frac{L_1 + L_2 - R}{2}$.

This resistance will give the distance in yards of the fault if it is divided by the resistance per yard of the wire which is being tested, or

$$\frac{\text{Resistance of wire to fault}}{\text{Resistance of } L_1} = \frac{\text{distance of fault}}{\text{Length of } L_1}$$

If the resistance to be measured is very low the ratio switch should be set to 10 or 100. In this case the resistance to the fault is obtained from the following formula :—

Switch at 10.

$$\text{Resistance to fault} = \frac{L_1 + L_2 - \frac{R}{10}}{1 + \frac{1}{1}}$$

Switch at 100.

$$\text{Resistance to fault} = \frac{L_1 + L_2 - \frac{R}{100}}{\frac{101}{100}}$$

As a rule it is best to make the test of the conductor resistance of the loop ($L_1 + L_2$) with the ratio switch in the same position as that used in the localizing test.

When a fault has been definitely located to underground cables where only one wire or pair of wires is affected and spare wires are available, a cross should be made to restore the circuit.

In main trunk cables where the number of spare wires available is usually small localization and clearing of the faulty wire should be proceeded with at once.

This practice, however, is somewhat modified in the case of local telephone cables. If sufficient spares are available to leave a margin between the Distribution Point and the Exchange the opening of intermediate Cable Distribution Heads to localize and clear the fault is not proceeded with immediately. It is better in such cases to deal with several faulty wires at one time or to wait until circumstances make it necessary to open the Cable Distribution Heads before proceeding to clear it. The more often that Cable Distribution Heads are opened and the wires handled, the greater is the possibility of other faults developing there.

4. MAINTENANCE OF CABLE DISTRIBUTION HEADS.

Special attention should be directed to the following points when dealing with the maintenance of, or clearing of faults in, a Cable Distribution Head.

Wires should be examined throughout their length to ensure that they are not bare of insulation at any point and particular attention should be paid to the neck of the cable at its entrance through the lining. The pairs of wires should be double laced inside the box.

The length of each group of wires should be such that they are not so short as to be tightly stretched between the linings, or unnecessarily long, thereby taking up too much space in the box. Joints close up to the linings should be avoided. The paper lining of the box should be in good condition. The washer for ensuring that the cover is a watertight fit and the bolts for securing it should be complete and serviceable.

Low Insulation in a Cable generally occurs at Cable Distribution Heads or Cable Connection Boxes owing to the presence of moisture in the air, which can be removed by the use of the desiccator. In cases where the paper insulation is perceptibly moist, braziers should be used in conjunction with the desiccators. The escape valve for the air should always be placed near the damp portion and the inlet arranged so that the dry air from the desiccator passes over the faulty portion.

5. DAMAGE TO SHEATHING OF CABLES.

Punctures in the sheathing of lead-covered cables are liable to produce complete breakdowns of the circuits in the cables, although indications of the damage may be given by a gradual fall of insulation as the pairs nearest to the point of damage become affected.

Cases of damage to the sheathing which arise from excavations or from subsidence of the ground may often be traced by an examination of the ground along the route. Failing such an indication, in order to localize a fault in the sheathing it is necessary to apply air pressure from a desiccator and to examine the cable to ascertain where the air is escaping. The exposed parts of the sheath should be smeared with soap suds so that the escaping air will form a bubble and indicate the position of the puncture. If this method does not determine the position of the puncture, pressure gauges should be placed at several points over the section concerned, and after a fairly steady air pressure has been obtained on the cable, readings of the gauges should be carefully noted. When the fault is between two gauges there will be a marked difference between the readings, and the fault will be nearer the gauge with the lower reading.

To ascertain whether a fault is in a particular length, the space between the cable and the edge of the conduit at the end of each length is filled with clay through which a pinhole is made. The hole is then covered with soapsuds. The formation of bubbles in the clay indicates the existence of a fault in the section.

Electrolytic Damage.—Where damage to the cable has occurred in the vicinity of a tramway system or any other D.C. power plant and is suspected to be due to electrolysis, it should be reported as early as possible, so that arrangements can be made for officers experienced in electrolysis testing to carry out the necessary tests. A sample about 12 inches long, exhibiting the character of the corrosion, should be secured and forwarded to the Pattern Room, Engineer-in-Chief's Office, with a Label T.E. 834 attached giving particulars of the case.

Chemical Action.—When there is reason for suspecting a cable has been damaged by chemical action rather than by electrolytic action, a sample of the damaged cable and also of any soil and fluid present in the actual duct in which the cable was laid should be forwarded to the Pattern Room, Engineer-in-Chief's Office. Labels T.E. 834, with particulars of the case, should be attached to the samples before they are despatched. Arrangements will then be made for the samples to be submitted to a laboratory examination, from which, together with the results of the electrical tests, it will be possible to determine whether the provision of protected cable is desirable for replacing the damaged length.

Road Works.—Where road widening or works involving the breaking up of a road surface are being carried out, and an officer of the Department is not detailed permanently to watch the Department's interests, the Department's duct or pipe line should be staked out in order that the plant may not suffer damage. The stakes should be painted Post Office red.

6. DESICCATORS.

A desiccator is a machine for providing air which is free from moisture and for forcing it into a cable under pressure.

There are three types of desiccator employed.

(1) Stationary motor-driven desiccators which are installed at large exchanges.

(2) Portable Petrol Motor Desiccators mounted on a four-

wheeled truck and able to be drawn to any required position in the street.

(3) Hand-driven desiccators for use when the drying operations do not require to be sustained for long periods.

The Portable Petrol Motor Desiccator consists of a water-cooled petrol motor, an air compressor, air receiver, four cast-iron cylinders to contain calcium chloride, tanks for petrol and water, a circulating pump and the necessary gearing and connections.

The capacity of the plant is the compression of 10 cubic feet of free air per minute to a pressure of 30 lbs. per square inch. The air is passed through the 4 cylinders, which contain calcium chloride packed in small bags each containing about 4 lbs. Calcium chloride has the property of absorbing water to the extent of 50 per cent. of its bulk, and the circulation of the air through the cylinders will effectually dry it if the calcium chloride is renewed at sufficiently frequent intervals. To prevent waste of calcium the bags in the last three cylinders will be transferred to the first three when renewal is necessary. This should be done as soon as moisture can be drawn from the drain cock on the third cylinder.

The secondary battery provided for the ignition has a capacity of 40 ampère-hours. One charge should be sufficient for a 200 hours run.

When the plant is in use the weight of the carriage should be removed from the springs by means of the bolts near the axle guides or by the lifting jacks. Before starting it should be ascertained that the petrol and water tanks, the lubricators and grease boxes are full and the lubricators open.

A few turns should be given to the engine before closing the tumbler switch on the ignition circuit, and the engine started on a light load by opening the drain cock in the receiver. The timing lever should be depressed as far as possible, so that the ignition takes place late in the stroke at starting. When the engine is running the timing lever and air lever will be adjusted so that no smoke proceeds from the exhaust and there is no "knocking" at full load. The governor is provided with a lever to adjust the running speed to suit the load on the compressor.

It is essential that the flow of circulating water should be maintained; this is indicated by the discharge of the water from the curved brass pipe into the funnel on the top of the water tank. In cold weather the engine jacket must be emptied of water at night to prevent freezing. Whenever the engine is stopped all lubricator and drain cocks must be closed and the petrol supply cut off. Precautions must be taken to ensure that naked lights are not brought near the plant unless all petrol has been removed.

Hand-driven Desiccators.—The action of the air compressor and the calcium cylinders is similar in this machine to that in the motor-driven plant. A separate cylinder is fixed on this plant to contain cotton wool and prevent any dust being blown into the cables. Iron supports are provided to take the weight from the wheels when the machine is in use.

The connections for applying a desiccator to raise the insulation of a length of cable are shown in Fig. 7.

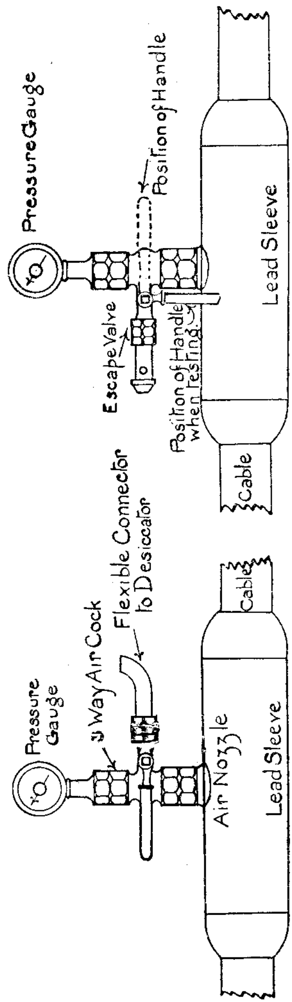
An alternative method of drying cables is the use of Carbon Dioxide (CO_2).

This gas has the property of absorbing moisture, and it can be obtained at a reasonable cost in cylinders in which it is stored at a high pressure.

The cylinders are obtained fitted with an outlet valve, and to this is connected a reducing valve which permits of the gas being released direct to the cable at the desired pressure of from 20 to 30 lbs. per square inch.

The cost of this method, which is easily applied, compares favourably with the use of specially dried air.

Precautions are necessary to prevent the accumulation of the CO_2 in manholes where the escape valve is fitted.



CONNECTIONS FOR DESICCATING CABLE

Fig. 7.

LIST OF

Technical Pamphlets for Workmen

(Continued.)

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2. Subscribers' Apparatus C.B.S. Part I—C.B.S. No. 1 System.
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4. Private Branch Exchange—C.B.
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GROUP G.

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

GROUP H.

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2. Open Line Construction, Part II.
3. Open Line Maintenance.
4. Underground Construction, Part I.
5. Underground Construction, Part II.
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.