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THE DESIGN AND MANUFACTURE OF CABLEFORMS IN THE TELEPHONE INDUSTRY

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A high proportion of the labour force in a telecommunications factory is employed on wiring, and this operation accounts for a major part of the total cost of telephone apparatus. This article details the methods used in the design and fabrication of complex cableforms for point-to-point wiring.

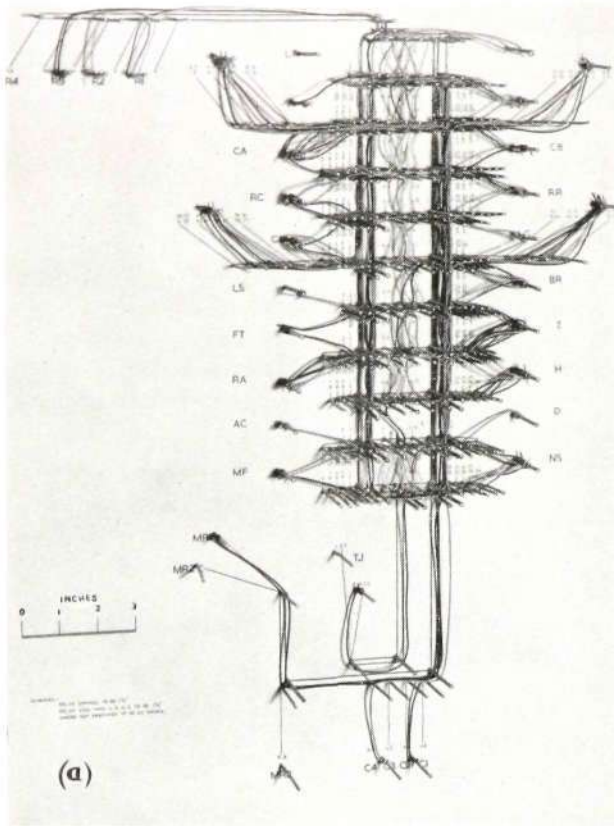
IN the electronics industry printed circuit techniques are, to some extent, replacing the conventional method of making electrical connections by means of insulated wires. Printed circuits are also finding an increasing number of applications in the telephone industry, though these are chiefly on sub-assemblies; for practical and economic reasons the use of insulated wires laced together in the form of a cable must be retained in the majority of instances. It is frequently necessary for large numbers of conductors to follow the same routes, and the space available for the laying of such conductors is often very restricted. Moreover, the wires have to be connected to components having a

comparatively large number of wiring tags; on B.P.O. 3000 type relays, up to 23 separate terminating points may exist. The wiring routes can be of complex shape and connection to apparatus on hinged mountings or gates may also be involved. Examples of such cases are to be found on apparatus racks, manual switchboards and desks, and plug-in type units equipped in telephone exchanges throughout the world.

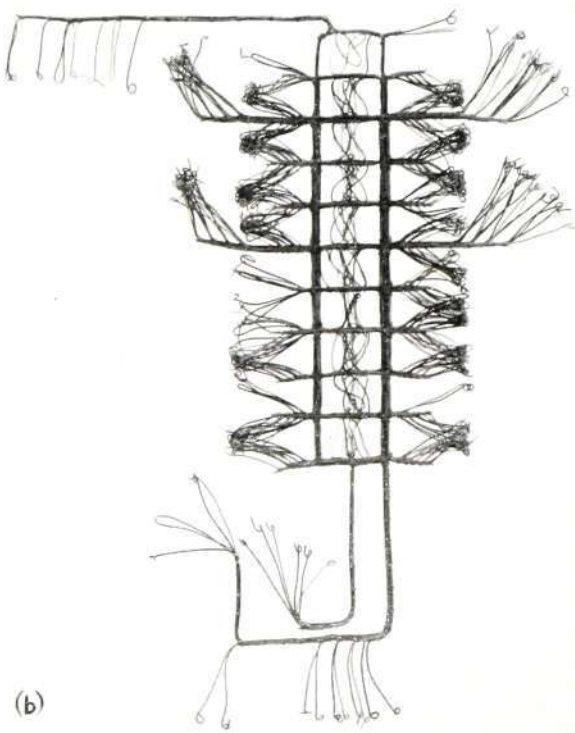
To illustrate the method of providing the requisite electrical connections for equipment of this type, the factors involved in the design and manufacture of handmade cables used in British Post Office type



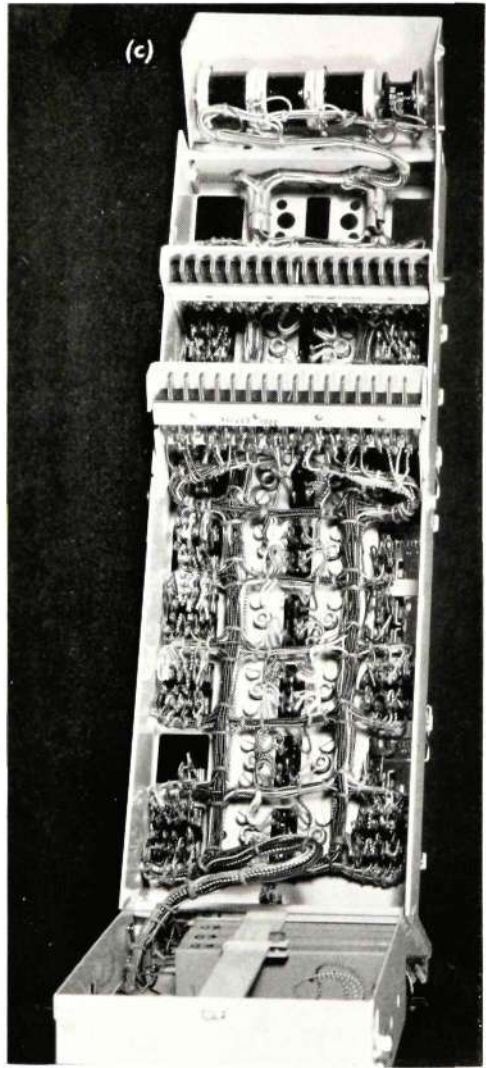
Fig. 1—The laying of a rack cable for a P.B.X. apparatus rack



(a) The partly layed cable is built up on top of a cableform drawing



(b) The completed cable removed from the board



(c) The cable wired in position in the relay set

Fig. 3—Stages in the manufacture of a typical cable for a B.P.O. Type 2000 relay set

table and the earth connections last. This ensures that when the cable is fitted to the mounting plate, the battery connections are remote from the earthed plate—a safeguard in the event of the insulation becoming damaged.

The cableform drawing proper indicates, by means of interconnecting arms, the actual size and shape which the finished cable will take when all the wires have been laid-in and laced together. Unlaced wires, known as skimmers, are brought out from the arms at points which are convenient for connection to their associated wiring tags. They are indicated by means of single lines marked at their free ends with their relevant tag letters or numbers. Groups of skimmers serving the same item of apparatus are marked with the appropriate component nomenclature, such designations corresponding with those quoted in the running table. Skimmers are normally drawn to their full required length but where this may cause congestion they are shortened and covered by a referring note. Their lengths must be sufficient to allow the wires to be easily removed and re-terminated since this may be necessary during normal maintenance replacements.

When designing a cableform of this type, the first step is to plan the shape which the cable must take in order to serve its associated apparatus in the best way and to take into account the space which will be available for it. The cable arms must be restricted to a width such that they will not foul wiring tags, screws, nuts or studs, etc. since contact with sharp edges may cause chafing which will ultimately impair the wire insulation. Congruous with this requirement is the fact that should the arms be drawn too narrow, the cable cross-section may tend to build up into an oval shape. As far as is practicable, the width of all arms, relative to the number of wires contained at any point, should be such as to give an approximately circular cross-section. This is especially important at points where the cable is fed through apertures or bushes, or is held in position by cable cleats.

The eventual soldering of the wires to their tags must also be borne in mind. On this type of equipment the space available for the manipulation of the soldering iron is somewhat restricted, and the cable must be designed in such a manner that the wiring tags are obscured as little as possible and that the wiring can be carried out with the minimum risk of the insulation being burned. The wiring tags of certain components are accessible only with difficulty,

and to facilitate soldering, these items may be temporarily released from their normal mounting positions. The associated cable arm must, therefore, be long enough to reach the item when displaced from its normal position. The length and general shape of the cable arm should also permit it to easily fall into place when the wired component is returned to its final location.

Apart from the initial wiring operation, it is sometimes necessary to remove a component from its normal position, for maintenance adjustment purposes, without disconnecting its wired leads; this requirement arises for example in the case of a uniselector mounted on a relay set plate. Here again the cable arm must have sufficient flexible length to allow the withdrawal of the item, whilst, at the same time, avoiding excessive slack which would require stowing and which might possibly come into contact with moving parts.

Cable arms feeding apparatus mounted in covers or boxes hinged on the main plate are arranged to leave the main cable as near as is practicable to the point of hinging. They should be of sufficient length to permit the mounting to open to its fullest extent and should be formed in such a manner that rubbing action and the possibility of wire breakage is reduced to a minimum.

Points at which the cable will take up a fixed bend when fitted to the apparatus are drawn as near as possible to their actual shape, since in lacing the cable such points are double-stitched to assist in retaining their form without the necessity of tying to adjacent equipment.

As a general rule, all wires running together for a distance of more than approximately three inches are drawn in the form of an arm, as opposed to separate skimmers. This ensures that the wires will eventually be laced together. There are, however cases, for example on the B.P.O. 2000 type selector, where it is necessary to thread wires through an aperture in the casting and through confined spaces between various parts of the selector mechanism. Here a formed and laced cable would be too rigid to permit of easy manipulation and it is therefore necessary to arrange for long skimmers to be fed from a convenient point on the main cable. These loose wires can be fed through the mechanism as required and skimmers serving a particular group of wiring tags are, as necessary, tied together by means of a single stitch to assist in identification during the wiring operation.

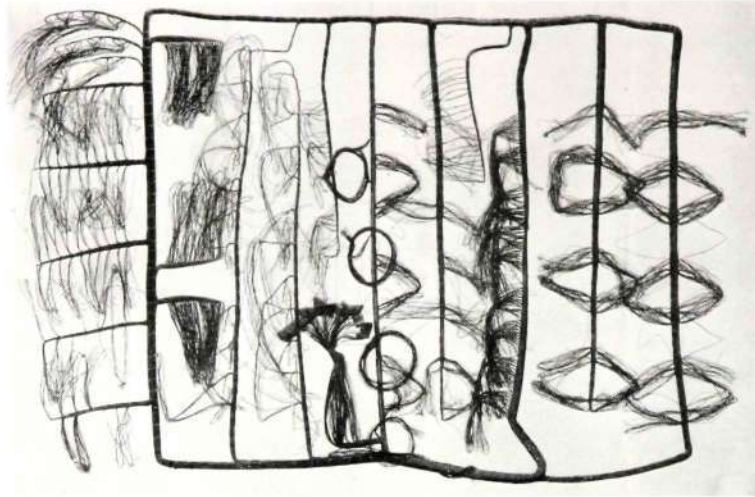


Fig. 4—A completed cable of a P.B.X. apparatus rack.
This is shown under construction in Fig. 1.

THE MANUFACTURE OF THE CABLE

A print of the cableform drawing is first laid on a stout wooden board. No. 12 gauge round headless nails, approximately of $2\frac{1}{2}$ to 3 inch length, are driven firmly in at each corner where arms intersect and on the inside of all bends in branch arms. These nails mark the outline of the cable and fix the various routes along which the wires are to be laid. Lighter gauge, No. 14, nails of a similar type are then driven in at all points from which skimmers are to be fed and also at points which mark the free ends of skimmers. Where a number of skimmers leave the cable in close proximity to each other, one nail can serve as a common terminating point and so save labour and avoid the congestion which would occur if each skimmer had an individual terminating nail. This results in certain skimmers having a length slightly in excess of that required but this is of no consequence since all the wires are subsequently cut to length in readiness for wiring.

When all nails are in position the laying of the wires commences in the order specified in the running table, all wires of similar colour being run in before proceeding with the next colour. At the starting point of each run, the wire is given one turn round the appropriate skimmer nail and then taken past the nail where it is to enter the cable. From there the wire is laid between the nails marking the main framework of the cable and taken by the shortest possible route to the skimmer nail corresponding to the next point in the wiring run. Should this be an

intermediate point, the wire is left uncut, looped round the nail, taken back into the arm and thence to other points in the same run similarly. When the final point is reached the wire is given one turn round the terminating nail and cut. It is important to ease the stress on individual wires at bends in the cable, and sharp bends and kinks must be avoided. The laying process is continued until all runs have been covered. The wires are pressed down the board and then lifted a short distance off the board by means of a 'prodder' tool to facilitate lacing. The partly made cable shown in Fig. 3(a) has been laid on a cableform drawing for a typical 2000-type relay set. The photograph illustrates the positioning of the nails and the method of terminating, laying and looping the wires.

The lacing of the wires into a self-supporting cable is carried out with fine (4 strand) lacing twine, either waxed or p.v.c. covered depending on the type of wire insulation being used. The twine must be drawn sufficiently tight to hold the wires firmly in position whilst at the same time avoiding damage to the insulation. Each section of lacing commences and terminates with a double knot, and intermediate stitches or knots are made by means of half-hitches so that if the twine should be cut or break on either side, the knot will not slip. Stitches are made at approximately $\frac{3}{4}$ -inch intervals and adjacent to all nails. Double stitches are made at all bends in order to assist in holding the cable to the required shape and points at which arms intersect are tied by either double or cross stitching.

All lacing knots are made on the uppermost side so that they are hidden from view when the cable is fitted to the equipment. At points where skimmers enter an arm and feed off in opposite directions the lacing must be taken through the loop so formed to ensure that one stitch may securely hold all wires. The lacing commences with the horizontal members and each is treated as a separate section. The vertical members together with the top and bottom horizontal arms are then laced as a complete section, and finally all branch arms are laced. Jointing knots are not normally tied in the twine, the loose end of one section being left long enough to be laced in for a short distance with the wires of an adjoining section.

When the cable has been completely laced it is removed from the board and is then ready to be prepared for fitting and wiring to the apparatus. Fig. 3(b) shows the completed cable and Fig. 3(c) the same cable wired to its relay set. In Fig. 3(c) it will be noted how the arms serving the top cover and lower capacitor mounting are looped to permit the unrestricted hinging of these items without causing any strain on the soldered connections. In this illustration the lower plug-strip has been displaced from its normal position to show the arrangement of its associated cable arms.

RACK AND MANUAL SWITCHBOARD CABLES

Although the cables required for apparatus racks and manual switchboards and desks are very much larger than those provided for plug-in type apparatus, the basic principles of design and manufacture are similar. As a general rule the space available for these larger cables is not so restricted as in the case of relay sets and selectors with the result that large numbers of wires can be accommodated in a minimum number of arms.

A main rack cable consists essentially of arms which run vertically down one or both sides of the rack and which have horizontal branch arms feeding the various apparatus shelves. Subsidiary arms to miscellaneous mountings, fuse panels, connection strips, etc. are provided as required and connections which are local to a particular shelf are normally made up into a separate shelf cable. Each form is drawn full size except that long straight arms are shown broken and indication is given of the distance to be allowed between each end of the break. Prior to being nailed on the cable board the cableform drawing is cut at the breaks and the separate sections are spaced at the specified distance.

The closed box-type formation of a cable for a plug-in type unit provides, in some cases, alternative routes of equal length along which a wire connecting two points may be laid. With a rack cable such alternative routes do not exist and it is therefore possible to count the number of wires which will be located at any particular point. Since the gauge of wires is also known the diameter of the completed cable can be calculated and the widths of the arms are drawn accordingly on the cableform drawing.

Branch arms serving apparatus on hinged mountings and those serving mountings for relays, etc. on switchboards or desks are designed to allow sufficient slack from the main vertical arm to permit the mountings being moved through 90 degrees to facilitate access to the wiring points. Connections to key, jack and lamp strips are arranged in the form of long skimmers for the same reason.

Because of the size and weight of this type of cable it is necessary to use stout 4 in. nails to mark the bends on main arms. These are often covered with p.v.c. sleeving to avoid damaging the wires when the cable is removed from the board particularly when lapped and lacquered insulation is used. Medium or thin nails are employed at other points depending on the number of wires involved and the strength required. At bends in wide arms, two rows of closely spaced nails are inserted across the width of the bend and equal numbers of wires are laid between adjacent nails. This assists in maintaining a regular cable cross-section at such points by avoiding the tendency, which would otherwise occur, for the wires to build up against the inside nail. Temporary ties are made on each side of the bend to hold the cable in shape while the nails are withdrawn and lacing is carried out. This arrangement of nails can be seen in the bends in the top right-hand side of the cable in Fig. 1.

Lacing twine of 4, 6 or 12 strands, waxed or p.v.c. covered, is used depending on the size of the arm. On the majority of rack and switchboard cables the thin—6 strand—twine is adequate, the medium—12 strand—generally being required only for arms exceeding $\frac{3}{8}$ in. diameter and for tying cables together. For arms exceeding 1 in. diameter it is advisable to employ medium twine used double to ensure that if one twine breaks the wires will still be held in position. Lacing knots are made at all points where skimmers are brought out and, where the distance between such points exceeds 1 in., additional evenly spaced knots

are made at approximately 1 inch intervals. Fig. 4 shows the completed cable for a P.B.X. apparatus rack, the laying of which is illustrated in Fig. 1.

CONCLUSION

A very large section of the labour force in a tele-communications factory is employed on wiring and this operation accounts for a large proportion of manufacturing time. The cutting, stripping, terminating and soldering of the wires requires the

employment of highly trained workers and accounts for a major part of the total cost of telephone apparatus. A carefully designed and accurately made cable which can be readily fitted to the equipment can, however, materially assist in reducing to a minimum the time and labour spent on wiring. The method of laying and lacing the wires as described results in a neat and effective means of providing the requisite electrical connections for the most complex circuit arrangements.

