

# THE ETELCO BULLETIN

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The logo for Etelco Limited, featuring the word "Etelco" in a stylized, cursive script font with a thick underline that sweeps under the letters. Below the script, the word "LIMITED" is printed in a simple, bold, sans-serif font.

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THE



'ETELPHONE'  
COLOUR RANGE

## THE \* 'ETELPHONE'

W. SINCLAIR — Apparatus Engineering Department

*Many new features are embodied in our latest telephone. Improved methods of construction and the choice of materials which are durable but can be given a superior finish and colour have resulted in the production of an instrument of very attractive form and appearance. The dial markings have been laid out so as to improve their legibility, and new types of desk and handset cord can be fitted. The Etelphone is provided with a regulator which compensates for the effect on the transmission performance of variations in the line length. Among the special features which can be provided on request are means for adjustment by the subscriber of the loudness of the bell, and a dial lock to prevent unauthorized calls from being made. The instrument can be supplied as a table or a wall mounting telephone, and a version with tropical finish is available.*

**T**HE 'Etelphone', latest addition to the Company's range of telephones, meets a demand for an instrument which is pleasing in appearance, available in a wide range of light-fast, attractive colours, has outstanding technical performance and is suited to modern manufacturing techniques.

Since the Company in conjunction with the British Post Office introduced the P.O. 300-type telephone in 1936, there has been steady development of most of the component items until, at the present time, only the transmitter remains substantially unaltered. Throughout this period, however, the main external lines and the internal layout have remained unchanged, so that the time was ripe for a new look at the subscribers' set as a whole. The first reported reactions to the instrument in Britain, the Commonwealth and many foreign countries have been so favourable as to promote a real confidence that it will be a worthy successor to the twenty-three-years-old P.O. 300-type.

Up to the present, British telephones of moulded type have been made in compression moulded thermo-setting plastics, although thermo-plastics have been used to provide a limited colour range. The new

instrument, particularly in the design of the handset, exploits the possibilities of injection moulding. Its simple lines, which are largely functional in their derivation, are seen to advantage in Fig. 1 and present a pleasing appearance which blends readily with a wide variety of styles.

The legibility of dial numbers and letters is vastly improved by the exterior designation ring. On C.B. telephones an attractive dial dummy with a label for the subscriber's number, replaces the dial.

The mechanical design of the set presents many novel features. Notable among them are the way in which the same basic instrument is used as a table set



Fig. 1—The 'Etelphone'—Auto Two-tone version with coiled cord

\*Trade Mark



Fig. 2—The 'Etelphone' Auto Wall Type

or for wall mounting, (see Fig. 2), and the simple manner in which the case is attached. It is freed from the base by releasing two screws without inverting the instrument and may be lifted off to give easy access to all the components without affecting the working of the set. The whole internal arrangement is designed to facilitate maintenance operations.

The provision of an 'off-hook' position for the handset is a useful feature on a table telephone and essential for a wall telephone. Figs. 3 and 4 show these positions on the Etelphone. In Fig. 3 also may be seen the metal carrying handle across the cradle.



Fig. 3—'Off-hook' Position of Handset

#### MOULDINGS

Modern plastics are extensively used in the construction of the major components. The materials have been selected after comprehensive tests and investigations in our Laboratories. These have been supplemented by a series of field trials conducted in collaboration with customers at home and overseas during the last few years. Reports submitted by a number of Administrations on the performance of telephone instruments employing a variety of plastics under differing climatic conditions have provided valuable information on the relative merits of the materials, and this has largely influenced the selection of the plastics used for the Etelphone.

The handset and case are injection moulded from Diakon, a pigmented thermo-plastic acrylic resin which combines high quality finish and general appearance with durability. This plastic is particularly satisfactory in withstanding tropical conditions where high humidities and temperatures prevail. The mouldings have good impact strength and possess considerable hardness and abrasion resistance, so that the characteristic high polish is maintained.

No metal inserts are incorporated in the handset or case, a feature which has been a principal design



Fig. 4—'Off-hook' Position Wall Telephone

objective. The form is therefore one of robust simplicity, with consequent advantages in the stability and technical properties of the mouldings. The outer surfaces are free from recesses, while the smooth profiles of the handset and case facilitate cleaning.

The instrument base is moulded from high impact polystyrene which combines mechanical strength with excellent insulating properties. This material does not become corroded and therefore has advantages over metal. Again, the material and form of the base were determined after extensive trials under practical conditions which have been conducted for several years.

The Company has installed modern equipment and plant for the production of all the telephone instrument mouldings, which are subjected to close technical control to ensure uniform high quality. Strict attention is also given to the internal mouldings, in which nylon, polyvinyl chloride, clear acrylic resin and phenolic mouldings of various types are used. Each of these plastic applications has been the subject of close technical study.

#### COLOURS

The telephone is available in a wide range of colours, the standard shades being Black, Ivory, Topaz Yellow, Concord Blue, Lacquer Red, Two-tone Grey and Two-tone Green.

Behind this simple fact lies an extensive programme of painstaking development to establish a sufficient degree of control over the moulding of colours to

ensure that not only will the various parts of instruments be produced in matched, light-fast colours, but that replacements also will be accurate in shade. To do justice to this development work would necessitate a separate article, but it is worthwhile to give a brief review of what has been entailed.

Acrylic resin is basically colourless, transparent, and unaffected by exposure to the sun. The required shades are produced by the addition of pigments, and the fastness of the colouring therefore depends primarily on this processing.

Until recently the manufacture of coloured acrylic compounds has been undertaken by the supplier of the plastic materials, and the moulder has been mainly concerned with the techniques of the injection moulding processes. Any adjustment made to the colours or type of pigments has therefore been remote from the moulder, with consequent delay and difficulty. The Company has installed a relatively new 'dry-mix' process which has been adopted for the colouring of Diakon for Etelphones. The acrylic resin is supplied in a new and very finely divided form. Carefully selected pigments are incorporated into this polymer by tumbling in specially constructed barrels so that uniform dispersion of the pigments is achieved. The moulding powder thus prepared provides a number of advantages in the close control and adjustment of the shades, especially when used in conjunction with appropriate injection moulding equipment. Pigments can be selected which are specially suitable for

the injection processes and have properties most advantageous to the finished product in terms of fastness to light and stability under adverse conditions.

The long-term maintenance of colour is very important to the user Administrations, and the standard of colour fastness achieved is very high. The minimum standard

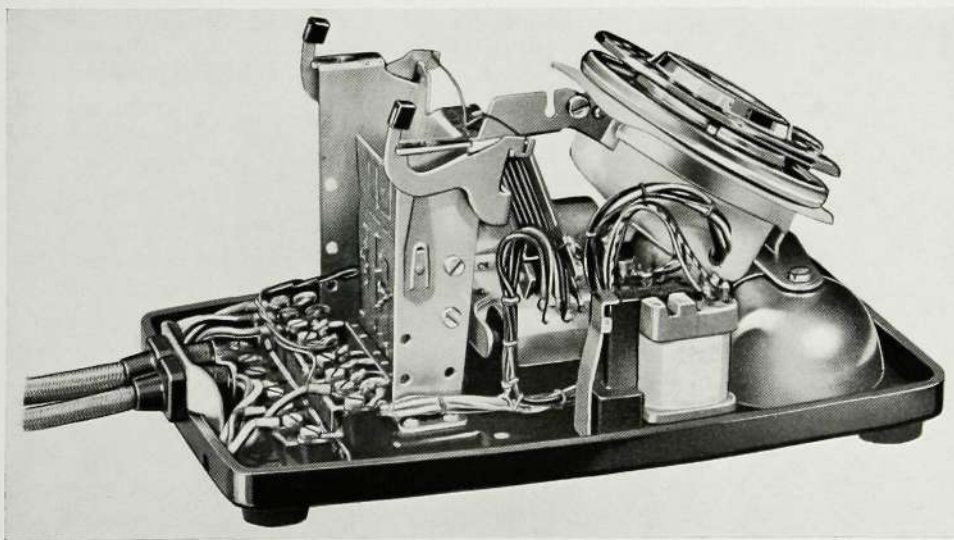


Fig. 5—Base Assembly

of No. 7 in accordance with B.S. Specification 1006 is maintained, and this has been confirmed by exposing the material to natural sunlight during tests extending for some years. A No. 7 degree of fastness ensures absence of fading for indefinite periods under normal conditions of use within the office or home. These results are achieved by the application of high-grade pigments throughout the whole range of shades.

The colours have been carefully developed in co-operation with the Council of Industrial Design and will harmonize with most schemes of internal decoration.

#### INTERNAL LAYOUT

All the components are assembled on the moulded base, (see Fig. 5), and constitute a functional unit completely independent of the case. The shape of the base, which is formed to locate and support the components, considerably enhances the natural strength of the material, the insulating properties of which allow inset terminals to be used. A generous number of terminals have been provided to cater for the many special requirements of our customers. A terminal and three recesses provided behind the induction coil are used for anchoring the dial connections when no dial is fitted, in which case the impulse spring connections are commoned at the terminal, and the tags on the wires from the other three springs pressed into the recesses.

The use of fixing screws has been avoided wherever possible, the main bracket being riveted to the base and the induction coil and capacitor secured by clips. The dial mounting bracket is shaped to hook in the plate above the bell domes and is held at the top by a single screw. The only screws on the underside of the base are two fixing the ringer unit, and the heads of these are sealed to avoid confusion with the case fixings.

An automatic regulator unit which controls the performance of the instrument on short lines, is plugged into a moulded socket centrally located between the sides of the main bracket, (see Fig. 5). For tropical conditions an alternative unit secured by screws is used and connections are made to terminals in the base of the unit by means of flexible leads fitted with spade tags. The regulator is described in greater detail later.

Lengthy experiments using various materials were undertaken to determine the best shape and moulding material for the feet, so as to eliminate any chance of

their causing pressure marks or stains on furniture. The feet are pressed into holes in the base, certain sections of which are made thin so that they can be cut or pressed out to permit entry of additional cords that may be necessary if, for example, a second receiver is used.

#### CRADLE SWITCH

For the standard of reliability demanded of the modern telephone, adequate provision must be made to prevent failures due to the occasional adverse coincidence of dimensional divergencies within the normal tolerance limits set by sound manufacturing techniques. The use of plungers in the case to operate an internal switch from replacement of the handset has been found as a system to be susceptible to difficulties on this account. A fresh approach to cradle-switch operation and case fixing has effectively

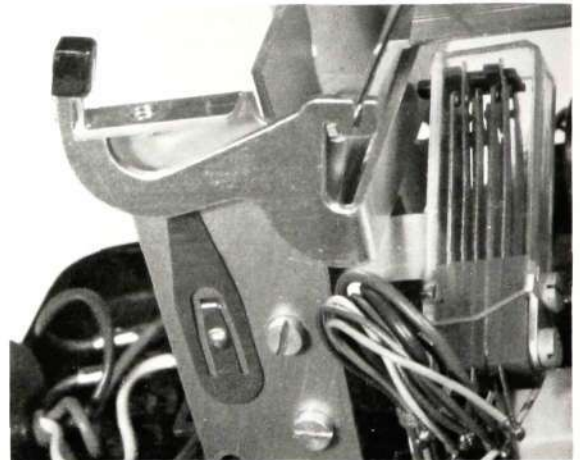


Fig. 6—Switch and actuating bracket

eliminated these variations, giving a corresponding reduction in fault liability. The switch actuating bracket, (Fig. 6), is carried on two knife-edge bearings to minimize friction and is retained by a light wire spring which also biases the bracket to the 'off-hook' position. Arms concentrically radiused round the pivotal point carry moulded tips which project through the case. The arms move in slots in the main bracket to guard against lateral distortion and to ensure adequate clearance when the case is in place.

A latch spring is fitted to lock the actuating bracket in the 'on-hook' position when the case is removed. In Fig. 7, part of the bracket has been cut away to show clearly the operation of the latch. Release is effected by slight pressure on the moulded tips of

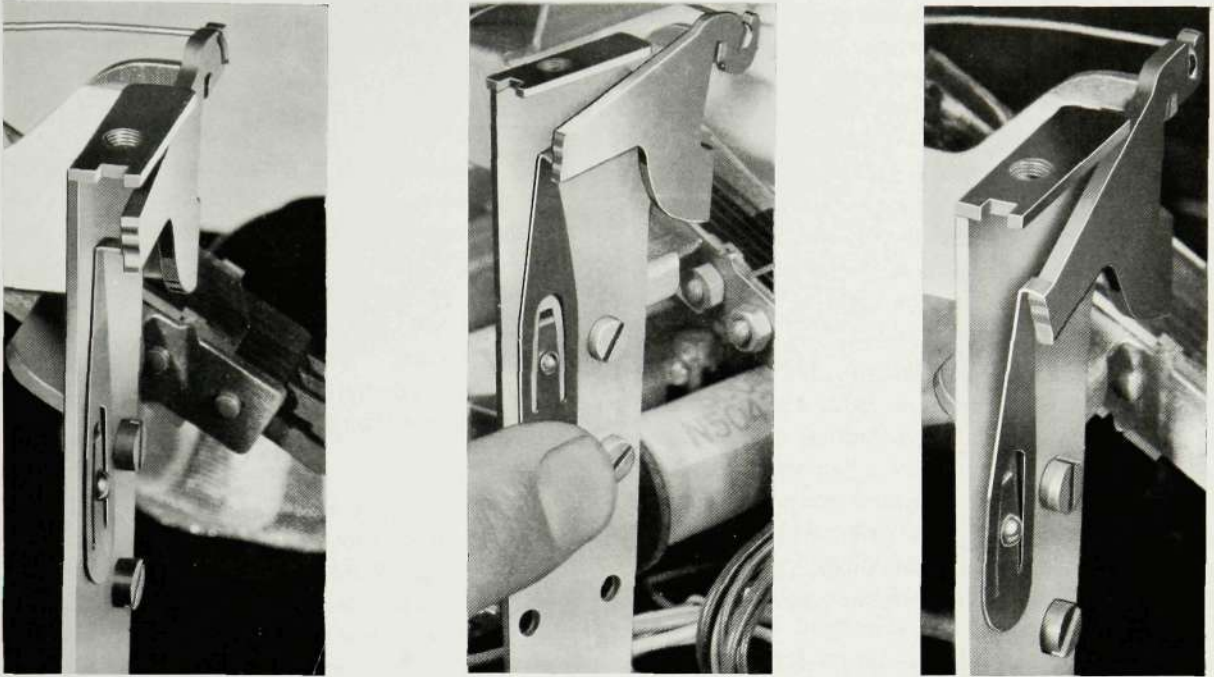


Fig. 7—Operation of latch to hold the switch in the 'on-hook' position when the case is off

the bracket ; thus the telephone is restored automatically to the 'off-hook' position when the handset is replaced, even if the case is fitted with the latch in operation.

The switch contact springs are protected by a transparent cover and the assembly secured to the main bracket by two screws which permit easy adjustment relative to the actuating bracket. A comb lifting plate ensures the correct sequence of contact operation and bears directly on the forward portion of the actuating bracket. The individual springs are divided from the root into parallel twin leaves and the independent action of each contact gives an improved performance without critical adjustment. Palladium has been chosen for the contact material because experience has shown its superior qualities compared with silver,

for example, in locations where the atmosphere contains traces of combustion products. As the contact assembly and actuating bracket are on the same mounting, the cumulative effect of manufacturing tolerances is reduced and the full movement of the bracket can be used. The mechanical advantage so obtained allows high contact pressures to be employed, notwithstanding the use of a light handset.

#### CASE

The case is fixed to the base assembly by two screws which are conveniently located at the top. Their removal can be effected without inverting the instrument or disturbing any adjustment. As shown in section in Fig. 8, these screws pass through the carrying handle and lock the case moulding firmly to the main

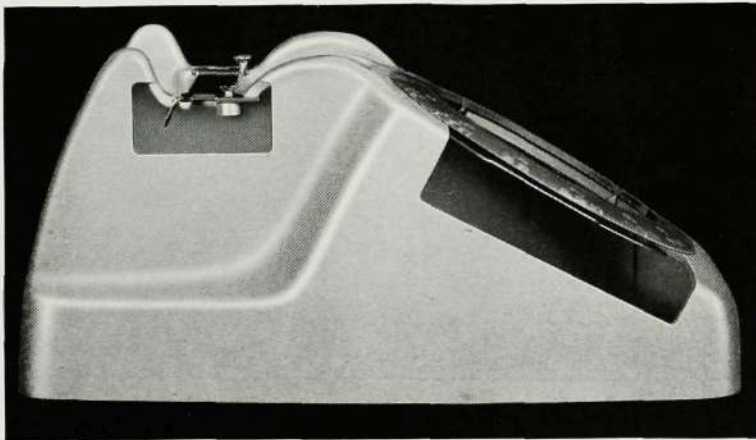


Fig. 8—Case, sectioned

internal bracket so that alignment of the moulded tips on the switch actuating bracket with the holes in the case is automatically ensured. The lifting forces on the handle are taken directly to the internal bracket without strain on the moulding, and any forces due to impact are taken at a very strong section. A number of projections are formed inside the lower edge of the case to give additional support and limit movement. Should a customer not require the carrying handle it can be replaced by a separate small plate under each fixing screw.

So that it may be easily changed, the number ring for the dial is clipped to the case. This method of fixing also allows considerable latitude in the relative positions of the case and dial. Alternative marking to suit customers' requirements is easily provided, as the number ring is moulded in transparent material and the marking is screen printed on the under-face, which is subsequently finished to suit the colour scheme of the telephone. The form of the cradle is such that the handset is received and correctly positioned, no matter how carelessly it may be replaced after use.

#### DIAL

Pending the completion of current development work on a new dial which is being designed expressly for the telephone, the standard B.P.O. No. 12 trigger dial is fitted. A cover, vacuum formed from p.v.c. sheet, is clamped between the frame of the dial and its mounting bracket. In addition to protecting the dial contact springs, the flange of the cover rests against the telephone case and seals the space between dial and number ring.

#### RINGER

A new type of ringer has been developed which utilizes the latest ceramic permanent magnet material and a pressed iron frame to obtain stable performance with simplification. It is completely interchangeable

with the B.P.O. Type 59A ringer and is fitted with a simple wire biasing spring when required to stop bell tinkle on party-line working.

#### INDUCTION COIL

The induction coil is wound on a thermosetting plastic bobbin. The ends of the coil are joined directly to tags embedded in the bobbin cheeks so that the use of flexible end wires and internal joints is avoided. The grain-oriented silicon-iron laminations provide an efficient closed-loop magnetic core of small dimensions. Separate carbon resistors are used for the side-tone balance network, instead of non-inductive windings on the coil as heretofore.

#### CORDS

Several new types of cords using p.v.c. insulated tinsel conductors have been developed for use with the Etelphone. Since previously established types can also be used there is considerable freedom of choice. In one of the varieties, the tinsel conductors are strengthened by a high-tenacity rayon core and insulated with high-grade p.v.c., giving a surface which is very easy to keep clean. One alternative to this has the outer sheath of braided nylon instead of p.v.c., the inner construction being the same.

Unless otherwise specified, the cords will be p.v.c. sheathed and coloured to match the handset, the desk cord being straight and the handset cord coiled. Alternatively, where it is desired to simplify problems of replacement, the same type of cords can be supplied but coloured 'Grebe' for all colours of telephone. 'Grebe' is a silver grey shade ideally suited to harmonize with all instrument colours. A second alternative offered is that of straight cords for both the handset and the desk but sheathed in Grebe nylon braid.

Rubber grommets are fixed to the ends of the cords to prevent strain on the connections. A forked

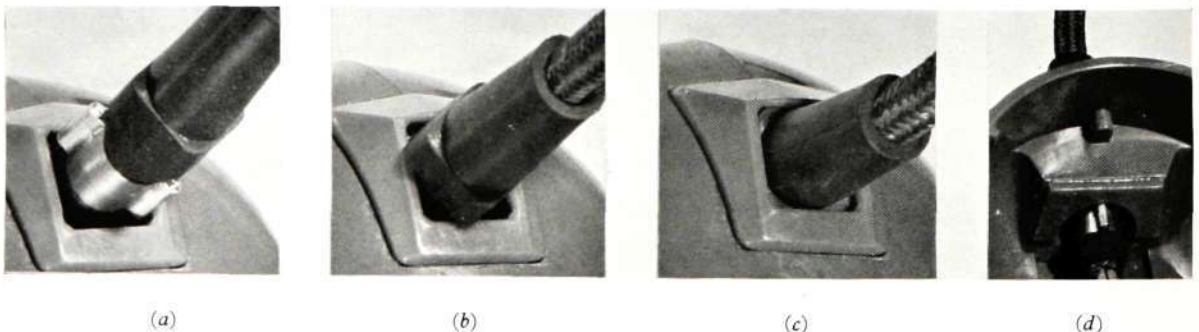


Fig. 9—Showing method of securing the cord to the handset  
(d) is an internal view. Others are external



Fig. 10—The Handset

plate located by grooves in the grommets and holes in the base secures the cord to the telephone. At the handset end a metal ring is clinched over the grommet, and projections formed as the ring is fixed are used to secure it to the handset by a bayonet action which is shown in detail in Fig. 9.

#### HANSET

The shape of the new lightweight handset, (Fig. 10), is both aesthetically pleasing and practical. The broad rectangular section and lateral contours of the handle form a shape which snugly fits the hand so that the transmitter is automatically held in the position of maximum efficiency. Wide-pitched special threads are moulded on to the handle, providing positive fixing for the earcap and mouthpiece without auxiliary locking devices. The transmitter and receiver are both inset capsules. They are self-locating and rest on spring rings which tension them against the caps and ensure correct mating of the mouldings under all conditions. The transmitter is the well known British Post Office Type 13, whilst the rocking armature receiver is the same as that used in the Type 1000 telephone and described in Bulletin No. 35, July 1957.

#### CIRCUIT

Fig. 11 shows a typical circuit for the Etelphone. Variants of this are of course available to suit special requirements. The circuit uses a conventional hybrid transformer with a fixed balance network to reduce side-tone, and includes a regulator which is described in detail below. Four components are employed in the balance network (the ringer capacitor has a dual function) to obtain the best side-tone network ; this arrangement has the advantage that the

connections within the instrument remain the same for different line conditions.

#### REGULATOR NETWORK

The Etelphone is the first of the Company's sets to be fitted with a performance regulator. Recent developments in telephone instrument design have

increased the sensitivity of the transducers so that the length of line can be increased without sacrificing the performance, or alternatively, the gauge of cable (and therefore line cost) reduced. Because of the success of these developments, a subscriber on a short

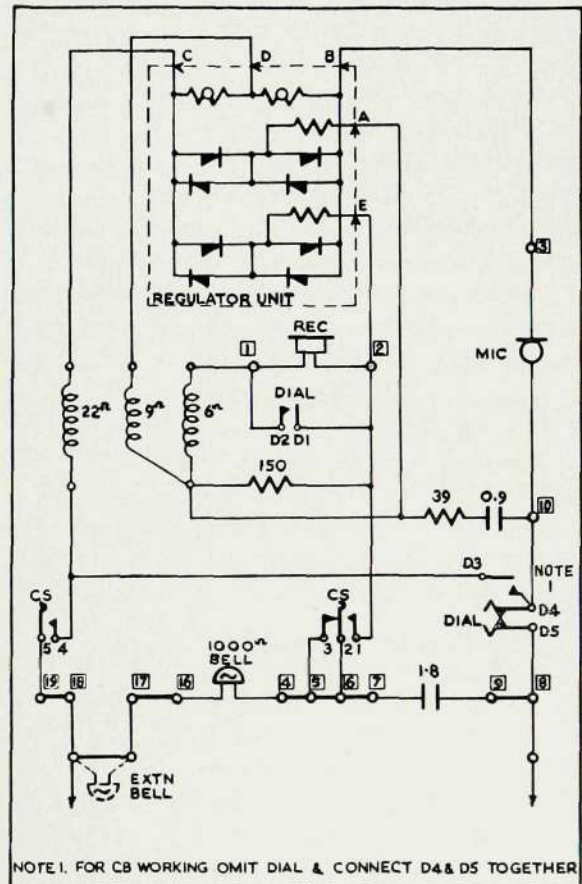


Fig. 11—The Telephone Circuit including Regulator Unit

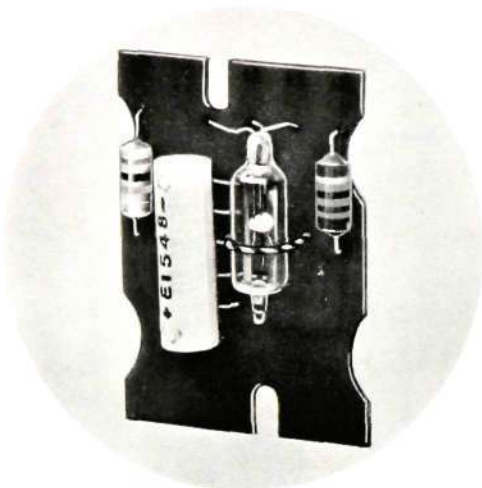


Fig. 12—Regulator Unit

line may now be embarrassed by the high efficiency of his telephone. Furthermore, a subscriber on a P.A.B.X. with a short local line and a long exchange line may be troubled by a considerable difference in level between local and exchange calls. The regulator has therefore been introduced in the Etelphone to reduce the sensitivity on short lines without affecting that on long lines.

Figs. 13a and 13b

**Loudness Efficacy compared with Line Length**

*200 + 200 ohm non-ballast bridge and 50 volt, 600 ohm junction*

Briefly, the action of the regulator is as follows:—rectifier units are connected across one winding of the induction coil and the transmitter, also across the transmitter through the ringer capacitor. The line current flows through a resistance lamp and applies d.c. bias to the rectifiers. The magnitude of the bias, and hence the impedance of the rectifiers, varies

with the line current, which in turn depends on line resistance. The shunting effect of the rectifiers thus increases as the line resistance falls, so that the sensitivity of the telephone is controlled in such a way as to compensate for the change in level with line length. The regulating effect is increased by the resistance lamp, which has a non-linear characteristic, its resistance falling as the current increases so that the rectifier bias increases more rapidly than the line current. The rectifier unit across the coil winding controls both transmission and reception performance, whilst that across the transmitter limits transmission only.

An alternative method of regulation using silicon carbide discs has not been used in the Etelphone as

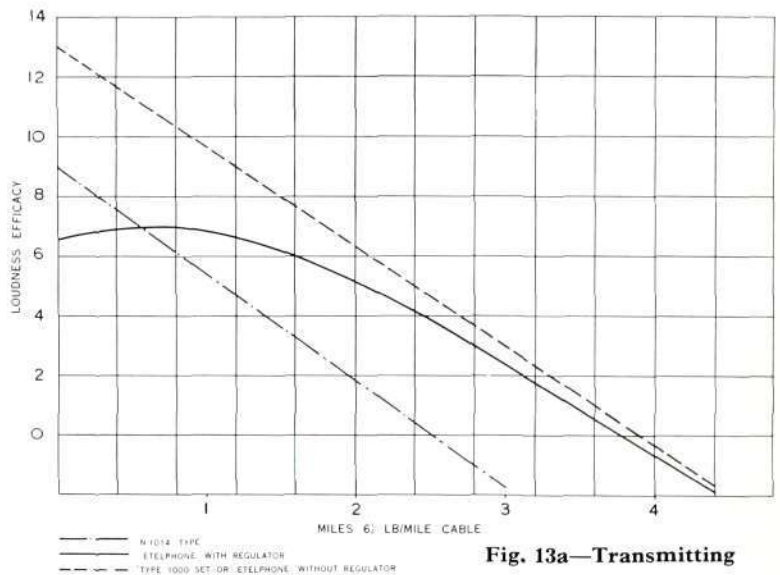


Fig. 13a—Transmitting

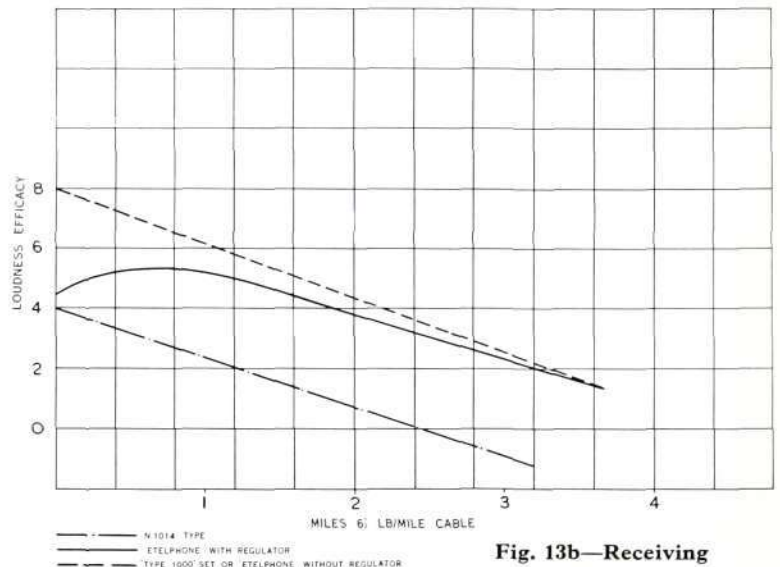
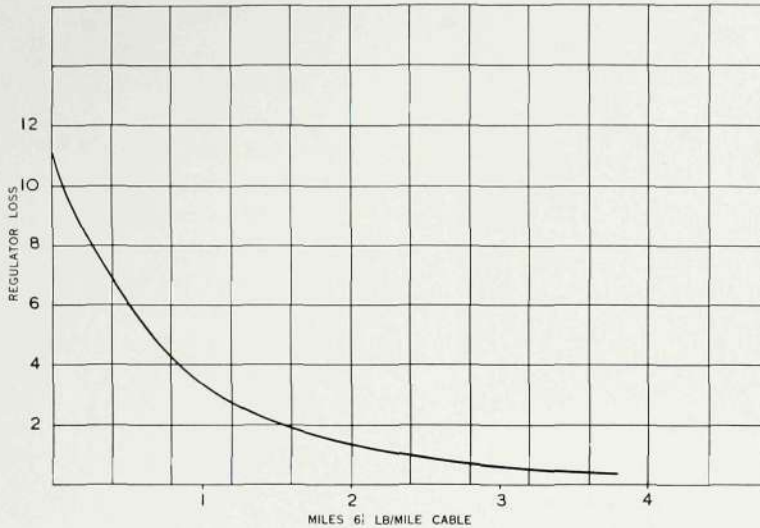


Fig. 13b—Receiving



**Fig. 14—Side-tone (Regulator Loss / Line Length)**  
 200+200 ohm non-ballast bridge—50 volt, 600 ohm junction

it is very dependent on the resistance of the transmitter, which during the life of the telephone may alter sufficiently to upset the regulation. The rectifier-lamp regulator does not suffer from this disadvantage.



**Fig. 15—Gauze Covers on base**

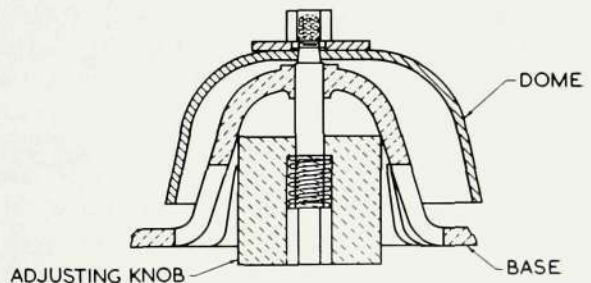
The construction of a regulator unit is shown in Fig. 12. A printed circuit carries the components and also provides connection points for the contacts in the socket in which it is fitted. An off-centre locating slot prevents the incorrect insertion of the unit. To enable the telephone to be used without a regulator, a shorting strip is printed on the end of the printed circuit panel opposite to that which is normally plugged in. In the event of a component failure it is possible to reverse the panel, which removes the regulator from the circuit and makes the necessary alternative connections automatically.

#### PERFORMANCE

As the performance of this telephone is, except for the regulator, the same as that of the Type 1000 which has been described in bulletin No. 35, it is only necessary to discuss the modification to which the regulator gives rise. Fig. 13 shows the curves of the transmission and reception performance of Type 332 (P.O.) and Type 1000 telephones and of an Etelphone fitted with a regulator. The curves are on a loudness basis and show that the transmission performance of the Etelphone on long lines is the equivalent of the Type 1000, and on short lines is similar to that of the P.O. Type 332. Fig. 14 shows the side-tone improvement due to the regulator.

#### TROPICAL PROTECTION

The Etelphone is available with full tropical finish. All metal parts are specially protected, coils impregnated and openings limited to prevent the entry of insects. Fig. 15 shows gauze covers fitted over holes



**Fig. 16—Adjustable Dome Assembly**

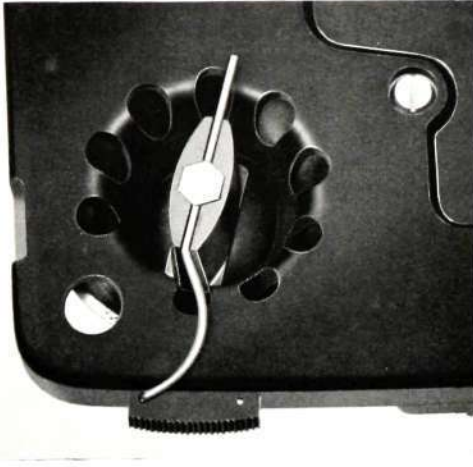


Fig. 17—Volume Control knob

in the base. A slotted press button dummy can be fitted to the case to give additional ventilation when necessary, but the air flow allowed by the clearance round the cradle switch actuating bracket arms is usually sufficient.

#### OPTIONAL FEATURES AVAILABLE

##### *Bell Volume Adjustment*

There are many situations in which it is advantageous to have the loudness of the bell under the subscriber's control. Calls for maintenance staff to adjust volume can be costly in a widespread network. In offices containing many telephones, it is useful to be able to adjust each instrument individually so that no confusion arises and the minimum of disturbance is caused. Parents of young children will readily appreciate the convenience of being able to quieten the bell at night. On the Etelphone, provision can be made for external control of the bell volume by the rotation of one eccentric dome after the ringer has been suitably readjusted. Fig. 16 shows a cross-sectional view of the adjustable dome assembly. The metal strap across the domes has a large clearance hole at one end and the normal screw and nut are replaced by a shouldered nut and long stud which are locked to the dome but rotate freely in the base. A moulded plastic knob is mounted on the stud and pressed against the base by a spiral spring in order to retain the adjusted position. Fig. 17 shows the adjusting knob with an extension to the side of the base; in this way volume control can be made without moving the instrument. The loudness may be reduced over a range of approximately 15 db.

#### SHARED SERVICE

A shared service adaptor, Fig. 19, can be fitted to the main bracket by a single screw which is captive in the unit, and flexible leads terminating in spade tags are used for connection to terminals on the base. A rectifier, which was an essential part of the previous shared service units is no longer necessary because of the use of a high-speed micro-switch. The need to provide variable marking and colour has been met by making a detachable face for the press button. (Fig. 18). Marking is printed on the underface and finished in a colour to suit the telephone.

A locking switch similar to the shared service unit is also available. Pressure downwards on one end of the press button will operate and lock; release is effected by pressure on the opposite end.

#### DIAL LOCK SWITCH

To prevent the origination of unauthorized calls, a special lock switch can be fitted. Fig. 20 shows the method of mounting the switch on the bracket across the ringer dome. A hole is drilled in the case to allow entry of the key.

#### WALL MOUNTING

As stated earlier, the Etelphone is available as a wall telephone. The conversion of the table instrument is a very simple matter and only entails the use of a new cradle bracket in place of the carrying handle on the case and turning the dial and number ring through 180 degrees.

A bracket which is secured to the wall, hooks into holes in the base from which the rubber feet have been removed. The lower fixing is by means of a



Fig. 18—Press Button Label Construction

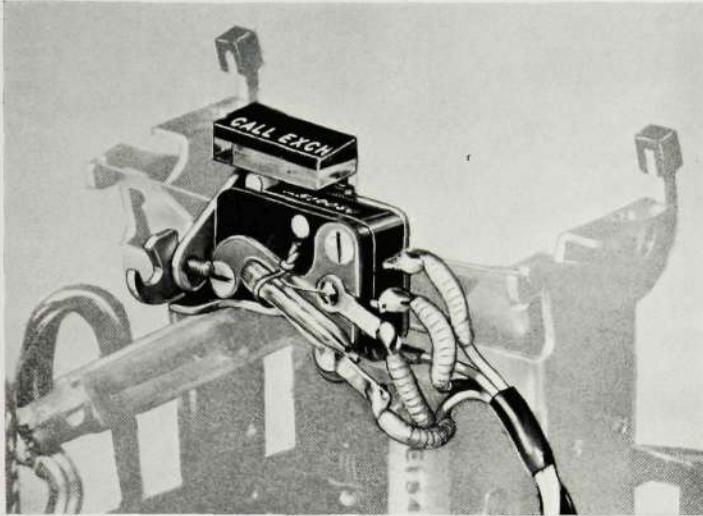


Fig. 19—Shared Service Adaptor

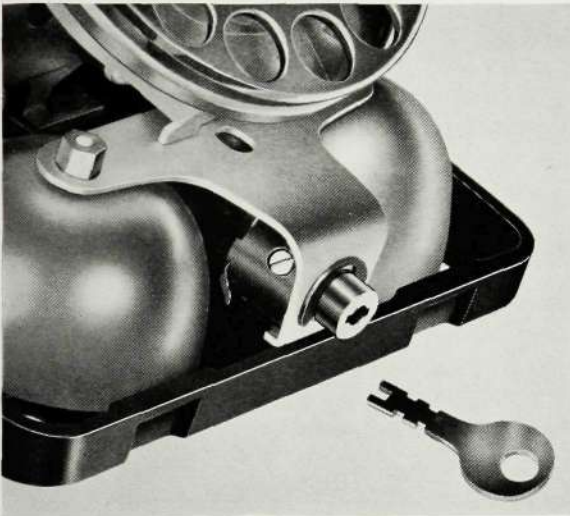


Fig. 20—Dial Lock Switch



Fig. 21—Handset with Amplifier

single screw which passes through a bracket fitted to the base and is vertically in line with the top fixing screw in the wall bracket.

#### HANDSET WITH AMPLIFIER

Amplified reception is particularly helpful to subscribers who are hard of hearing, but can also be of advantage to all users in noisy locations. An amplifier which is built into the handle of the handset, see Fig. 21, uses a single junction transistor, with operating power derived from the telephone line current when used with automatic and central battery systems and from the transmitter battery in local battery and magneto systems. The maximum gain of the amplifier is over 20 db. and can be adjusted by the subscriber by means of a miniature edgewise volume control which projects slightly from the handset. Sound output from the receiver is limited at a pre-determined level to prevent damage to the user's hearing from clicks and transient noises. The amplifying handset is connected to standard types of Etelphones by means of the usual cord, and no changes are necessary within the instrument.

#### FUTURE DEVELOPMENTS

A further extension of the facilities provided by the Etelphone is visualized in the provision of Plan switching arrangements which are in course of development.

#### ACKNOWLEDGMENTS

The Etelphone is a development of the Telephone 706 designed for the B.P.O., and Post Office Engineers were responsible for numerous and considerable contributions to the design which are duly acknowledged.

The tropicalised version of the instrument was developed in conjunction with Messrs. Preece, Cardew and Rider and acknowledgment is made to the assistance received from Sir Norman Frome and his staff.

# TRANSISTOR MULTI-CHANNEL CARRIER EQUIPMENT

(PART I)

H. T. GOACHER AND G. ASHMORE — Carrier & H. F. Development Department

*This is the first of three articles on the TCS12 multi-channel carrier system. The remaining two articles, dealing with Carrier Frequency Generation and Group and Super Group Translation, will follow in subsequent issues.*

*It is a requirement of the C.C.I.T.T. that in any large multiplex system employing frequency division techniques and providing circuits to international standards, the frequency translation shall pass through the band 60-108 kc/s (C.C.I.T.T. primary group B). The TCS12 system provides a 12-channel group in this spectrum. It has been developed as a basic channelling unit for incorporation in systems handling from 12 to 600 or more channels and is intended for use on cable or radio links. Considerable economies in power consumption have been attained by the use of transistors, and the compact construction permits three 12-channel groups to be carried on a single-sided rack nine feet high.*

## DESIGN CONSIDERATIONS

**I**N designing a 12-channel system to meet the present C.C.I.T.T. recommendations, there are two main methods of approach. A single modulation may be used to place the speech channels in the 60-108 kc/s band, crystal filters being employed to obtain the discrimination needed to isolate the

sidebands ; alternatively, two or more modulations may be carried out in such a way that the basic channel selection takes place at comparatively low frequencies, in which case coil and capacitor filters may be used. At first sight the more direct single modulation method may appear the more attractive in view of its greater simplicity. Crystal filters, however, are expensive to manufacture and much less

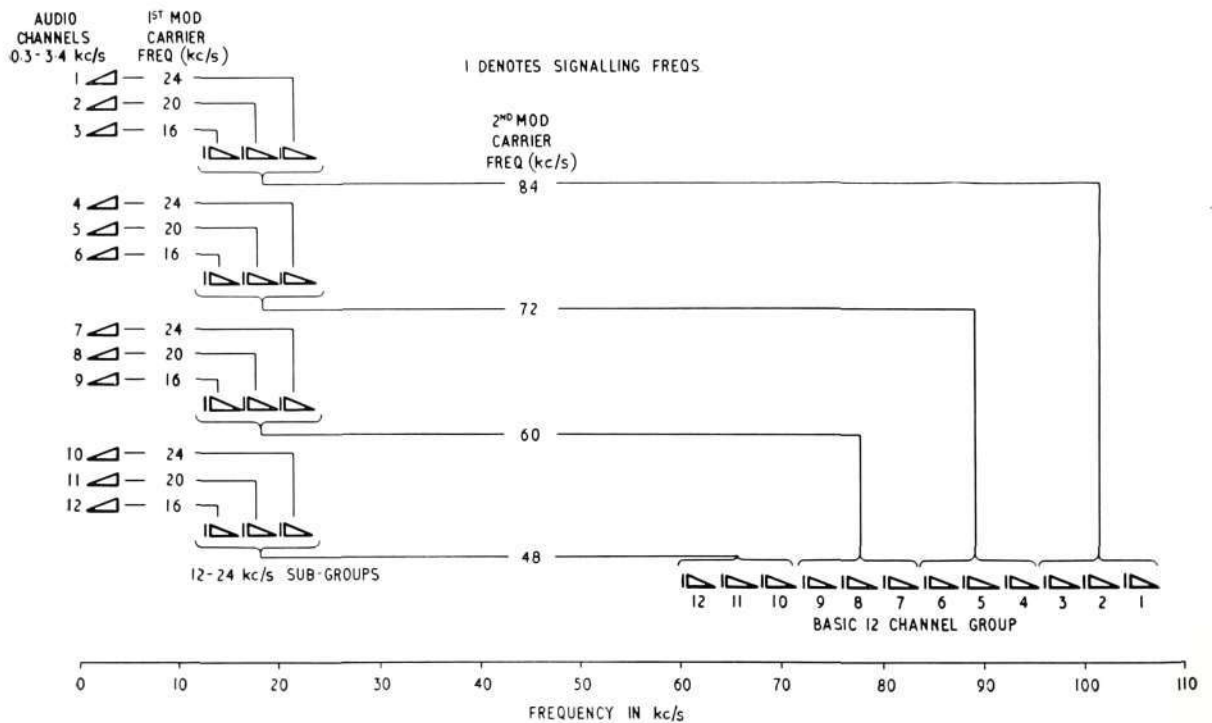


Fig. 1—Modulation Plan showing basic group derivation

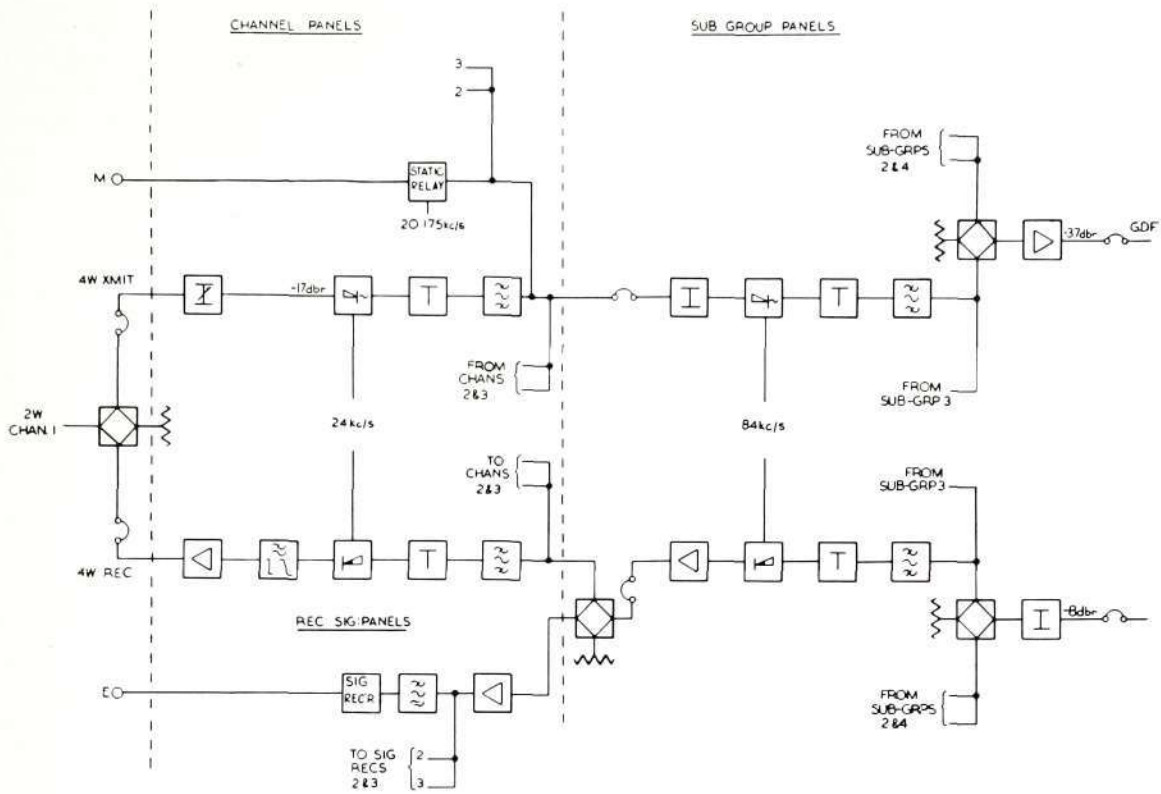


Fig. 2—Circuit Arrangement. TCS12 System

robust than coil and capacitor types—an important consideration where the apparatus may be subjected to shocks in transport. Further, good quality quartz suitable for resonators has to be imported and must be regarded as a strategic material. Other piezo-electric materials which can be substituted for quartz require elaborate manufacturing processes, so that they also are costly and little is gained by their use. The second approach, employing double modulation, permits greater flexibility in design; a reduction can be made in the number of different types of filter required, and the carrier generation equipment can be simplified because fewer carrier frequencies are necessary. A further not inconsiderable advantage is the ease with which a high quality music circuit can be introduced into the spectrum.

It is primarily for these reasons that double modulation is used in the TCS12 equipment.

#### FREQUENCY ALLOCATION

Fig. 1 shows the modulation sequence used. It will be seen that by means of a first modulation, four 3-channel sub-groups are formed at a low frequency and these are then translated by a second modulation into the 12-channel band.

A sub-group is formed by the modulation of the carrier frequencies 24, 20 or 16 kc/s by speech circuits 1, 2 and 3, respectively; the lower sidebands are selected by channel filters and are combined to form a sub-group extending from 12-24 kc/s. Channels 4-12 are assembled into three more sub-groups in a similar manner. All four sub-groups then modulate carriers of 84, 72, 60 and 48 kc/s, respectively, and the upper side-bands 96-108, 84-96, 72-84 and 60-72 kc/s are combined to form the basic 12-channel group 60-108 kc/s. It will be noted that only seven carrier frequencies are required for the above process compared with twelve for a single modulation system.

#### GENERAL CIRCUIT ARRANGEMENTS

The general circuit arrangement is shown schematically in Fig. 2.

Incoming speech at the four-wire point is adjusted to a line-up level of -17 dbm before application to the modulator input. The modulator is of the double-balanced type in which the input signal and carrier frequencies are suppressed and only the sidebands appear at the output. The modulator is designed to have a limiting action so that the output/input

characteristic is linear only up to an input of +4 db relative to normal line-up level. A further increase of input up to +16 db does not increase output by more than 9.5 db. This limiting action prevents overloading any common group equipment and the consequent generation of undesirable inter-modulation products.

The channel filter following the modulator accepts the lower sideband and offers high attenuation at the carrier and other sideband frequencies. The filter output is combined with the outputs of two adjacent channels to form a 3-channel sub-group. This group of sidebands in the range of 12-24 kc/s is passed to a second modulator where a carrier of 84 kc/s is modulated to produce an upper sideband extending from 96-108 kc/s. Similarly, sub-groups 2, 3 and 4 modulate carriers at 72, 60 and 48 kc/s, respectively, to complete the remainder of the primary group band 60-96 kc/s.

The sub-groups are now combined, a hybrid transformer being used for this purpose to minimize distortion due to the frequency/loss characteristic of the sub-group filters. The hybrid also provides a convenient means of converting the 600 ohms filter impedance to the 75 ohms impedance required at the Group Distribution Frame termination. The group amplifier increases the level to -37dbr at this point.

The reverse process applies in the receive direction. The sub-groups are separated by the appropriate sub-group filters, and after demodulation the sidebands are raised in level by sub-group amplifiers before application to the channel filters. These

filters are of similar design to the transmit channel filters and select the lower sidebands resulting from the first demodulation. Channel demodulation follows and a simple voice frequency filter eliminates the unwanted upper sideband and reduces any residual 'carrier leak' from the channel demodulator. An audio amplifier having a maximum gain of 32 db raises the speech output level to +10 dbr.

#### SIGNALLING

The system incorporates within-channel, out-of-speech-band signalling paths which may be used for manual or automatic operation. A static relay associated with each channel responds to the incoming ringing or dialling signals, and is arranged to inject a signalling frequency into the circuit at the sub-group point. Three tones of frequencies 12.175, 16.175 and 20.175 kc/s are used for each sub-group. They pass over the channel and at the receive terminal at the sub-group output they are selected by signalling receivers which apply d.c. pulses to line. These frequencies, if fully demodulated by the corresponding receive channels, would appear as audio tones of 3,825 c/s, but since the signalling frequencies are outside the transmission bands of the channel filters they cannot appear as interfering tones in the audio circuits, nor be simulated by speech components at the transmit end.

This method overcomes the problems inherent in most v.f. signalling practice and provides the utmost simplicity in operation.

#### AMPLIFIERS

A channel or v.f. amplifier is fitted to each channel.

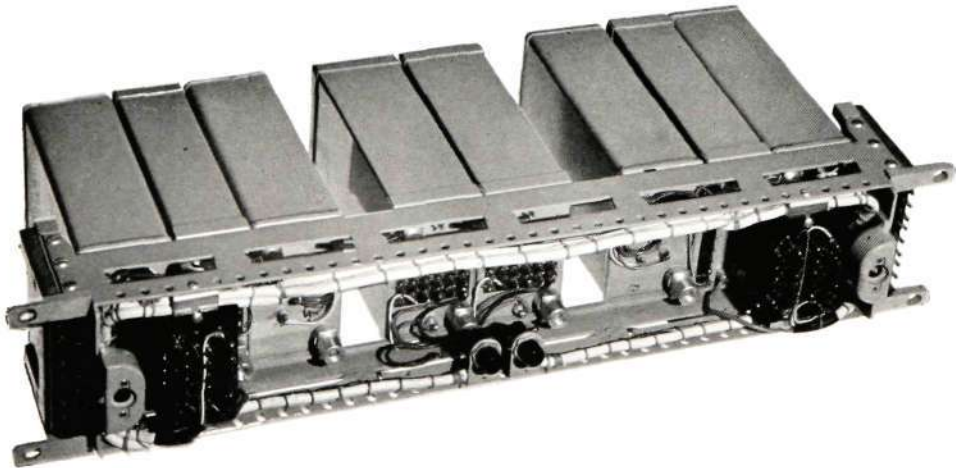


Fig. 3—A typical Channel Panel

It gives a gain of 32 db and the normal maximum working output level is +10 dbr, although a maximum output of +17 dbm is available if required. A single transistor is used in the grounded emitter configuration, and negative feedback is employed to stabilize gain and reduce distortion. The nominal input and output impedances are  $600\Omega$ , and return losses are better than 25 db.

One sub-group amplifier is required per three channels. Harmonic distortion is kept to the minimum by the use of two grounded collector transistors in the output stage. A maximum gain of 36 db is provided and the output level is -7 dbr per channel. Input and output impedances are  $600\Omega$ .

The group amplifier is designed to carry the whole 12-channel group, and cross-modulation must therefore be of a very low order. Since the output level required is very low (-37 dbr) it has been possible to use a single transistor in a grounded collector circuit. The maximum gain is 15 db, and input and output impedances are  $75\Omega$  with return losses better than 25 db.

#### SIGNALLING OSCILLATORS

Three oscillators of frequencies 12.175, 16.175 and 20.175 kc/s are used for signalling over the channels. Each oscillator uses an OC71 transistor to generate the required frequency. The transistor is used under common base conditions to reduce the inherent phase shift to a minimum and thus improve frequency stability. A second OC71 operating in grounded collector mode provides a buffer stage of low impedance and good regulation.

#### SIGNALLING RECEIVER

The signalling receiver makes use of two transistors in a simple amplifier-detector circuit. The first stage consists of an OC70 amplifier which is fed from a narrow-band filter tuned to the signalling frequency. This is followed by a detector which employs an OC71 transistor. The OC71 is normally non-conducting, but on receipt of a signal it functions as a rectifier-amplifier and operates a high-speed relay in its collector circuit which in turn extends earth or battery as required on the 'E' wire.

#### CONSTRUCTION

The construction of the equipment follows the method standardized by the Company for its transmission equipment, in which all circuit elements such

as amplifiers, modulators, etc., are built on individual frameworks carrying terminal plates and are arranged

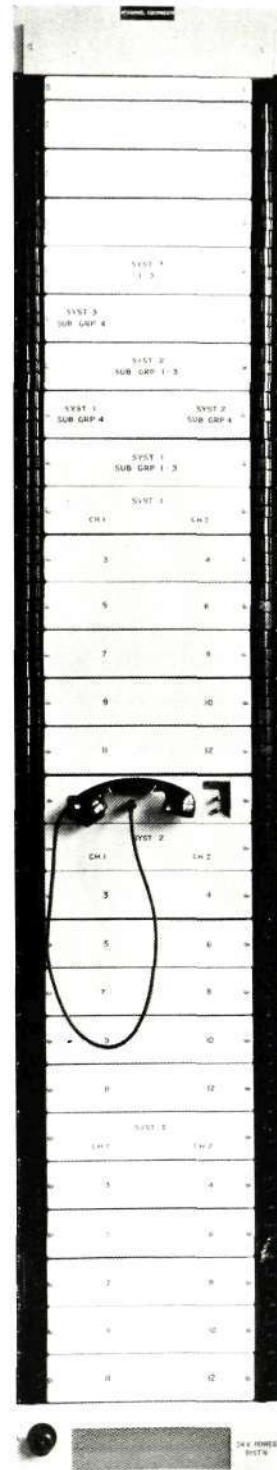


Fig. 4—Channelling Rack with three groups of TCS12 equipment

to clamp directly to a panel framework. Since very compact assemblies have been achieved, it has been found possible to mount the apparatus for two 'go' and 'return' channels on a single 3½" panel. (Fig. 3). With the exception of filters, which are hermetically sealed, each unit has a close-fitting dust cover easily removable to facilitate maintenance. Items such as attenuators are assembled in the form of tag boards and are mounted directly under the panel cover.

Each panel framework consists of die-cast end members connected together by pressed steel side plates reinforced by steel channels to increase stiffness. These steel members serve as mountings to which the units are clamped. Socket connectors, through which contact is made with similar connectors on the rack wiring, are housed in the die-cast end members. Silver-plated contacts are used and pressure is exerted upon the contact surfaces by separate steel springs. A soldering tag formed on each contact punching provides a means of bridging the panel-bay connectors by a soldered connection if desired. The face of each panel is covered by a shallow dust cover fixed by quick-release fasteners.

The rack consists of a pressed steel frame equipped to form a single-sided unit (Fig. 4). The frame sides

are of folded section to increase stiffness, and two frames may be bolted back to back when a double-sided rack is required. The rack height is normally 9 feet and such a rack will accommodate up to three 12-channel groups. Socket connectors corresponding to those on the individual panels are mounted on the sides of the frames, and 'U' links moulded together in blocks of five are used to connect the sockets on the panels to those on the rack.

#### POWER SUPPLY

The equipment is designed to run from the normal 24 or 50-volt exchange batteries, the current drain being approximately 0.4 amps per 12-channel group. Where power cannot be obtained from an existing battery, a comparatively low-capacity battery is supplied and this is maintained by a 100-130 or 200-260 volt a.c. mains-operated float charge unit mounted on the carrier equipment rack. The capacity of the battery is sufficient to ensure that service is not interrupted during any temporary failure of the mains supply.

The characteristics of the TCS12 system are summarized in the table below.

#### DATA SUMMARY

Audio Channel Bandwidth	..	..	..	..	300-3400 cycles per second
„ „ Input Impedance	..	..	..	..	Nominally 600 ohms balanced
„ „ Output „	..	..	..	..	Nominally 600 ohms balanced
„ „ Input Level (4-wire)	..	..	..	..	-14 dbr to +17 dbr.
„ „ Output Level (4-wire)	..	..	..	..	-5 dbr to +10 dbr.
Transmit Carrier Leak on each Channel	..	..	..	..	Less than -40 db referred to 0 db point
Total Carrier Leak	..	..	..	..	Less than -30 db referred to 0 db point
Channel Equipment Output Impedance (GDF)	..	..	..	..	Nominally 75 ohms unbalanced
Channel Equipment Input Impedance (GDF)	..	..	..	..	Nominally 75 ohms unbalanced
Sideband Output Level	..	..	..	..	-37 dbr.
Sideband Input Level	..	..	..	..	-8 dbr.
Signalling Frequency	..	..	..	..	3825 cycles per second equivalent
Signalling Distortion	..	..	..	..	Less than 3 milliseconds at 20 i.p.s.
Power Supply	..	..	..	..	24V or 50V d.c., 0.4 amps.



## A SMALL TRANSISTOR RINGER FOR 6-VOLT D.C. OPERATION

E. H. NORMAN — Carrier & H.F. Development Department

*The unit described was developed for use with the single channel carrier equipment type ETL14 which operates from 6 volts, sometimes obtained from dry batteries. An integral 17 c/s ringing supply is often necessary and the present printed wiring unit has been designed to provide sufficient output to ring a standard bell or operate a drop indicator over a line having up to 1500 ohms resistance and leakage up to 100 $\mu$  mhos. It will actually operate two bells in series or parallel, and up to four in series parallel, over the above line. Current consumption is 70 to 100 mA depending on the load conditions.*

WHEN a 17 c/s ringing supply is necessary at a carrier terminal station for signalling to the local exchange, a tapping is taken from the exchange supply or suitable generating equipment provided. This supply would normally be mains or exchange battery driven. In some instances, however, neither mains nor exchange batteries are available, and transistor-operated carrier equipment is used and operated from dry batteries. Such a condition may exist when using our single channel ETL 14 equipment which requires a 17 c/s supply of low output, and as the battery supply is a 6-volt dry battery it is essential to keep the current drain to the minimum. Although ringing may last only for a few seconds, if the current drawn is large, excessive polarization of the battery may occur, temporarily causing the supply voltage to fall sufficiently to affect the functioning of the equipment. Even when a mains-operated power unit is used, it is necessary to keep the current consumption of the ringer low, since a power unit with good regulation at heavy currents would be expensive.

In designing a ringer unit to operate from the same supply (6 volts d.c.) as the ETL14 equipment, several special considerations arise. In particular, the output transformer must give a large voltage step-up ratio and at the same time have a relatively high primary inductance; however, the primary winding resistance must not cause a large voltage drop, since only 6 volts are available from the supply. The simplest way of constructing a 17 c/s transistor oscillator is to use two transistors and an output transformer connected so that saturation of the transformer initiates

the switching of current from one transistor to the other, and an arrangement of this kind was tried in conjunction with an experimental version of the ETL14. However, with a low supply voltage this type of circuit does not permit the output power and frequency to be kept within acceptable limits unless the transformer characteristics are so closely specified as to raise the cost unduly. The circuit shown in Fig. 1 was therefore adopted for the transistor ringer unit.

In this circuit, a multivibrator using two OC71 transistors drives a push-pull Class B power amplifier. The collector resistors for the multi-vibrator are chosen so that there is adequate current drive to the output stage. The maximum value of base resistor is then determined by the lower limit of current gain for the type of transistor used. This resistor in turn fixes the value of C1 and C2 to ensure operation at 17 c/s (subject to component tolerance). The frequency of operation depends chiefly on R2, R3, C1 and C2 and with  $\pm 10\%$  resistors and  $\pm 25\%$  capacitors the frequency, if designed to be nominally 17 c/s, will range from 12.5 to 23 c/s. The component

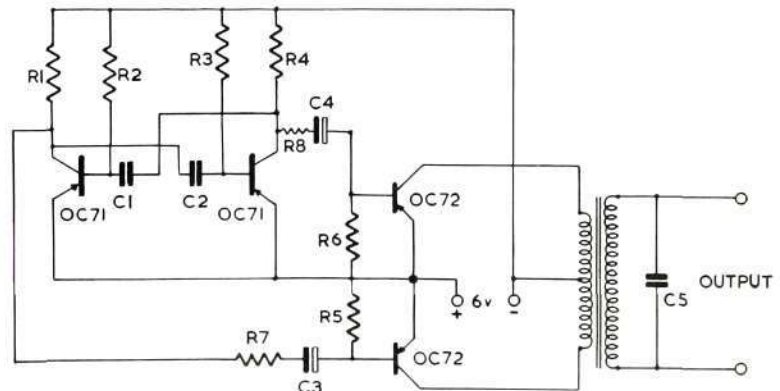


Fig. 1—Circuit of Transistor-operated Ringer

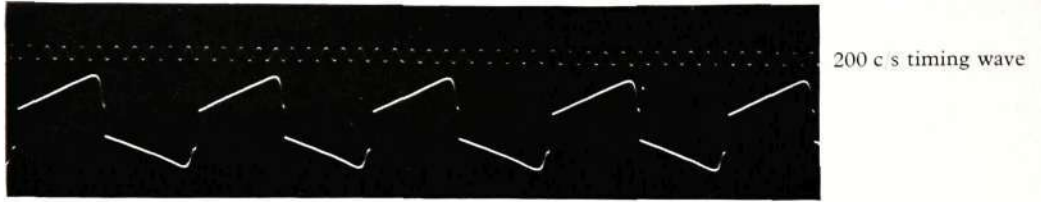


Fig. 2—Ringer Current Wave Form. Load : 2000 ohms non-inductive

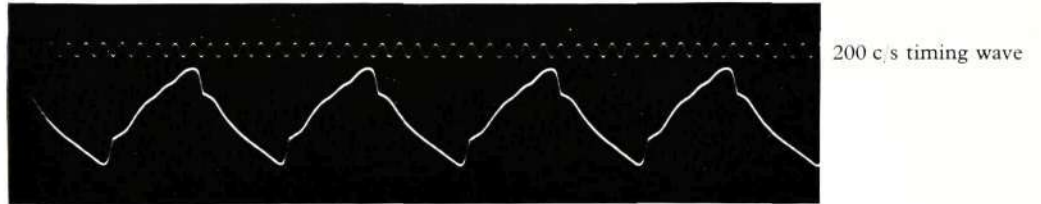


Fig. 3—Ringer Current Wave Form. Load : 1500 ohms + 2 $\mu$ F + bell

values actually used give a nominal frequency of about 20 c/s and a range in production samples of 15 to 27 c/s.

The output transformer design is eased considerably by the interposition of the amplifier. The saturation flux density is only of secondary importance, and since the inductance does not control the frequency of oscillation it may be made low enough to cause some differentiation of the waveform, resulting in less voltage drop in the windings.

It was found necessary to use paper dielectric capacitors in the frequency determining circuit (C1 and C2). These are obtainable with a tolerance of  $\pm 25\%$  as against  $-20\% + 100\%$  for electrolytic capacitors.

The performance of the ringer operating into various resistive loads is shown in Table I, the output current waveform being as shown in Fig. 2. Performance tests with a.c. bells as the load, operated via a 1500 ohms series resistance to represent the

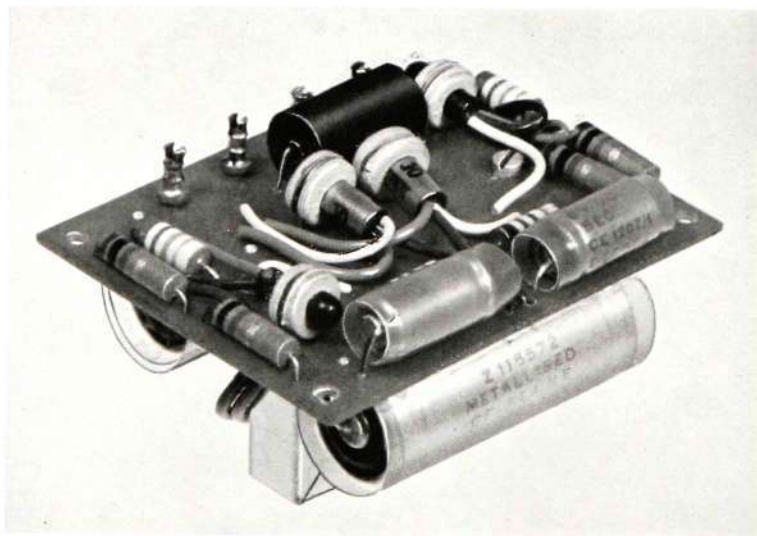


Fig. 4—The Ringer Unit Panel Assembly

line, yielded the results in Table II. The waveform of the current in the bell coils when driven by the ringer via 1500 ohms and the usual 2  $\mu$ F capacitor is shown in Fig. 3. It will be observed that the ringer unit tends to have a constant current characteristic. It is therefore very suitable for operating a single bell over a high resistance line. If more than two bells are to be operated, series-parallel operation is desirable, the unit being capable of operating four bells (with capacitors) in this arrangement, via a 1500 ohms series resistor.

Under certain conditions the original application required the ringer to operate a 3000-type relay via a 2  $\mu$ F capacitor and rectifier bridge. The power delivered to a 4000-ohm relay is about 100 mW, which is sufficient to actuate a springset consisting of four change-over contacts using 12-mil springs.

The ringer unit is assembled on a printed wiring panel (Fig. 4), approximately 3" x 2 $\frac{1}{2}$ " which is designed to mount on Type 51 equipment panels.

TABLE I — PERFORMANCE WITH RESISTIVE LOAD

		LOAD RESISTANCE				
		500 $\Omega$	1000 $\Omega$	2000 $\Omega$	5000 $\Omega$	10,000 $\Omega$
Output current (mA, p-p) .. ..		30	30	29.5	22	13.5
Output voltage (V, p-p) .. ..		16	31	60	118	140
Supply voltage (V, d.c.) .. ..		6.07	6.0	6.0	6.03	6.07
Supply current (mA d.c.) .. ..		82	100	98	88	79

TABLE II — PERFORMANCE WITH STANDARD 1000 $\Omega$  A.C. BELLS AS LOAD  
(Each bell unit consists of a 2  $\mu$ F capacitor in series with the bell)

		LOAD CONDITIONS			
		1 Bell Unit	1 Bell Unit with 1500 $\Omega$ in series	2 Bell Units in parallel and 1500 $\Omega$ in series	3 Bell Units in parallel
Output Voltage (V, p-p) .. ..		75	72	53	40
Output current (mA, p-p) .. ..		36	29	30	32
Input voltage (V, d.c.) .. ..		6.0	6.05	6.03	6.03
Input current (mA, d.c.) .. ..		92	88	92	100

# THE DESIGN AND MANUFACTURE OF CABLEFORMS IN THE TELEPHONE INDUSTRY

J. E. HOLLOWAY — Circuit Development Engineering Department

*Reprinted from "British Communications and Electronics" (October 1958) to whom acknowledgments are due for permission to reprint and for the loan of certain blocks.*

*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

plug-in relay sets and selectors will be considered. The basic principles described are equally applicable to desk and rack mounted apparatus, and mention is also made of the cables for this type of equipment.

### WIRING INFORMATION ON CIRCUIT DIAGRAMS

The requisite circuit design is indicated by means of a schematic diagram to which is added wiring information in the form of runs and symbols. In cases where more than three points are to be electrically connected, the order of wiring is indicated by point-to-point runs adjacent to the particular conductor convention. Such order is arranged in a standard manner to utilize the shortest length of wire compatible with the pre-determined layout of the apparatus. Where only three points are to be connected, loop or 'L' signs are shown on the lead to the component on which the wires are to be looped. The order of wiring to battery and earth connected points is indicated by means of separate detached runs.

The complete diagram is known as a schematic wiring or routed schematic diagram. A section of a typical diagram is shown in Fig. 2 and indicates direct connections, looped connections and multi-point wiring runs. This information, although complete in

itself, is not suitable for use by factory production departments and it is therefore necessary to present it in the form of a manufacturing drawing.

### THE DESIGN OF CABLEFORM DRAWINGS

Information for the manufacture of hand-made cables consists essentially of two parts, (i) a running list or table, and (ii) a full-size drawing of the form the finished cable will take. The running list is derived directly from the routed schematic diagram and lists all the wiring connections shown on the latter. The connections are arranged in groups, under headings of the colour code of wire to be used, the colours being chosen from a standard range for the particular size and type of insulation of the wire being used. With the exception of full battery and earth connections which are wired in white and red wire respectively, colours are allocated in such a way as to avoid duplication within groups of wires which will be fed from the same point in the cable. This facilitates identification and avoids the necessity for the electrical checking of the point-to-point connections during the wiring operation. The cableform is drawn as seen from the front of the equipment and the battery connections are arranged first in the running

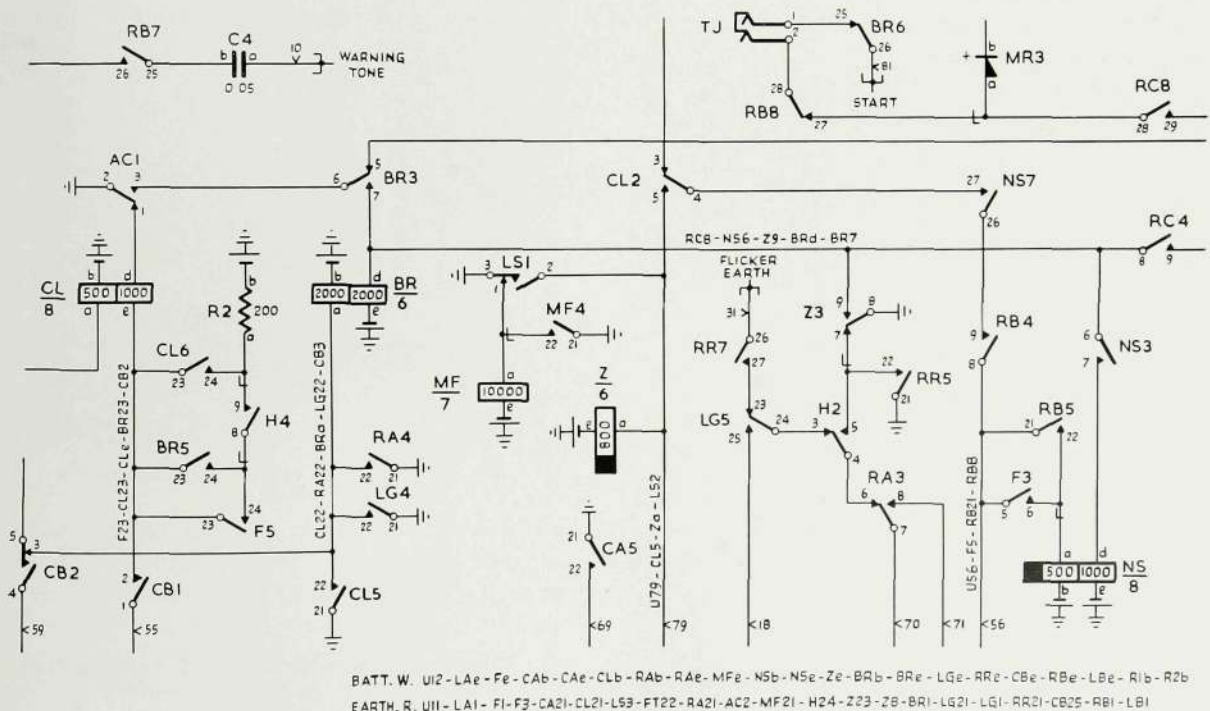
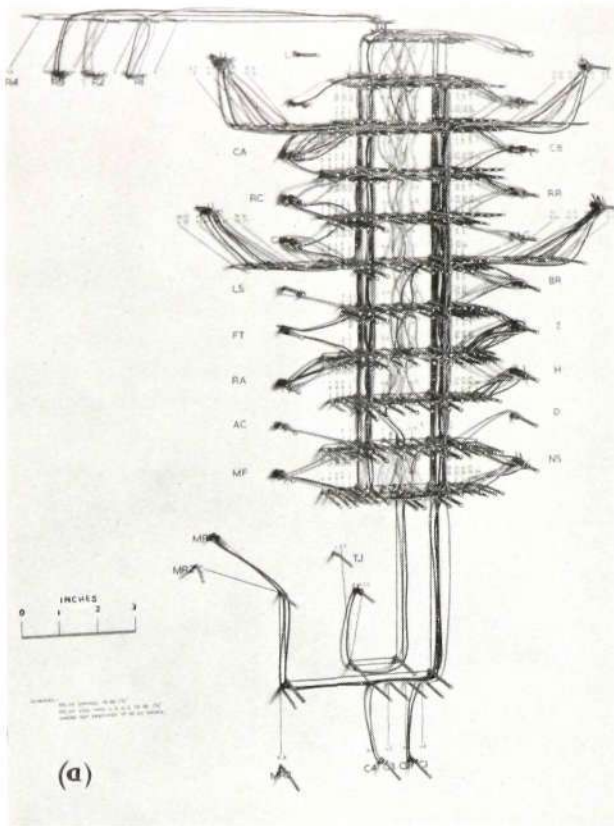
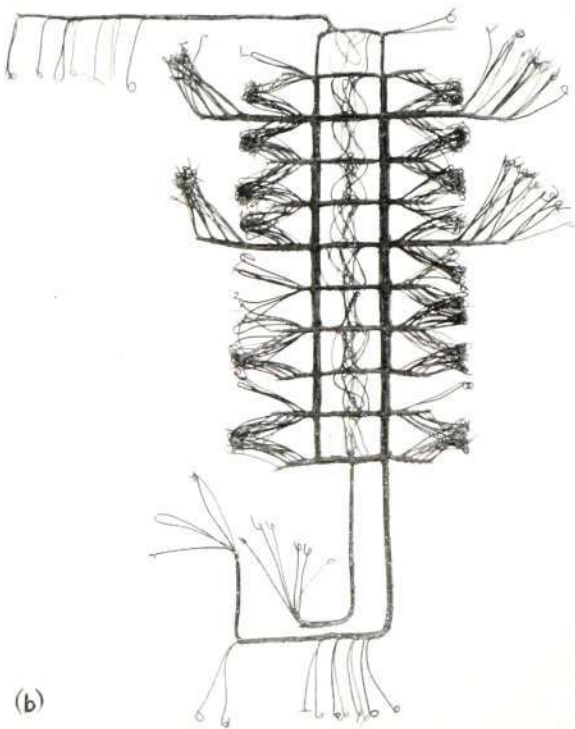


Fig. 2—A section of a routed schematic diagram.

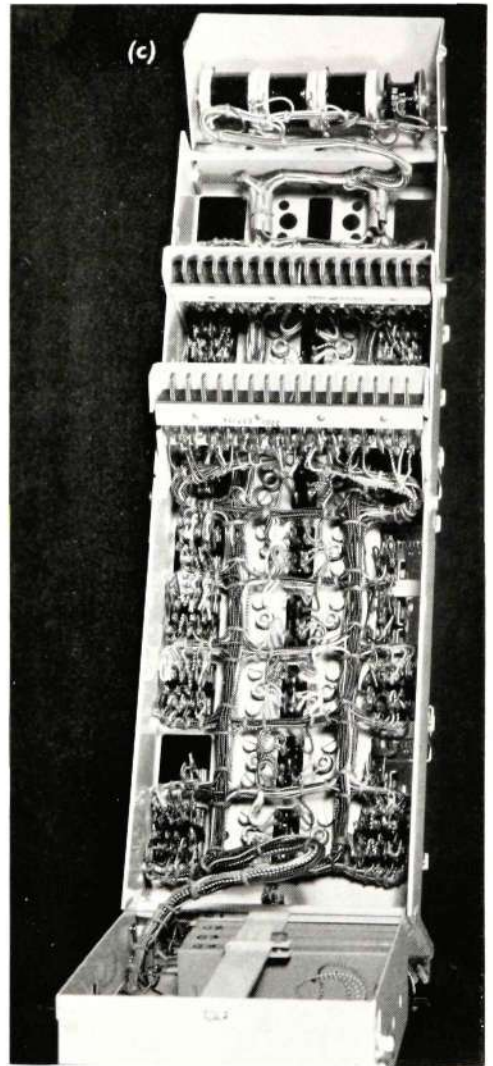
*This information alone is not suitable for use by factory production departments*



(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.

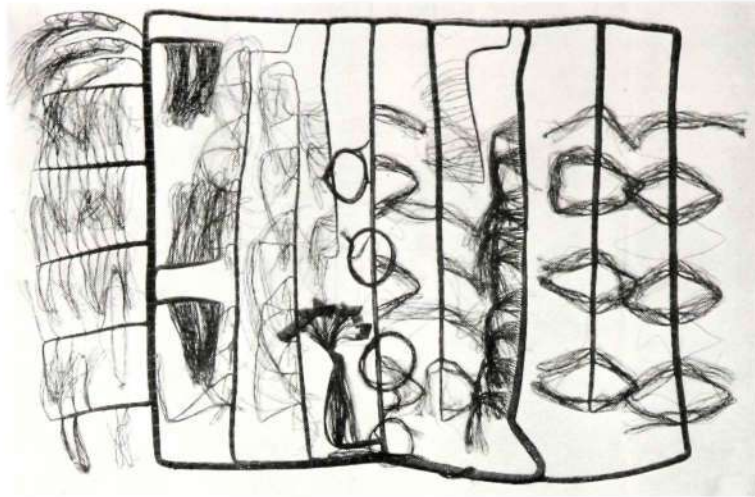


Fig. 4—A completed cable of a P.B.X. apparatus rack.  
This is shown under construction in Fig. 1.

#### 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 nails and then lifted a short distance off the board by means of a 'prodger' 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.

