

D 17

*Crown Copyright Reserved*

PW—D 17

# Post Office Engineering Department

## TECHNICAL PAMPHLETS FOR WORKMEN

*Subject*

### Internal Cabling and Wiring

ENGINEER-IN-CHIEF'S OFFICE

1919

(Reprinted February, 1926, including Correction Slips to date)

{	"	March, 1929,	"	"	"	"	"	"
{	"	May, 1931,	"	"	"	"	"	"
{	"	January, 1933,	"	"	"	"	"	"
{	"	Sept., 1935,	"	"	"	"	"	"
{	"	Dec., 1935,	"	"	"	"	"	"

# LIST OF Technical Pamphlets for Workmen

## GROUP A.

1. Magnetism and Electricity.
2. Primary Batteries.
3. Technical Terms.
4. Test Boards.
5. Protective Fittings.
6. Measuring and Testing Instruments.
7. Sensitivity of Apparatus.
8. Standard List of Terms and Definitions used in Telegraphy and Telephony. (*Not on Sale.*)
9. Standard Graphical Symbols for Telegraphy, Telephony and Radio Communication. (*Not on Sale*)

## GROUP B.

1. Elementary Principles of Telegraphy and Systems up to Morse Duplex.
2. Telegraph Concentrators.
3. Wheatstone System. Morse Keyboard Perforators.
4. Quadruplex, Quadruplex Repeated Circuits and Telegraph Repeaters, Simplex and Duplex.
5. Hughes Type-printing Telegraph.
6. Baudot Multiplex Type-printing System.
7. Western Electric Duplex Multiplex. Murray Duplex Multiplex. Siemens and Halske Automatic Type-printing System.
8. Fire Alarm Systems.

## GROUP C.

1. Wireless Transmission and Reception.
2. Interference with Reception of Broadcasting.

## GROUP D

1. Elementary Principles of Telephony.
2. Telephone Transmission. "Loading." Telephone Repeaters and Thermionic Valves.
3. Principles of Telephone Exchange Signalling.
4. Magneto Exchanges—Non-Multiple Type.
5. Magneto Exchanges—Multiple Type.
6. C.B.S. No. 1 Exchanges—Non-Multiple Type.
7. C.B.S. Exchanges—Multiple Type.
8. C.B. Exchanges—No. 9 Type.
9. C.B. Exchanges—No. 10 Type.
10. C.B. Exchanges—No. 12 Type.
11. C.B. Exchanges—22 Volts.
12. C.B. Exchanges—40 Volts.
13. Trunk Telephone Exchanges.
14. Maintenance of Manual Telephone Exchanges.
15. Telephone Testing Equipment.
16. Routine Testing for Manual Telephone Exchanges.
17. Internal Cabling and Wiring.
18. Distribution Cases, M.D.F. and I.D.F.

[Continued on page iii of Cover.]

**FOR OFFICIAL USE**

**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.

---

## **CORRECTION SLIP TABLE—(cont.)**

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.

---

# INTERNAL CABLING AND WIRING.

(D.17.)

---

---

*The following are of kindred interest :*

*Pamphlets in this series—*

D.18. Distribution Cases, M.D.F., and I.D.F

F. 8. Wiring of Subscribers' Premises.

*P.O. Technical Instruction—*

T.1. XVIII., Wiring of Buildings.

---

---

## TABLE OF CONTENTS.

	PAGE
GENERAL PRINCIPLES:	
CLASSES OF INSTALLATION ... ..	3
DESIGN OF INSTALLATION ... ..	3
METHODS OF SUPPORTING CABLES... ..	5
CUTTING AND PLUGGING WALLS ... ..	7
TYPES OF CABLES AND COLOUR SCHEMES ... ..	8
TERMINATING CABLES ... ..	10
CABLE FORMING AND LACING ... ..	11
JUMPER WIRES ... ..	13
POWER LEADS ... ..	13
EARTH CONNECTIONS ... ..	13
LABELLING AND RECORDS ... ..	14



# INTERNAL CABLING AND WIRING.

## GENERAL PRINCIPLES.

**Classes of Installation.**—Installations may be classed under three main heads :—

1. Trunk and Long Junctions.
2. Subscribers' and Short Junctions.
3. Telegraphs.

(1) *Trunk and Long Junctions.*—In this class the “speaking efficiency” is the most important consideration. The external paper-core cables, owing to their high insulation, low capacity, and good conductivity, have a high “speech efficiency.” It is impracticable to maintain an equally high standard in the internal cabling, and for this reason it is essential that the internal cabling should be reduced to a minimum. A very high standard of internal wiring must be maintained and, except for short distance wiring in switchboards and to apparatus, all cables employed should be lead-covered types. The conductors forming a speaking pair must be twinned and, where external paper-core cables are designed for superimposed circuits, the multiple twin formation should be retained up to the transformer racks.

(2) *Subscribers' and Short Junctions.*—With this class the number of circuits involved is very large and the speech efficiency requirements are less stringent. In dry situations the less expensive types of braided cables may be used for internal wiring. As exchanges should always be “dry,” switchboard cables are largely employed for internal wiring. The twin formation of wires forming a speaking pair must be maintained.

(3) *Telegraphs.*—A high insulation is necessary and the requirements are somewhat similar to trunk wiring, except that single conductor cables are employed in most cases.

**Design of Installation.**—The chief points to keep in mind with internal wiring are :—

- (a) Speech efficiency of circuits.
- (b) Security from damage.
- (c) Accessibility for maintenance.
- (d) Facilities for extension of plant.
- (e) Economy of cost.
- (f) Reduction of fire risk.
- (g) Neatness and appearance.

The best lay-out, including such points as selection of runs, type of cable, and methods of supporting cables, will strike a sound balance between these somewhat conflicting requirements, their relative importance varying with the class of installation.

*Damage to be Guarded Against.*—Damage may arise from mechanical injury, damp, and from direct or indirect contact with other plant carrying electric current. Wires or cables should be kept not only well clear of electric lighting or power circuits, but also of all metallic pipes, particularly compo. gas-pipes.

*Protection Against Damp and Mechanical Injury.*—Damp is the chief enemy. Main frames or other equipment on which cables are terminated should be in dry situations. Cable runs should be selected which avoid the dangers from damp or mechanical injury. Generally, lead-covered cables are used for trunk and telegraph wiring, as a high standard of insulation is necessary, and for subscribers' wiring in damp situations. Cheaper types of braided cables are used for subscriber and junction wiring in dry situations. Lead-covered cables should be used in under-floor runs where it is necessary to protect from mechanical injury, rats or fire danger.

Wood casing or iron troughing is used as a protection against mechanical damage.

Wires or cables passing through floors to a higher or lower level require special protection against floor sweeping and washing. The protective casing or covering used for this purpose should project above the floor level.

Unless properly constructed cable chutes are built, long under-floor runs should be avoided. Where such runs are unavoidable, sheet-iron floor troughing should be used unless the floors are of special fire and damp-proof construction.

Lift shafts are best avoided for important cable runs owing to the danger of mechanical injury and difficulty of access.

*Fire Risk.*—Lead-covered cables reduce the fire dangers. Braided cables must be made "flameproof" by impregnating the coverings with suitable chemical sizing material which is flameproof but does not absorb moisture.

The ends of vertical chutes should be closed by packing asbestos fibre tightly round the cables to prevent the chute acting as a chimney in the event of a fire. A similar precaution is necessary where a number of cables pass through a floor.

*Economy of Cost.*—Short runs are obviously desirable. For subscriber wiring, dry runs which enable braided cables to be used reduce the cost. Cheap construction on trunk wiring may be false economy. The lay-out of exchange plant is always planned with a view to economy in cabling. In a large subscribers' exchange it is desirable to have the I.D.F. close to the switch sections, relays and meters, even if it is necessary to place it some distance from the M.D.F.



## METHODS OF SUPPORTING CABLES.

In large exchanges, where many cables are involved, special supports are designed for cable runs. For lead-covered cables,

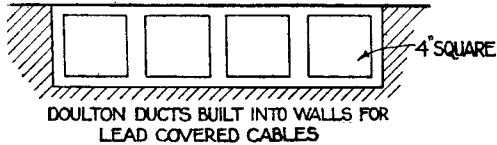


Fig. 1.

conduits or cable chases are usually built into the wall. A common type of conduit is the square Doulton duct shown in Fig. 1. With this arrangement intermediate supports for the cables, even on vertical runs, are not necessary.

If lead-covered cables are run in large vertical chutes, the cables should be secured at six feet intervals by plumbers' tacks

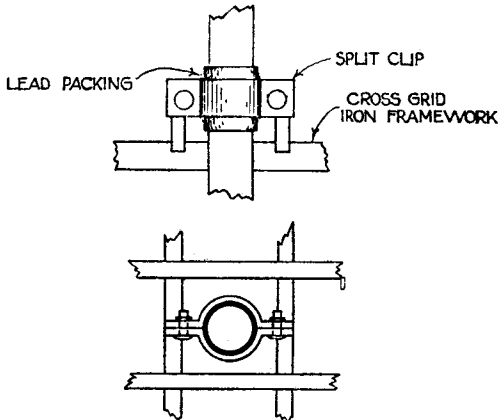


Fig. 2.

*i.e.*, lead strips sweated to cable sheaths. Where the number of cables is very large, it may be necessary to provide a special iron framework with cross bars supporting split clips attached to each cable. Lead packing is placed between the clip and the cable sheath and the clips secured to the cable by screwing up a bolt and nut. (See Fig. 2.)

Where the cable enters the pipe at the top of the run "Plugs, Hardwood," sawn through lengthwise and shaped to the size of the cable should be wedged between the cable and the pipe entering the cable trench.

The method of leading external cables to the main frame is shown in Fig. 3.

Switchboard cables are usually carried on cable racks made by a light flat iron framework supported from the ceiling or walls. Iron troughing suspended from the ceiling is sometimes employed.

It is undesirable to run switchboard cables in closed conduits where there is danger from damp. In vertical runs, where it is necessary to carry them in cable chases, the packing with asbestos fibre at each floor level should be designed to support the weight of the cables.

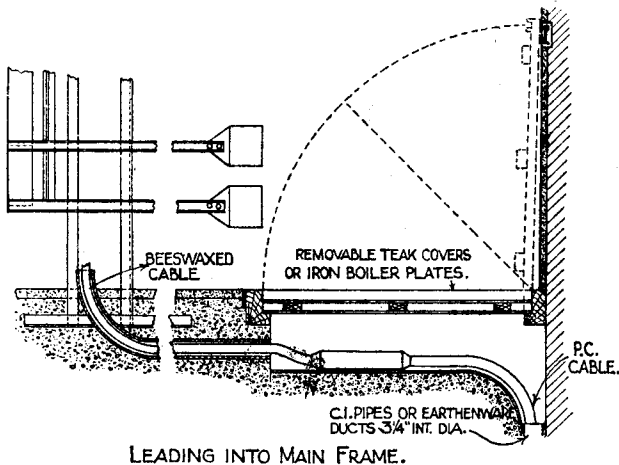


Fig. 3.

In small offices, small cables, if few in number, should be cleated separately to the walls by means of zinc cleats or clips unless protection from mechanical injury is necessary. Wood casing or (where greater cable accommodation is required) iron troughing is used when several cables are run together or where it is necessary to protect from mechanical damage. In cases where it is necessary to carry the wiring externally, lead-covered cables in galvanised iron troughing are employed. Iron troughing used externally should be painted. Lead-covered cables of more than  $\frac{1}{2}$  in. diameter are supported every four to six feet by plumber's tacks. The lead strip or tack is secured to wood plugs driven into the wall.

## CUTTING AND PLUGGING WALLS.

**Cutting Walls.**—Hole cutting and drilling should not be wholly carried out from one side. To prevent splintering woodwork or forcing off sections of plaster, indications of the cutting or drilling tool should be looked for upon the far side. When the breaking out point has been ascertained, the tool should be withdrawn and the cutting completed in the reverse direction. Careful measurement and level drilling will enable a cutting to be made from either side at will.

**Plugging Walls.**—Great care in centring and cutting holes for wall plugging is essential.

The following plugs are available :—

1. Wooden plugs, which are  $\frac{3}{4}$  in. square, from 2 in. to  $2\frac{1}{2}$  in. long and tapered obliquely.
2. Fibre plugs, described as Rawl Plugs.

Larger plugs may be required to carry supports for heavy cables.

They should be made of well seasoned hardwood and cut as shown in Fig. 4.

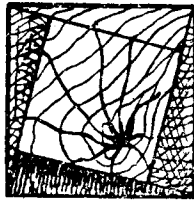


Fig. 4.

A solid wall of not less than 9 in. brick work should be selected where possible. Slab, lath and plaster walls are not suitable and  $4\frac{1}{2}$  in. brick walls should be plugged only as a last resource.

A cold chisel 9 in.  $\times$   $\frac{5}{8}$  in. or a jumper 10 in.  $\times$   $\frac{7}{8}$  in. is a suitable tool for cutting holes for wooden plugs. The hole should be cut a little smaller and also a little longer than the plug.

A special holder and bit are supplied for cutting holes for "Rawl Plugs".

## TYPES OF CABLES AND COLOUR SCHEMES.

Switchboard Cables are employed for wiring subscribers' and junction circuits between the M.D.F., I.D.F., switch sections, and apparatus, and also for apparatus wiring in trunk switchboards. The cable, which usually has a  $9\frac{1}{2}$  lb. tinned copper conductor, is provided in four sizes, 21, 42, 63, and 84 wires. It will be noticed that all these figures are multiples of 21, each cable being designed for the wiring of 20 subscriber or junction positions with one spare wire, or group of wires, for clearing faults; 21, 42, 63 or 84 wire cables are employed according to whether 1, 2, 3 or 4 wires per position are necessary.

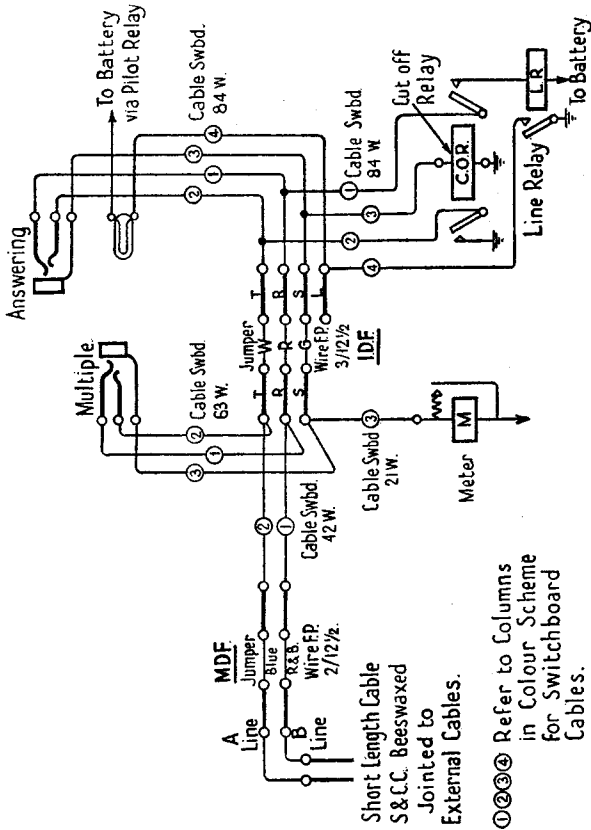


Fig. 5 illustrates part of the wiring of a C.B. exchange to show the use of switchboard cables. The cables are made flat, oval, or round to suit the various requirements. The conductors are insulated with layers of silk and wool, but earlier types were insulated with silk and cotton. The outer coverings consist of wool, paper tape, waxed paper, lead foil and flameproof braiding. A high insulation is, therefore, possible in dry situations only.

#### Colour Schemes for Switchboard Cables.

Pairs.		Pairs.	
Column 1	Column 2	Column 3	Column 4
1. Blue	White	22. Red, blue	Red
2. Orange	"	23. Red, orange	"
3. Green	"	24. Red, green	"
4. Brown	"	25. Red, brown	"
5. Slate	"	26. Red, slate	"
6. Blue, white	"	27. Red, blue, white	"
7. Blue, orange	"	28. Red, blue, orange	"
8. Blue, green	"	29. Red, blue, green	"
9. Blue, brown	"	30. Red, blue, brown	"
10. Blue, slate	"	31. Red, blue, slate	"
11. Orange, white	"	32. Red, orange, white	"
12. Orange, green	"	33. Red, orange, green	"
13. Orange, brown	"	34. Red, orange, brown	"
14. Orange, slate	"	35. Red, orange, slate	"
15. Green, white	"	36. Red, green, white	"
16. Green, brown	"	37. Red, green, brown	"
17. Green, slate	"	38. Red, green, slate	"
18. Brown, white	"	39. Red, brown, white	"
19. Brown, slate	"	40. Red, brown, slate	"
20. Slate, white	"	41. Red, slate, white	"
21. Red	"	42. Red, white	"

21 wire cables are made by cols. 1 or 3.

42 wire cables are made by cols. 1 and 2 twinned.

63 wire cables are made by cols. 1 and 2 twinned and col. 3.

84 wire cables are made by cols. 1 and 2 twinned with 3 and 4 twinned.

Wires coloured as col. 2 are used for tip or "A" wire.

Wires coloured as col. 1 are used for ring or "B" wire.

Wires coloured as col. 3 are used for sleeve or test wire.

Wires coloured as col. 4 are used for lamp.

Cable, E. and C. Core (lead covered), is used for battery leads, power generator leads, wiring of supervisors' desks, and other cases in subscribers' exchanges where under-floor runs

are necessary, or where, for other reasons, protection from damp or injury is required. It is made in 1-pair, 3-wire, 4-wire, 4-pair, 6-pair, 7-pair, 9-pair and 11-pair sizes with 10-lb. conductors, and 1-wire, 5-pair and 11-pair with 20-lb. conductors. The wires are coloured in a scheme similar to switchboard cables. The conductors are insulated with enamel and covered with two lappings of cotton impregnated with wax.

**Cable, Silk and Cotton Core, single (lead covered)**, was used for trunk and telegraph wiring from main frames and protector cases to test boards and switch sections, and for subscriber exchange wiring in special cases when protection from damp was required. For the latter purpose it has been superseded by Cable E. and C.C., whilst for trunk wiring a higher grade Cable, Cable E.S. & W.M.T. n.pr/20 or a termination made with Wire V.I.R. 2 pr/20 M.T. is used.

**Cable, Enamelled, Silk and Wool Core, Twin** is used in short lengths for terminating paper core subscribers' cables and also for short runs in internal trunk wiring.

For long runs it is more economical to use a paper core cable terminated at each end by a short length of Cable, Enamel, Silk and Wool Core.

#### TERMINATING CABLES.

**Cable Waxing.**—The ends of switchboard cables must be waxed before connecting to tag strips. The outer covering and wrappings are first removed for a length equal to the length of required lacing *plus* two or three inches, care being taken that the wires are not damaged in the process. The stripped ends are then immersed in beeswax at boiling point and kept immersed until all air bubbles have ceased to appear on the surface of the wax. When taken out, the wires are carefully wiped with a clean cloth to remove superfluous wax. If the wax is absolutely at boiling point before immersion and reasonable care is exercised, not only will the silk and cotton coverings of the wires be saturated and coated, but the molten wax will have crept well up beneath the covered portion of the cable and have effectively sealed it against the entrance of damp.

The following three points to avoid fire risks are important :—

1. The proverb which says a watched pot never boils does not refer to a wax pot. The unwatched pot boils and also may cause a bad outbreak of fire.
2. A bucket filled with sand is a valuable stand-by.
3. Wire cuttings, cable strippings, or other inflammable material should not be allowed near a heating wax pot.

**Cable "Forming" and "Lacing."**—These are terms applied to the work of leading wires out of a cable at short spacings for the purpose of making them off upon soldering tags. The principles are explained below.

**Cable Forming or Lacing Board.**—This is illustrated in Fig. 6. It is a stout frame of wood used for the purpose of lacing cable wiring for switchboard jacks. *A* is a button or clamp holding the cable firmly in position while being formed. *B* is a row of ten pins spaced along the frame round which, as shown, one pair or one set of wires is bent at right-angles to the cable. *C* is a sliding section of the frame which can be adjusted to

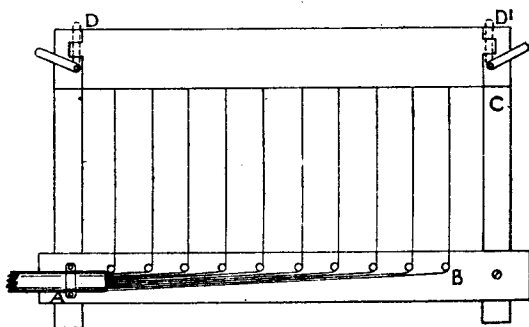


Fig. 6.

the length of lacing required. The jack to be wired lies between *D* and *D*<sup>1</sup>, which indicate the clamps holding it rigid when turned to the dotted position. The tags of the jack, of course, point in the direction of the pins. The board here described provides a means for forming out and lacing the cable wires and for soldering them to their respective tags on the jack.

The lacing of the cable, a very important part of the work, is carried out with lacing twine immersed before use in molten wax. The lacing should commence with a double turn at the butt of the cable and continue in single twine to the end, one tie being made at the point at which each pair or set of wires is turned out from the cable. It is essential that in every tie the knot be self-binding, or the lacing will run back to the butt and the cable lose its formation. The proper knot and the

general appearance of the lacing are shown in Fig. 7. All spare wires are continued to the end of the lacing, and a short length there turned back under the last one or two ties.

Where space is available for cables, adequate length of lacing should be given to allow easy access to tags. On main frames and I.D.F.'s the cables should be run on the uprights

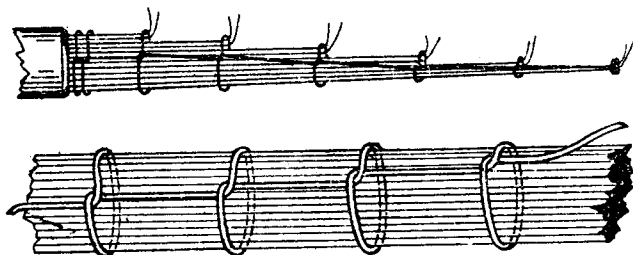


Fig. 7.

behind the fanning strips or tags, so as to give ample room for jumpering.

**Soldering to Tags.**—When the ends of the laced-out wires are stripped preparatory to making them off upon tags, the insulation should be pushed well back and twisted firmly round the wire. To prevent nicking, or otherwise weakening the conductor, all stripping should be carried out by flat-nosed pliers and not, as is sometimes done, by those of the cutting type. The bared wire is drawn through the hole in the soldering tag until the insulation is reached. Care is necessary in the subsequent soldering to ensure that the insulation is not damaged by the hot iron. Considerable practice is necessary to obtain proficiency in tag soldering. The iron should not be overheated, and should be frequently cleaned and tinned. Resin core solder should be used for all soldering or tinning of soldering irons.

All surfaces to be soldered must be clean.

**Terminating Paper-Core Cables.**—Subscribers' Cables are terminated by short lengths of beeswaxed Silk and Wool Twin Cables. The paper-core cable should be carried well inside the building, and slightly beyond the point at which internal wiring is adversely affected by damp.

Trunk Cables not carrying phantom circuits and all Junction Cables are terminated on Main Frames by short lengths of beeswaxed Silk and Wool M.T. Cable. This cable is lead



sheathed and of the multiple twin type. The conductors are insulated with enamel, in addition to the silk and wool coverings. In terminating enamelled wire cables, care must be taken to remove the enamel before soldering to the tags.

Special arrangements are necessary for terminating long distance trunk cables which carry phantom circuits, so as to maintain a proper balance and a very high insulation up to the transformers. Wire V.I.R. 2pr/20 M.T. is used for this purpose. Telegraph cables are also terminated with the same type of wire.

### JUMPER WIRES.

When cables have been laced out on tag strips they should not be disturbed unless renewal or replacement of equipment or cables is necessary. Jumper fields are provided, e.g., in M.D.F. and I.D.F., to enable cross-connections between cables to be made or altered without disturbing the cabling.

The types of wire used for jumpers are :—

*Wire, Flameproof—*

*Single.* Coloured White.

*Twin.* Coloured Blue ; Red and Blue.

*Triple.* Coloured White ; Red ; Green.

*Quad.* Coloured Red ; Red and Green ; White, Green

In damp situations *Wire, Enamelled and Flameproof, should be used.*

A consistent colour scheme should be used in jumpering so that one colour is always used for the same purpose. Any jumper wire made spare should at once be removed.

### POWER LEADS.

Lead covered cables should always be used for power distribution leads. Cable E. and C.C. 5pr/20 is the usual type for wiring Battery Racks or Power Distribution Boards to switch sections, for both signalling and speaking purposes. As far as possible cables for power leads should be run apart from other wiring. Cable E.L., Impregnated Paper Core, is used for secondary cell leads.

### EARTH CONNECTIONS.

A very low resistance earth is required at telephone exchanges and large telegraph offices. Several small earth plates in parallel are better than one large earth plate. *Wire, copper, soft, 19/16 and 37/16, is employed for the main earth lead, which should be run as straight as possible, especially from lightning protectors.*

Wire, copper, soft, 19/16 strand is sufficient at exchanges from 300 to 5,000 lines and 37/16 at larger exchanges. At exchanges with wall pattern switchboards the earth wires from the plates are continued to the protectors by means of wire, copper, soft, 3/20 or 7/18 strand, and at exchanges with floor pattern switchboards by means of wire, copper, soft, 7/16 strand.

*Wire, E. & F.P.*, 1/20, is used for connecting the common earth to switch spring tags.

All metal frame work should be earthed.

#### LABELLING AND RECORDS.

Great care is necessary to ensure that labelling and records are clear and kept up-to-date. Card records should be kept of all cross-connections on main frames and I.D.F's. For permanent work labels should be engraved.

---

S.O. Code No. 43-9999

# LIST OF Technical Pamphlets for Workmen

(Continued)

## GROUP D—continued.

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.

## GROUP L.

1. "Safety First" for P.O. Engineering Workers.