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CONTENTS

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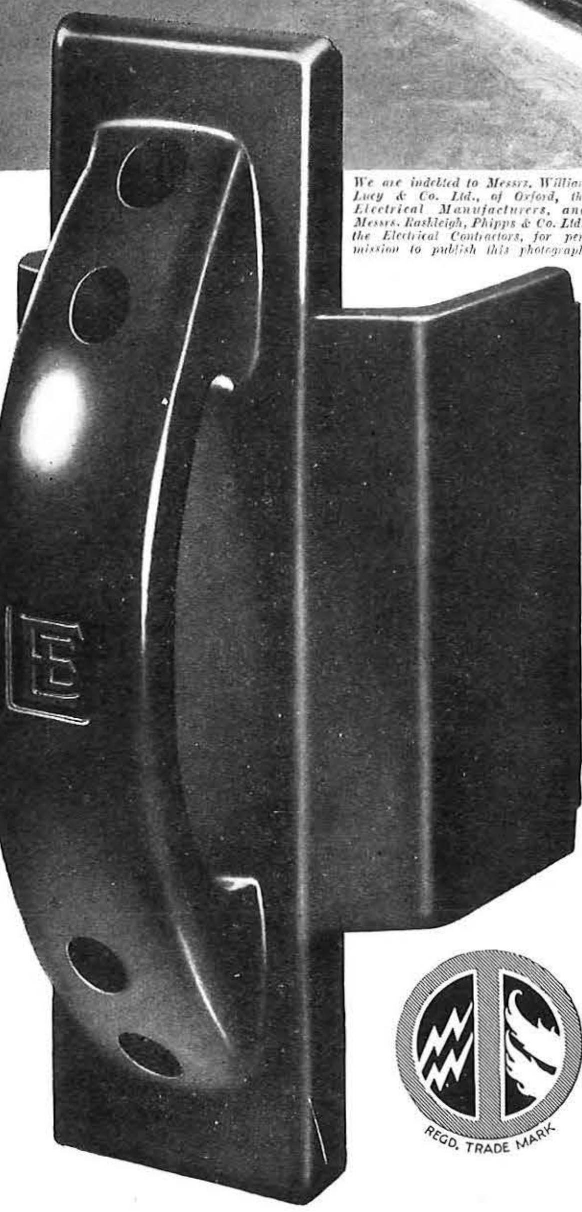
THE INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

We are indebted to Messrs. William Lucy & Co. Ltd., of Oxford, the Electrical Manufacturers, and Messrs. Rashleigh, Phipps & Co. Ltd., the Electrical Contractors, for permission to publish this photograph.



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The illustration above shows part of the main power and lighting board at Carmelite House, the headquarters of Associated Newspapers, Ltd.

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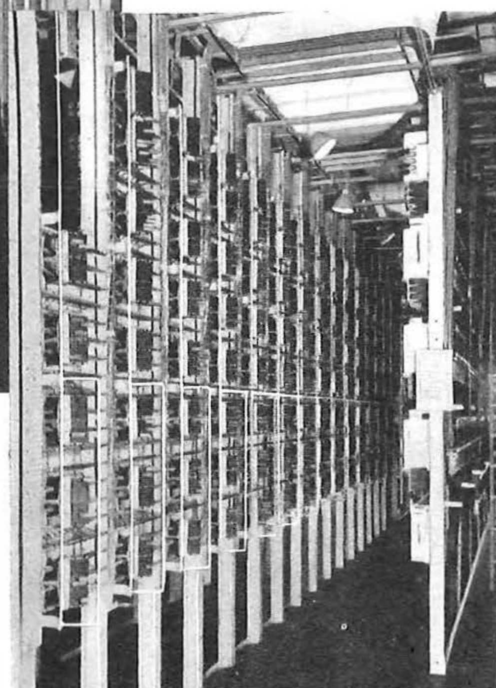
PORTUGAL

Norte Exchange, Lisbon, was installed in 1934 with an ultimate capacity for 10,000 lines of Strowger automatic telephone equipment. Of this total, 8,800 lines were initially installed, and the excellent service provided for subscribers resulted in a further 1,200 lines of Strowger equipment being added in 1937. This extension to Norte Exchange was not the sole evidence of progress in telephone communications, for another Strowger exchange, Estrela, was also installed in 1937 and some 4,600 additional subscribers catered for in result.

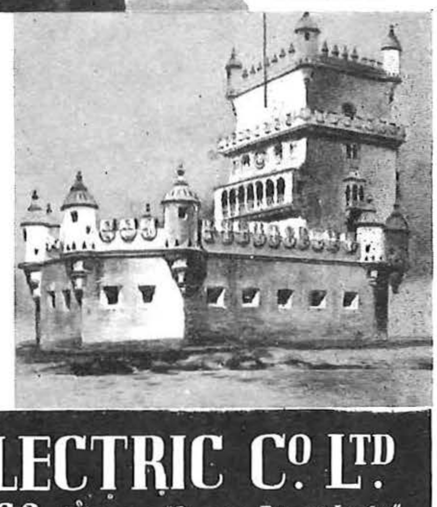
Final Selector Racks, Norte.



Meter Rack—Rear View, Norte.

The cloisters of Jeronimos, a beautiful ecclesiastical building in Lisbon.

The Praça do Comercio and bronze statue of Joseph Ist, Lisbon.



The Tower of Belem, built in 1520 to protect shipping, Lisbon.

Portugal is a country of charm and colour . . . a land where deep blue skies blend with the soft green of trees and fields to form a rich background for the fierce grandeur of Moorish castles, the ornate beauty of Renaissance churches, and the simpler but equally picturesque allurement of villages of clustering white houses. In the 15th and 16th centuries Portugal was the maritime nation of the world. From the Tagus at Lisbon—" where all the navies of the world may anchor "—sailed Vasco de Gama in 1479 to discover the Sea Route to India, and that spirit has not passed. His mantle has descended, for in 1922 Cabral and Cortinho departed from the same spot on their epoch-making Atlantic flight. Portugal has a proud history . . . and she is adding to it an impressive record of modern achievement.

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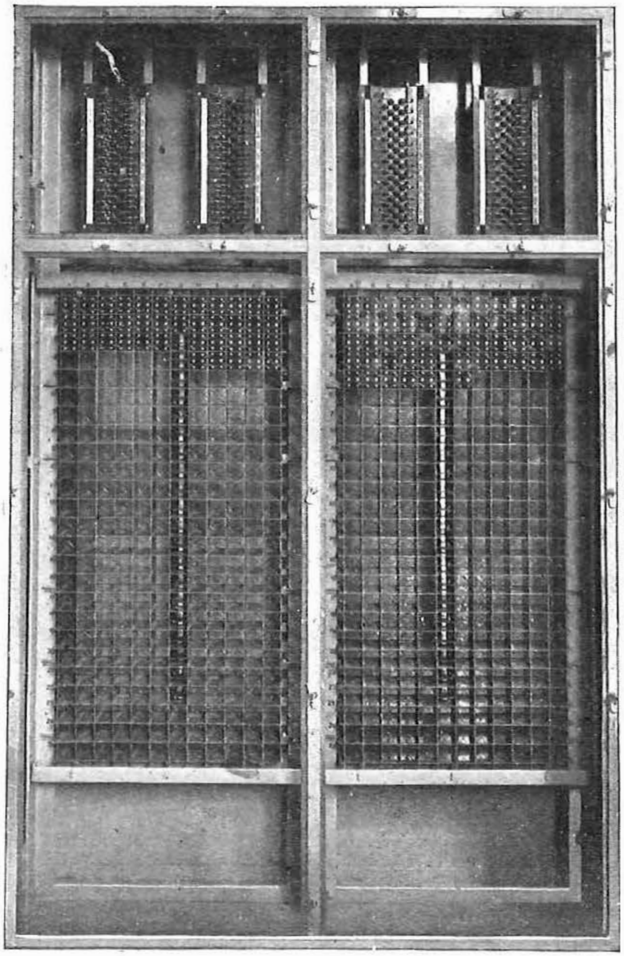
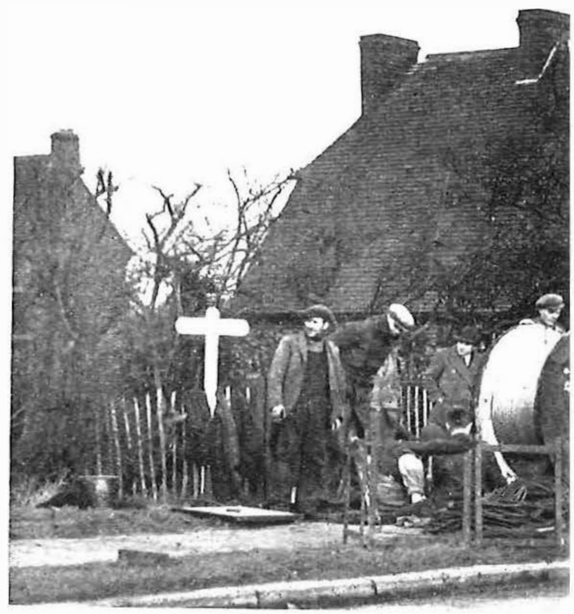


Balancing Network ; cover removed.



THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL

Vol. XXXI April, 1938 Part I

The New Combined Hand Microtelephone and Bell Set

C. A. R. PEARCE, M.Sc. (Eng.), D.I.C.

A new telephone is described in which the telephone instrument and bell set are combined in the same moulded case. The advantages claimed are ease of fitting and reduction of fault liability. Provision has been made for one, two or three press buttons to be mounted on the instrument, thus permitting a variety of extension and interconnection facilities to be given.

Introduction.

THERE has recently been developed by the Post Office Engineering Department, working in conjunction with Messrs. Ericssons Telephones, Ltd., a new standard subscriber's set in which the bell, condenser and induction coil are mounted as an integral part of the telephone instrument and not as a separate bell set as hitherto.

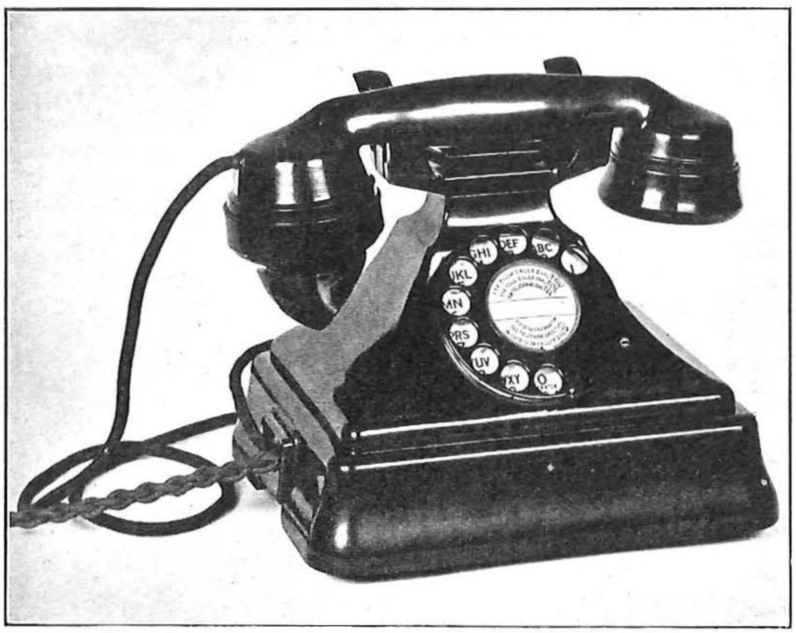


FIG. 1.—TELEPHONE NO. 162 MOUNTED ON BELL SET.

When the Telephone No. 162 was introduced in 1929 it was considered that the demand for a combined set, i.e. one in which the telephone and bell set form a single unit, would be insufficient to justify the development of a special piece of apparatus and consequently the only provision for such an item was the arrangement whereby the standard bell set (No. 25) intended primarily for wall fitting could also be mounted under the telephone in the familiar manner shown in Fig. 1. Experience has shown, however, that even with such an admittedly makeshift arrangement as this, approximately half the microtelephone instruments are fitted as combined sets and doubtless with the new design an even greater proportion of the demands will be for this class of instrument.

There is, however, a serious disadvantage in combining the bell with the telephone in residences where the bell has to be heard in all parts of the house. In such instances the best position for a bell is in the hall, whereas the telephone may be anywhere that is convenient. For this reason the new set is regarded as being primarily suitable for business subscribers and plan number installations, although its use is not, of course, restricted to these spheres.

The advantages of combining the telephone apparatus in a single unit are, first, the economy of a single case and chassis as compared with the variety of mouldings which make up the Telephone No. 162, and, second, the ease and simplicity of fitting. With a single unit the fitter has, on direct exchange lines, to connect only two wires to the block terminal and need not open up the instrument to do so. Thus the new instrument materially reduces the possibility of errors in fitting. Its use will also generally reduce the disfigurement to walls which is occasioned by this operation, since the block terminal can frequently be located on a window-frame or skirting-board and the fitter thus saved the plugging of the walls. A very prolific source of faults is bad fitting and the combined set is well suited for fitment by relatively unskilled staff.

General Design.

Fig. 2 shows the general appearance of the new set. Although the external shape is based on that of an instrument designed by the Swedish Ericsson Co., the internal arrangement is entirely new. The design of the case is centred around the use of a plastic moulding and the result is considered to be an extremely

Fig. 2.—New Combined Hand Microtelephone and Bell Set.

sturdy construction and ideally adapted for production in large quantities and in colours. The mould from which it is produced is practically a straight "draw-out," the only loose part being that which forms the dial aperture.

It will be appreciated that an important factor in the success or failure of any design of telephone instrument is the reaction of the general public to its external appearance. It is thought that the new set will be popular on this account as it has already received very favourable comment from many acknowledged authorities on design and was especially selected by the Duke of Windsor when Prince of Wales during his visit to the Stockholm Exhibition in October, 1932, for use in his own private residence.

The original design did not include the sliding tray in the base and it can hardly be claimed that this addition has improved the general appearance of the set. This tray (Fig. 3) was designed as a convenient holder for the list of "dialling codes" in those areas where a subscriber obtains other exchanges by the dialling of two or three routing digits, but it has been decided to provide it on all telephones as a container for a subscriber's private directory.

The shape of the H.M.T. rest has been designed so as to facilitate the removal and replacement of the hand microphone and it is anticipated that the use of the button type of "switch-hook," in lieu of the pattern used in the Telephone No. 162, will obviate the "sticking" trouble experienced with the latter class of instrument. Another important feature of the case design is its convenient width for gripping when lifting although it must be conceded that the weight of the set does to some extent mitigate against any great ease in this respect.

With the exception of the dial all the various components are mounted on a single chassis plate (Fig. 4). The condenser is the only component for which it has been found necessary to introduce a special variety on account of the new set. Advances in the technique of condenser manufacture have made it possible to produce a $2 + 0{\cdot}1\ \mu F$ condenser which is little more than half the size of the $2\ \mu F$ pattern at present used in bell sets. This new item will be the standard size for use in all future designs of bell sets and telephones.

The layout is such that all the main components with the exception of the switch springs and dial are revealed and made accessible for maintenance operations by the removal of the underbase, while the removal of three further screws frees the chassis from the case and enables any maintenance work on these two items to be easily carried out. Every effort was made to render the dial directly removable from the front of the instrument but this has not been found possible without spoiling the appearance of the set.

Circuit Arrangement.

The circuit of the CB and Auto. type is given in Fig. 5 and is simply the standard anti-sidetone arrangement (Coil Induction No. 22) which has been described elsewhere. The local battery circuit remains a sidetone arrangement and is practically the standard three winding induction coil circuit as at present used when a Telephone No. 196 is connected to a Bell Set No. 31. Although the local battery set will eventually disappear as a subscriber's instrument it will still presumably be necessary for private wires, etc., and it is likely that for these uses a local battery anti-sidetone induction coil will be introduced, but no entirely satisfactory design of coil is yet available. Space has been left, however, to permit of the use of any design of anti-sidetone coil which can be envisaged at the moment.

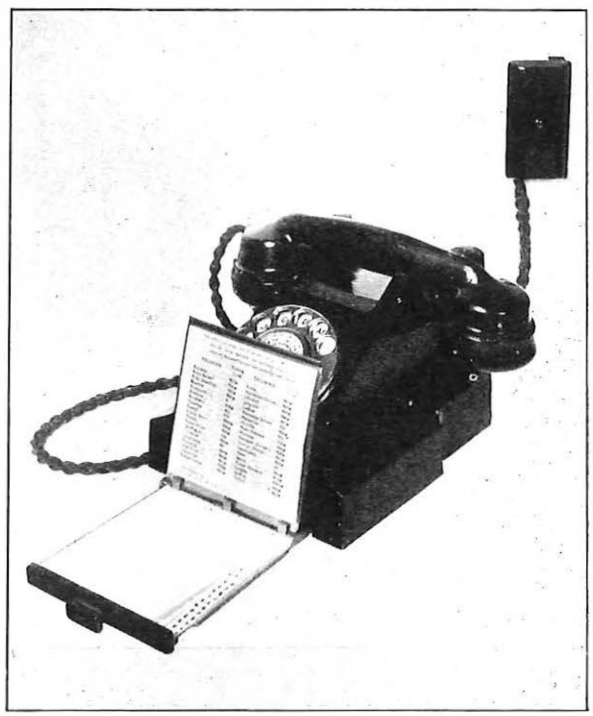


Fig. 3.—Tray containing List of Dialling Codes.

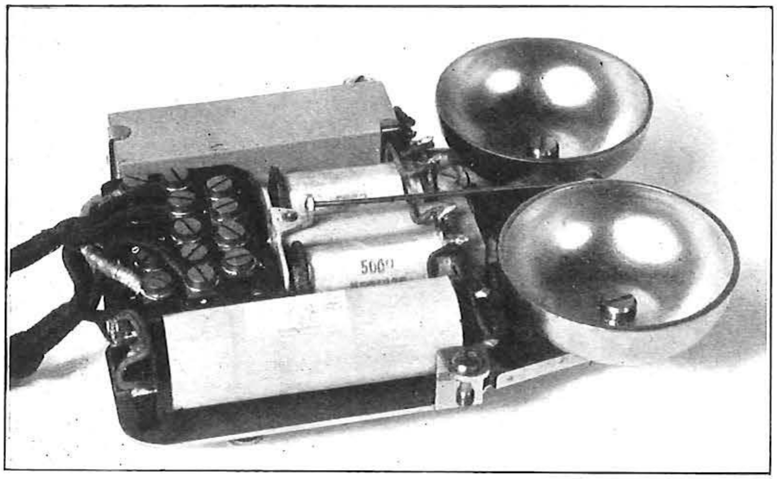


FIG. 4.—UNDERVIEW OF CHASSIS AND COMPONENTS.

A feature of both C.B. and L.B. circuits, which is novel to subscriber's sets in this country, is the shunting of the transmitter by a 0·1 μF. condenser.

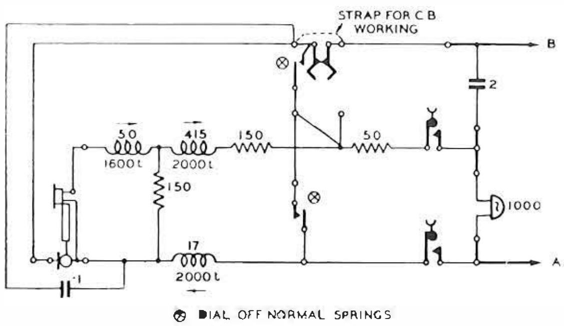


FIG. 5.—CIRCUIT OF AUTO AND CB TELEPHONE.

This condenser, besides preventing the rectifier action of the transmitter from causing interference between the telephone and nearby radio sets and vice versa, also has the effect of reducing the likelihood of the transmitter becoming packed by current surges occasioned by automatic switching, etc. A filter for preventing the dialling impulses from causing radio interference has also been designed and it has been arranged that, when required, it can be connected directly to the dial strip terminals as shown in Fig. 6.

There are in all some seven main varieties of the new instrument, excluding the sub-varieties necessitated by director and non-director working and the several colours. Patterns of both C.B. and L.B. types incorporating a trembler bell will be available for plan number working and these instruments will include a radio interference suppressor for dealing with the disturbance created by the bell contacts. This same suppressor will also act as a spark quench for the contacts and, in addition, reduce the disturbance created by the use of the bell when connected directly across C.B. and auto exchange lines.

Controls for Extension Instrument Installations, Plan Number Working.

One of the main features of the new instrument is the facility for accommodating on the telephone the controls for plan number working. This facility has for some time past been a feature of the telephone instruments used by certain continental administrations but the design of the British Post Office apparatus has not until now been such as would permit of the easy inclusion of switches and keys, etc. The whole of the facilities necessary for the existing plan numbers (excluding Nos. 5 and 7) as well as many others are provided by means of three key units, two of which are identical except that for economy one is equipped with just sufficient switch springs to meet the more popular of the plan number arrangements, whereas the other is equipped with enough springs to deal with all anticipated demands. The third key is fitted with one make contact only and is mounted and wired as an integral part of one particular variant of telephone, important uses of which will be as an extension instrument for P.B.X's, where the press button will be used for transferring calls.

There are several distinct advantages both to the subscriber and to the Post Office which are obtained by locating switching apparatus as part of the telephone. For the subscriber it simplifies operation and for the Post Office it simplifies fitting and enables the instrument to be prepared at the fitting centre complete with keys, terminal block, etc., ready for wiring. The labour economies possible from such an arrangement are obvious.

The convenience of this form of control and the fact that it may be linked with the switch-hook operation (switch hook release feature) has made possible considerable improvements in plan number facilities and it is anticipated that a complete revision of these will be undertaken in the near future together with the introduction of a simple house exchange system catering for up to three extensions with exchange line facilities. The switch-hook release feature is of particular importance because of the

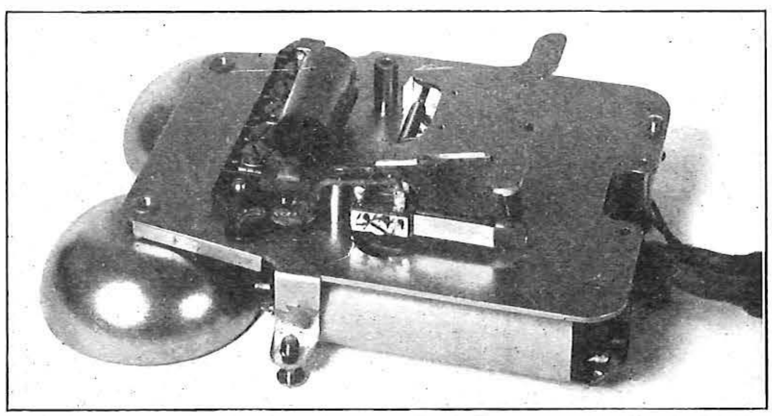


FIG. 6.—VIEW OF CHASSIS SHOWING DIAL INTERFERENCE SUPPRESSOR.

facility which it affords of returning conditions to normal at the completion of a call thereby obviating mis-operation due to forgetfulness in this respect on the subscriber's part.

A further economy to be introduced with this set is the standardisation of the label, it having been found possible to meet all the envisaged demands for plan number working by ten varieties of engraved label. Up to the present the labelling of keys on plan number installations has been carried out with mechanically engraved xylonite labels mounted adjacent to the keys. The new labels are a chemically engraved metal type of rather neater appearance than the old pattern and cheaper to produce.

Key Units.

Fig. **7** shows the larger of the two similar units, each of which consists of three plunger-type keys operated by press buttons located in front of the handset. The keys may be interlocked in various manners, e.g. all three can be left quite independent of each other to act as separate press buttons or it can be arranged that the first when depressed shall be locked in the operated position and only released from this position by the operation of the second or third. Alternatively the first or third may be locked down when operated and released by the replacement of the telephone on the rest, and so on.

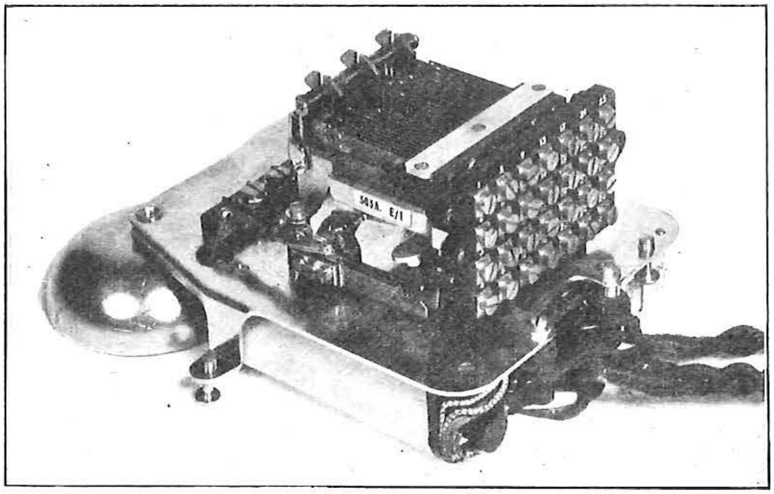


Fig. 7.—Chassis with larger type Key Unit mounted in position.

These facilities are all controlled by means of the very simple control plate shown in Fig. **8**. The key when operated is held in position by the lip of the spring latch plate meeting the projection on the key in ratchet and pawl fashion. The depression of a second similar button will, of course, force out the latch-plate and release the first button. To render any key non-locking, therefore, it is only necessary to prevent the latch-plate from overlapping the key projection. This is done by filling the lip with a portion of the control plate. The arrangement is such that the control plate may be mounted in a variety of positions on the latch-plate. In each of these positions it provides one form of interlocking between the three keys.

Switch-hook release is provided by removing a second control plate from the key frame where it is located for convenience and attaching it to the switch-hook mechanism of the telephone. The sloping face forming the underside of the top projection on the plungers has been provided to cater for cases where the subscriber inadvertently depresses two locking buttons simultaneously and where the conditions are such that there is no other means of releasing them. To obviate this the top lip is designed so that if either button is depressed beyond its locked position it will force the latch plate outwards and release the second button.

The key unit switch springs incorporate twin contacts and are mounted vertically to reduce fault liability. When one or two keys are not required the buttons are replaced by dummies.

Conclusion.

The new telephones and keys offer what are, in the writer's opinion, unique facilities for mechanical switching associated with the telephone and facilities, moreover, which could only otherwise be provided by complicated lever type keys or by press buttons with relays, either of which arrangements would indubitably be considerably more expensive than the new system, and it is considered that the new apparatus represents a real advance in telephone instrument design.

In conclusion the author wishes to tender his thanks to Messrs. Ericssons Telephones, Ltd., for the provision of the photographs used for the majority of the illustrations.

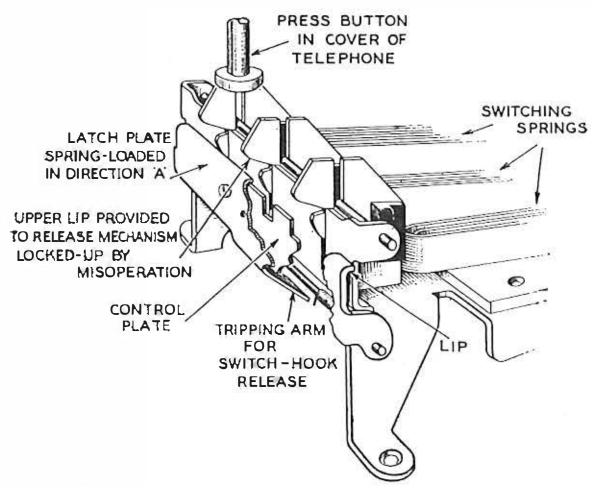


Fig. 8.—Key Interlocking Mechanism.

Multi-Fee Call Dialling and Registration at Non-Director Exchanges

F. WILSON and G. R. SUDELL.

The authors describe the general principles which are being followed in the design of non-director type equipment to permit the extension of the subscriber's dialling range so that all calls for which a fee up to a maximum of 4d. is chargeable may be completed automatically. A feature of the scheme is the provision of translating equipment which limits the number of routing digits to be dialled by the subscribers to a maximum of three. Multi-metering and route-barring facilities are also given.

Introduction.

HITHERTO subscriber-to-subscriber dialling in a non-director area has been confined to the main and satellite exchanges included in the linked numbering scheme and other automatic exchanges situated within the unit fee area, usually 5 miles.

The policy of automatisation of the Post Office telephone system has, as one object, the extension of the dialling range of subscribers, so that all calls, for which a fee up to a maximum of 4d. is chargeable, are completed automatically, and the programme of automatisation in the United Kingdom has now advanced sufficiently to necessitate the consideration of arrangements to achieve this object.

In the modern types of unit automatic exchanges, this facility has been provided where possible[1], and it is the purpose of this article to deal with the lines along which development is proceeding to give equivalent arrangements at non-director main and satellite exchanges.

Call Charges.

The system of charges now in use by the British Post Office is such that for calls between subscribers connected to exchanges more than 15 miles apart, i.e. calls for which the charge is 5d. and over, the fee varies according to the distance between the exchanges and the hour of the day in which the call is effected, and it is necessary for these calls to be supervised manually for charging purposes. For calls between subscribers connected to exchanges 15 miles or less distant from each other, the fee chargeable is dependent upon the distance only, irrespective of the hour of the day in which the call is effected, and the maximum fee for such calls is 4d. The charges are as indicated in Table I.

TABLE I.—CALL CHARGES

Distance between Originating and Called Exchanges	Fee
From 0 to 5 miles	1d.
From 5 to 7½ miles	2d.
From 7½ to 12½ miles	3d.
From 12½ to 15 miles	4d.

It will be seen from the foregoing that the equipment necessary at an exchange to provide the required multi-metering facilities should be capable of dealing with calls to all exchanges within 15 miles, and furthermore, of dealing with tandem traffic passing through the exchange. For the purpose of this article, the area enclosed by the circle of 15 miles' radius about an exchange is termed the multi-fee area, and includes exchanges outside the linked numbering scheme of the originating exchange. The term " central automatic area " is used to define all exchanges in the linked numbering scheme, i.e. main and associated satellite exchanges.

It will be appreciated that junctions between the exchanges in a multi-fee area are provided according to traffic requirements and that the traffic between some of the exchanges may not justify the provision of direct junctions. Consequently a number of calls will be routed via other exchanges, and it is necessary therefore to arrange for impulsing and signalling over junction networks which may consist of one junction or more in tandem.

Impulsing Considerations.

The inclusion of a transmission and signalling bridge in the auto-to-auto relay set involves impulse repetition which results in distortion of the repeated impulses additional to that already resulting from permissible variations in the subscribers' dial speed and from the subscribers' and junction line characteristics. These conditions impose limitations on the number and type of junctions in tandem over which it is possible to impulse without the aid of impulse regenerators[2].

TABLE II
JUNCTION RESISTANCE LIMITS FOR LOOP IMPULSING

Number of Junctions in Tandem	Loop Resistance of Junctions	
	Individual Maximum	Total Maximum
	ohms	ohms
1	1,500	1,500
2	800	1,600
3	700	1,000

Typical loop-impulsing limits for junctions are indicated in Table II from which it will be observed that a maximum limit of three junctions in tandem is imposed. A study of the type of junction networks likely to be involved in the completion of calls to exchanges in the multi-fee area of an originating exchange resulted in the general conclusion that in some areas the number of junctions in tandem which may be expected on such calls will exceed three, and it was obvious that the conditions could not be met with existing apparatus. It was therefore considered necessary to provide facilities for impulse regeneration en route. A portion of a typical junction net-

[1] *P.O.E.E.J.*, Vol. 28, p. 105; Vol. 29, p. 141; Vol 31, p. 41.

[2] *P.O.E.E.J.*, Vol. 30, p. 261.

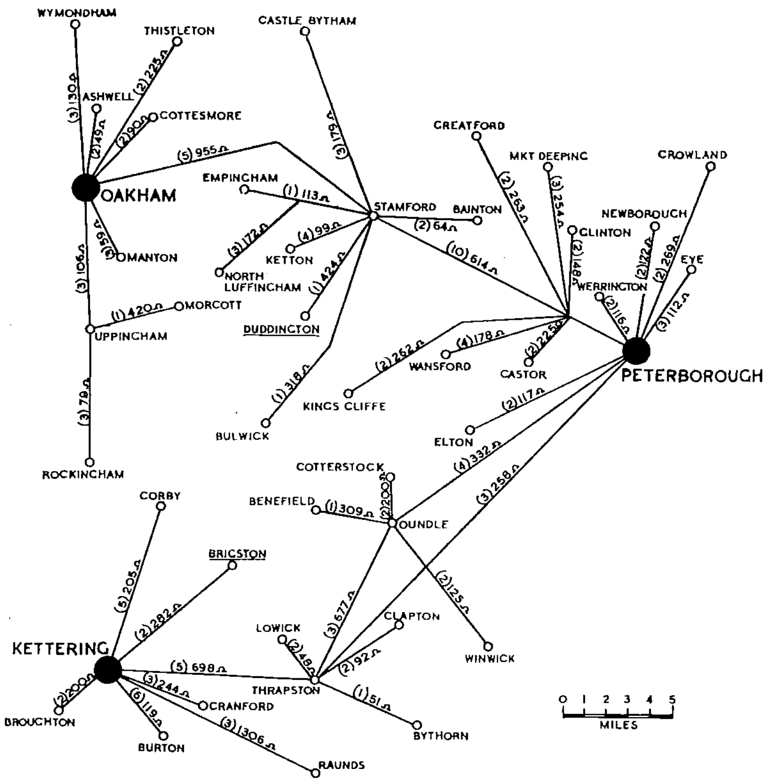


Fig. 1.—Typical Non-Director Area Junction Layout.

work is shown in Fig. **1**, from which it will be seen that a call from Duddington to Brigston involves the use of five junctions in tandem.

Consideration of the most favourable point at which to place impulse regenerators has indicated that it is most advantageous to associate them with the outgoing junctions at all tandem switching centres. The advantage of this arrangement is chiefly that the junction network is rendered completely flexible and independent of changes in the composition of the network. The effect of so placing the regenerators is to render each junction in a tandem connection subject to the limitations of single junctions only.

It is, of course, possible to meet the impulsing requirements by the association of the regenerators with the incoming ends of the junctions, or with both the outgoing and incoming ends of the junctions, according to the merits of each junction link. These methods are, however, subject to change as a result of extension or alteration in the junction networks and necessitate a careful study of the junctions over a large area. Furthermore, they prove to be less economical and involve additional transmission osses.

General Signalling Conditions.

Calls to Manual Exchange Subscribers.—It is proposed to introduce multi-metering facilities at main exchanges before full automatisation of all the exchanges in the multi-fee area is completed, and it is inevitable therefore that some calls will be dialled to manual exchanges. As manual exchanges will eventually be replaced by automatic exchanges, arrangements for the provision of manual hold facilities, discrimination as to the origin of the call to the distant operator, etc., are not justified.

Calls to Special Services.—Similarly, it is not considered desirable that the caller should be able to reach a distant auto-manual exchange via the multi-metering equipment for services which would involve the provision of re-call, manual hold and flashing facilities. It will be appreciated that such provision would involve relaying the necessary signalling conditions via each tandem exchange, with the consequent need of additional apparatus which would only be used for a small proportion of the total traffic. It is essential, as regards the existing exchanges, to keep the amount of apparatus required to a minimum in view of possible accommodation difficulties. It appears reasonable, therefore, to expect that all calls entailing services such as assistance, trunk, toll, etc., requiring manual intervention, should be dealt with at the local manual board and that the function of the multi-metering equipment should be confined to subscriber-to-subscriber connections within 15 miles of the originating exchange.

Dialling Codes.

From the subscriber's point of view, automatically setting up a call over a number of junctions in tandem would appear in some instances to be a formidable operation, should the caller be required to dial, as the code for the required exchange, the digits necessary to route the call via the appropriate selector levels at each intermediate exchange. Considering the call from Duddington to Brigston, if it is assumed that one digit is required at the originating, and at each tandem exchange, it will be observed that 5 code digits would be necessary in addition to those of the called party's number. Should more than one routing digit be necessary at one or more of the switching points, the number of digits in the code would be correspondingly increased. It was considered from this aspect of the problem that translation could usefully be employed and provided in the multi-metering equipment to generate the required impulse trains necessary to route the caller to the wanted exchange, so that the code digits which the caller would be required to dial could be reduced to a reasonable number. It is clear that such a reduction would improve operation from the subscriber's point of view and simplify the instructions necessary for the subscriber's understanding of the procedure involved in effecting such calls. It is emphasised at this stage that the use of translation is not intended to simulate the conditions obtaining in director areas, nor is it practicable to do so.

The scheme to be described (referred to as " the routing scheme ") has been proposed and is being developed by the Post Office Engineering Department for application at main and satellite exchanges. It limits to a maximum of seven the number of digits which the caller will dial for calls to subscribers connected to any other exchange within the limits of the multi-fee area, irrespective of the number of intermediate exchanges through which the call may be routed. This is achieved by the inclusion of a translating device in the multi-metering equipment at the main exchange.

The arrangement is such that a 2- or 3-digit code is prefixed to the called subscriber's number for calls to distant automatic exchanges, and a 3-digit code only is dialled for calls to distant manual exchanges. These dialling codes consist of a common 1st digit, the digit 8 generally being used, followed by one or two additional digits.

The use of a single-digit code is possible but has strictly limited applications depending on local conditions.

As the scheme aims at limiting the number of digits which the caller will dial for multi-fee area calls to a maximum of seven, it is necessary to allocate 2-digit codes to distant exchanges having a 5- or a mixed 4- and 5-digit numbering scheme. They can also be employed, if desired, on other exchanges having 4-digit numbering schemes if the code capacity and other local conditions render this possible.

The common 1st code-digit (generally 8) serves as a discriminating digit indicating that a multi-fee area call is to be effected and at the main exchange steps the 1st selector to the required level to give access to the multi-metering equipment. The next two digits are always used for translation, thus, when a 2-digit code is dialled, it is necessary to employ the 2nd code-digit and the 1st digit of the called subscriber's number, for this purpose. It will be evident therefore that a total of 100 3-digit codes are available.

Advantages of the Translation Scheme.

Apart from service advantages which accrue from the use of the translation scheme, there are considerable engineering advantages, the more outstanding of which may be enumerated as under:

(1) Routings which exist at the time of the introduction of multi-metering facilities may be retained without causing any restriction in the number of codes available for allocation.
(2) Dialling codes are unaffected by subsequent alterations of routings.
(3) Multi-metering discriminations and routings are given by straightforward jumpering arrangements.
(4) The trunking arrangements are considerably simplified.
(5) The subscribers' multiple capacity of an exchange is stabilised.
(6) The necessity for arranging the trunking at tandem exchanges so as to reduce the routing digits required to a minimum is eliminated.

Functions of Multi-Metering Equipment.

The essential functions of the multi-metering apparatus, in addition to those already discussed, are the determination of the appropriate fee chargeable for any particular call and the operation of the caller's meter in such a manner as to cause registration of that fee.

It is also necessary to apply suitable restriction to prevent certain types of calls being set up, and to limit the caller's access to the confines of the multi-fee area. In this respect the multi-metering equipment can be utilised as follows:

(*a*) To prevent coin-box users completing calls other than those for which a unit fee is chargeable, or completing calls to distant manual exchanges or auto-manual exchanges other than the one obtained by dialling "0."
(*b*) To prevent a caller setting up a call by means of irregular connections via distant U.A.X's which may result in the completion of calls for which the appropriate fee is in excess of that which would be registered in these circumstances.

As the incoming junctions at unit auto exchanges have access to routes which are also available to the U.A.X. subscribers, it is possible for a subscriber, having reached the U.A.X., to dial then a digit which would cause a call to be routed via an outgoing junction to another exchange.

Reference to Fig. **2**, which depicts a main exchange "A" having a route to U.A.X. "B" situated within

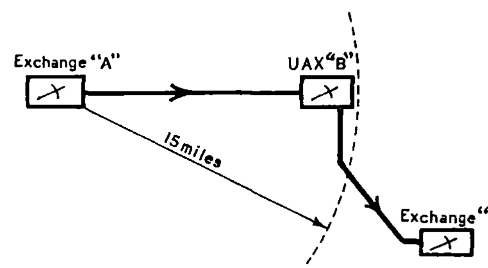


FIG. 2.—IRREGULAR ROUTING.

the multi-fee area of "A," and U.A.X. "B" having a route to exchange "C" outside the multi-fee area of "A," will illustrate this condition. It is assumed, for explanatory purposes, that the charge for a call from "A" to "B" is 4d., and from "A" to "C" is 5d., and that the code allocated at "B" for calls to exchange "C" is the digit "6." It will be evident that a caller at "A," dialling a code for exchange "B" and then, instead of following this with the called subscriber's number, dialling the digit "6" and following this with the number of a subscriber at exchange "C," could, unless prevented, effect a 5d. call for 4d., as the equipment at the originating exchange determines the fee as a result of the code dialled for exchange "B." The method of preventing this type of call is explained later.

Routing Scheme, Main Exchanges.

A typical application of this scheme is illustrated by the trunking diagram shown in Fig. **3**. The scheme can be applied to both new and existing main exchanges, but some modification of the equipment is necessary in existing satellite exchanges.

The outlets from the chosen level, say level 8, of 1st selectors at the main exchange are trunked to junction relay sets, each including an impulse

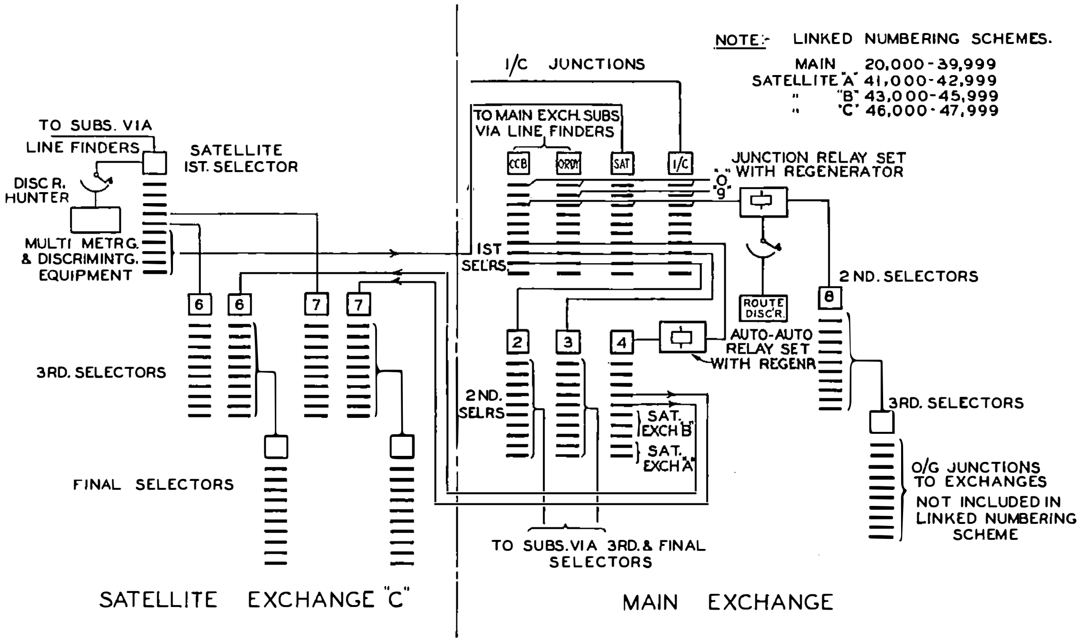


FIG. 3.—APPLICATION OF ROUTING SCHEMES.

regenerator, signalling relays and a transmission bridge. Associated with these relay sets via uniselector hunters are route discriminators which function as translating, discriminating, restricting and metering devices.

It will be seen that access to all junctions to exchanges included in the multi-fee area is obtained via this level of the 1st selectors, the junction relay sets, and thence via 2nd or 3rd selectors. A feature peculiar to the routing scheme is that it is necessary to associate the junction relay set with the outlets of the 1st selectors, because it is desired to translate the 2nd and 3rd digits dialled by the caller. The junction relay sets and route discriminators are therefore common to all the outgoing junctions. As a result, the arrangement has an economic advantage compared with schemes whereby the relay sets are associated directly with the junctions at a later stage of selection.

The impulse regenerators included in the junction relay sets are concerned in their regenerative capacity only on tandem calls passing through the exchange, i.e. calls from other exchanges via the incoming 1st selectors, but are employed as impulse storage devices on calls originated by the main or satellite exchange subscribers, and this function, it is interesting to note, is a further example of the use to which the mechanical impulse regenerator can be put.

The route discriminator consists of two parts, namely :

(1) Discriminating and controlling relays, a combined digit distributor and control uniselector and an impulse send control uniselector.

(2) Translation element, comprising a two-motion selector (which will be termed the BC Selector, for explanatory purposes), the banks of which are connected to an associated translation field in much the same way as in the director. Five double banks are provided on the selector, four of which provide for a maximum of 8 translated routing digits on any one of 100 codes, another bank is utilised for fee and other discrimination purposes, and the remaining bank for the association of call distribution and call totalling meters in connection with call-distribution records.

One impulse machine is provided per ten route discriminators for transmission of the routing digits resulting from the translation of the dialling code by the route discriminator and for operation of the caller's meter for fee registration, avoiding the necessity for meter pulse machines.

The 1st selectors are arranged in four groups, serving main exchange coin-box subscribers, main exchange ordinary subscribers, incoming junctions from the satellite exchanges, and incoming junctions from other exchanges respectively, in order that a signal may be passed forward from each group to the multi-metering equipment, to indicate the origin of the call, so that the appropriate conditions may be set up.

Operation of Equipment, Main Exchanges.

A main exchange subscriber calling another subscriber connected to an exchange included in the multi-fee area, will dial the appropriate code followed, on calls to automatic exchanges, by the called party's number. The 1st selector is thus stepped in accordance with the 1st digit, a free junction relay set is taken into use, and the discriminator hunter hunts for and associates an idle route discriminator. The 2nd and 3rd digits of the code are received by the regenerator in the junction relay set and are repeated to the route discriminator stepping the wipers of the BC selector to the appropriate position in the bank. The remaining digits composing the subscriber's number are held stored in the regenerator.

On receipt of the two code-digits by the route discriminator, discrimination is effected. Either NU tone is returned to the caller to indicate that a barred call has been attempted or a spare code dialled, upon which the discriminator is released, or the call is allowed to proceed, in which case the two digits are translated and the necessary routing digits to route the call to the required exchange are transmitted via the junction relay set, the 2nd and 3rd selectors and appropriate outgoing junction. Following transmission of the routing digits, the digits of the called subscriber's number are released by the regenerator in the junction relay set and transmitted over the junction.

When the called subscriber answers, the appropriate number of metering pulses are applied from the route discriminator to the caller's meter, via the junction relay set and the 1st selector. The route discriminator is then released and becomes available for use on other calls.

On calls to unit automatic exchanges, the 1st digit of the called subscriber's number is received by the route discriminator on the digit distributor uniselector at the same time as it is being transmitted to line by the relay set regenerator, and if the digit dialled is other than " 2 " or " 3," NU tone is returned to the caller, and the outgoing junction, distant exchange equipment and the discriminator are released. The unit automatic exchange numbering schemes are such that the subscribers' numbers commence with the digits " 2 " or " 3," and in this way the caller is prevented from setting up a call by the irregular connections previously described via the unit automatic exchange.

In the event of busy conditions being encountered en route, busy tone and flash are returned to the caller from the junction relay set and the outgoing junction, distant exchange equipment and the route discriminator are released.

The impulse regenerator in the junction relay set has a storage capacity for 40 impulses only, if none are transmitted by the regenerator in the meantime, and provision is made for the return of busy tone and flash to the caller in the event of this storage limit being reached before a route discriminator is associated with the junction relay set.

The satellite exchange subscribers dial the same codes as the main exchange subscribers for multi-fee calls, and such calls originated by these subscribers are dealt with at the main exchange in the same manner as those described for the main exchange subscriber, except that the route discriminator is used for translating purposes only, and is released following transmission of the routing digits.

On tandem calls originated at a distant exchange other than an associated satellite, a signal is received from the incoming 1st selector group to prevent association of a route discriminator with the junction relay set taken into use and the discriminators are not employed on this type of connection. Such calls pass via the level of the incoming selector, the junction relay set, which functions as an impulse repeater, and thence via the 2nd and 3rd selectors to the outgoing junction and distant exchange required, the necessary routing digits being transmitted from

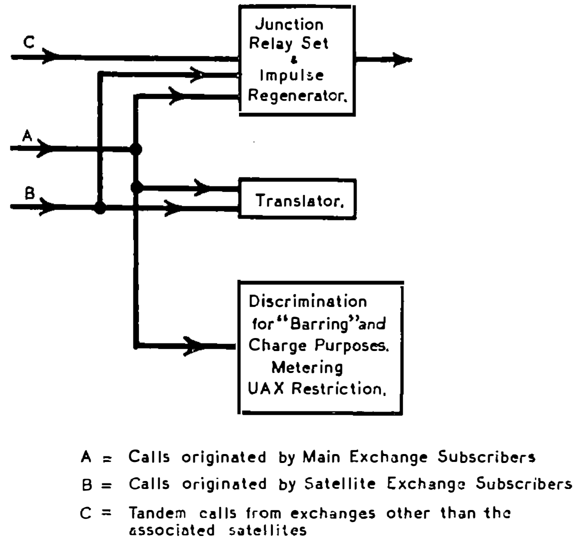


FIG. 4.—USE OF REGENERATION, TRANSLATING AND DISCRIMINATING EQUIPMENT.

the originating exchange. The chart given in Fig. 4 shows diagramatically, the equipment taken into use on each of the aforementioned types of traffic.

The conditions obtaining on calls to subscribers connected to the same exchange, or the associated satellite exchanges, are similar to those in existing practice. It will be noted, however, that the auto-to-auto relay sets used on the calls outgoing to the satellite exchanges are connected between the 1st and 2nd selectors instead of being directly associated with the outgoing junctions concerned.

In this connection, investigation has shown that the economic advantages derived from the association of the junction relay sets with the 1st selector levels for multi-fee traffic also apply to links to 2nd selectors serving routes to satellite exchanges, where the trunking arrangements permit, i.e. where a group of 2nd selectors only carries traffic to two or more satellite exchanges. The extent of the saving is dependent upon the number and size of the junction groups, the availability of the 1st and 2nd selectors concerned, and whether or not the traffic from the 1st selectors is smooth.

Routing Scheme, P.O. 2,000 Type Satellite Exchanges.

Advantages obtained from satellite working have been derived, as far as present design is concerned, from the use of a discriminating selector, which provides the following facilities :

(*a*) impulse repetition ;
(*b*) discrimination between junction and local calls ;
(*c*) absorption of digits for local calls, resulting in a saving of local selectors.

Access to the main exchange junctions is provided via the banks of a uniselector hunter.

With the necessity for the provision of multi-fee metering and the introduction of the 2,000 type selector, opportunity has been taken to design a satellite exchange in which a discriminator would provide, in addition to multi-metering, the discriminating and absorbing features of the discriminating selector. With this object in view, the following scheme has been developed and the arrangements shown for satellite exchange " C " in Fig. 3 illustrates its application. (Certain 2,000 type satellite exchanges are being installed at the present time with pre-2,000 type discriminating selectors. The scheme described in the following paragraphs does not apply to these exchanges.)

The line finders are connected to selectors termed satellite first selectors which are associated, via uniselector hunters, with a common group of discriminators which function as discriminating, route-restricting, metering, digit-absorbing and impulse-repeating devices. A transmission bridge is included in the first selector and access to the main exchange junction group is provided via one or more of the levels. Any levels, including level 1, can be allocated for junctions to the main exchange and the provision of automatic hunting gives full availability over the whole of the junction group. This method dispenses with the necessity for a separate junction hunter.

Junction hunting commences when a signal is received from the discriminator, which has previously determined that the call is required to proceed via the main exchange equipment. Thus a junction is not taken into use until required, resulting in a considerable saving in holding time. The discriminator includes a mechanical impulse regenerator which accepts the digits dialled by the subscriber and stores them until discrimination is given.

Should the call require to be routed via the main exchange all digits are sent over the junction by the regenerator, but where the call is local the first digit is absorbed by the discriminator and the satellite first selector steps under control of the second digit and functions as a second numerical selector giving access to third numerical and final selectors.

The trunking diagram shown in Fig. 3 shows a typical satellite exchange of 2,000 multiple occupying levels 6 and 7 of the satellite first selector. Five levels giving access to 100 junctions to the main exchange are also shown.

Junction Calls.—Should a call be set up to an exchange included in the multi-fee area the subscriber will be extended via a first selector to an idle discriminator from which dial tone is returned. The code will then be dialled commencing with the common 1st digit and discrimination is given, after the receipt of the 1st digit, that a junction to the main exchange is required and a signal is passed to the selector which causes it to step vertically until a level is found containing a free junction and then radially to find a free outlet. During this time the regenerator in the discriminator is receiving further digits from the subscriber. When a junction has been found the regenerator sends out the stored impulses, which are received at the main exchange, and the call proceeds from that point as previously described.

At the same time as the digits are being received by the regenerator they are received also by a relay group in the discriminator which, after the code has been dialled, discriminates for the following conditions :

(*a*) the fee chargeable ;

(*b*) the barring of multi-fee and other calls to coin-box users ;

(*c*) the barring of spare codes.

In condition (*a*), the call is allowed to proceed, but for (*b*) and (*c*) NU tone is returned to the caller and the junction released.

After discrimination has been given the remaining digits composing the called subscriber's number are accepted by the regenerator at the satellite exchange and repeated over the junction to the main exchange. The discriminating equipment is held until an answering signal is received which actuates the regenerator mechanism causing impulses to be delivered (by means of auxiliary impulse springs) to a uniselector which is stepped until a marked contact is encountered. During the stepping of this uniselector the appropriate fee is registered on the meter. After the fee has been registered the discriminator is released and can be used in the setting up and metering of further calls.

Local Calls.—Should the subscriber dial a local number commencing with 46 or 47, local discrimination is not given until the second digit has been dialled, as the digit 4 serves other satellite exchanges. All the digits will be repeated by the regenerator but the line-impulse springs are short-circuited during the time the digit 4 is being sent. The second digit will step the satellite first selector to the required level and subsequent digits will route the call via third and final selectors. Local discrimination provides for single-fee registration and the discriminator is held until this has been effected. Should the call require routing to another satellite exchange via the main exchange equipment, the second digit will be some number other than 6 or 7, in which case a signal will be sent from the discriminator to the selector to indicate that a junction is required, and when found all digits stored by the regenerator will be transmitted over the junction and the call routed through the main exchange equipment.

The discrimination for " 0 " level calls provides for manual hold and a coin box signal, and that for level 9 can provide for manual hold or metering as desired.

Calls to Manual Exchanges.—A 3-digit code will be dialled to obtain access to a manual exchange and discriminations are provided for either metering, in which case the discriminator is held until this has been effected, or non-metering, when the discriminator is immediately released.

Routing Scheme, Pre-2,000 Type Satellite Exchanges.

The provision of multi-metering facilities in this type of exchange must, of necessity, follow the same principles as that for 2,000 type satellite exchanges, as the equipment at the main exchange will be similar in both new and old types.

In order to reduce modification to existing equipment to an absolute minimum, the alterations to the discriminating selector have been restricted to those essential for providing the following circuit conditions to the new equipment :

(*a*) impulse repetition ;

(*b*) holding earth ;

(*c*) supervisory and metering signals ;

(*d*) busy back signal.

It will be appreciated that in this type of exchange there is no necessity to introduce a regenerator for storage purposes as all the existing features of the discriminating selector and junction hunter are retained. Associated with each discriminating selector is a small relay set and a discriminator hunter which functions for hunting, switching and return of busy and NU tones. The discriminators are provided in a common group, access being obtained by the discriminator hunters. This equipment receives a repetition of the impulses at the same time as they are being sent over the junction and discriminates for metering, coin-box barring and spare codes.

On reference to the trunking diagram shown in Fig. 5, it will be seen that a call to an exchange in the multi-fee area is dealt with in the following manner.

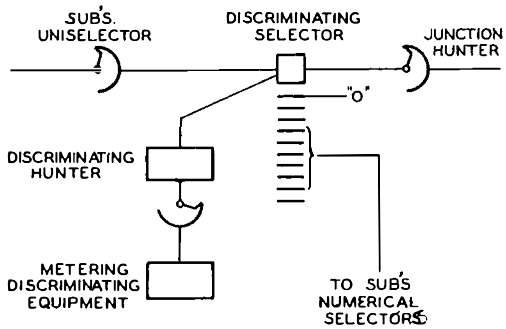


FIG. 5.—TRUNKING DIAGRAM. PRE-2000 TYPE SATELLITE EXCHANGES.

When a discriminating selector is taken into use the junction hunter is caused to find an idle outlet and the switching relay to operate and busy the junction found, but dialling tone is delayed until the discriminator is associated. When the common first digit is dialled junction discrimination is given and the discriminating selector functions in its normal manner. This digit is repeated over the junction, stepping the first selector at the main exchange to level 8, say, where an auto-auto relay set is seized together with a routing equipment. The second and third digits are also repeated over the junction, positioning the routing equipment at the main exchange. These three digits comprising the code are also received by the discriminator at the satellite exchange which determines the fee to be registered, or if a barred or spare code is attempted disconnects the junction and returns NU tone to the caller.

Should " busy " be returned from any switching stage during the setting up of a call, busy tone is returned to the subscriber by the discrimination and the junction is released. When a discrimination has been given, the impulsing circuit to a discriminator is disconnected and subsequent digits are transmitted over the junction only. The discriminator remains associated until the called subscriber answers and metering is effected.

In order to provide for meter impulses a similar method is adopted to that described for 2,000 type satellite exchanges, but in the absence of a regenerator, " flicker " earth is used to step the uniselector which controls the meter pulse relay.

Local Calls and Calls to Exchanges within Linked Numbering Scheme.—Although there are satellite exchanges of less than 1,000 multiple for which third digit discrimination is provided by the discriminating selector, it is not necessary to accept this number of digits by the multi-metering discriminator due to the fact that all calls of this nature require single-fee registration and the first digit will be sufficient to determine this. Therefore discrimination will be given after the first digit has been dialled and no further digits will be accepted by the discriminator. When metering has been effected the discriminator is released.

Calls to Manual Exchanges.—A 3-digit code is dialled as with 2,000 type satellite exchanges.

Conclusion.

This article provides an introduction to a subject which embraces many complex problems, as for example the incorporation of devices for impulse regeneration, junction guarding, etc., which are, of course, essential features for the materialisation of the Post Office policy to extend the subscriber's dialling range to 15 miles.

In future articles it is intended to give further details of the " routing " scheme and its adaptability for other purposes such as dealing with multi-fee traffic to a director network from non-director subscribers situated on the fringe of a director area, and the use of the route discriminator on tandem traffic originated by dependent U.A.X.'s, dialling-in operators, etc.

The History and Development of the 30-cwt. Utility Vehicle

R. T. ROBINSON, A.M.I.E.E., A.M.Inst.T.

The author traces the history of the 30-cwt. Utility Vehicle, which is used for subscribers' works, and gives details of its present-day bodywork.

Introduction.

ONE can imagine the feelings of Post Office gangs 20 or 30 years ago, when they had to travel to their work by slow and uncomfortable trains, and when the final stage of the journey often meant pushing a heavily-laden handcart for several miles. It was not until 1916 that the Post Office Engineering Department adopted a method of reducing the enormous expenditure of man power in getting to the job. In that year Army lorries were borrowed for work on the restoration of open lines damaged by the great snowstorm, and they showed so plainly the advantages to be gained from the conveyance of gangs, direct from their headquarters to the site of the work, that their use on a large scale was decided upon.

In 1919 a few 3-ton Albion lorries, 7-cwt. Ford vans, and Triumph and Douglas motor cycle combinations, about 600 in all, were obtained from the surplus army fleet, and this constituted the nucleus of the Engineering Department's fleet. Experience soon showed that vehicles intermediate in size between the 7-cwt and 3-ton were necessary and others of 1-ton, 30-cwt., and 2-ton carrying capacity were gradually introduced.

By 1925 motor transport was used to a considerable extent for conveying gangs, with their handcarts and other equipment, to the site of their work, but the number of vehicles was not sufficient to make journeys by train exceptional. The jobs were frequently at some distance from headquarters and even when a lorry was available to take the men the whole distance from their headquarters to the job, they were not brought back until the work was finished, so that lodgings had to be found for them during that time.

At the beginning of April, 1925, the fleet was made up as follows:—

	41	3-ton Albion Lorries
	4	30-cwt. Albion Lorries
	118	1-ton Ford Vans
	49	7-cwt. Ford Vans
	2	Cable Testing Vans
	736	motor cycle combinations
Total	950	

None of these vehicles possessed any distinctive character other than being rather more robust than many of the standard products of motor firms. The greater strength was essential for the cartage of poles, cable drums, handcarts and other heavy concentrated loads.

All chassis are bought direct from the makers, and the bodies are constructed by body-building firms to Post Office specifications and drawings. A selected group of body-builders are invited to tender for the construction of bodies about twice a year.

Early Utility Vehicles.

Between 1921 and 1925 several papers dealing with Motor Transport were read at local centres of the I.P.O.E.E. and one advocated the use of a specially designed vehicle for gangs engaged on overhead work. There were to be facilities for arranging in an orderly manner the tools and stores hitherto carried in the handcart and the vehicle was to remain with the gang at all times.

A vehicle was designed and tried out at Loughborough early in 1925. Later in the same year, six more of the same pattern were built. In this model the cab was as high as the body and one roof covered both.

It was soon discovered that this type of vehicle would be much more useful on telephone subscriber's work if one or two light poles could be carried. Various means suggested themselves, some of which would have involved restricting access to the cab to one side only, a common practice at that time: but from the outset, when designing the various types of body used in the service, "Safety First" has been the rule and the carrying of ladders and poles on the vehicle in its modified design in no way interferes with the use of either door of the cab.

The alteration consisted in lowering the cab roof

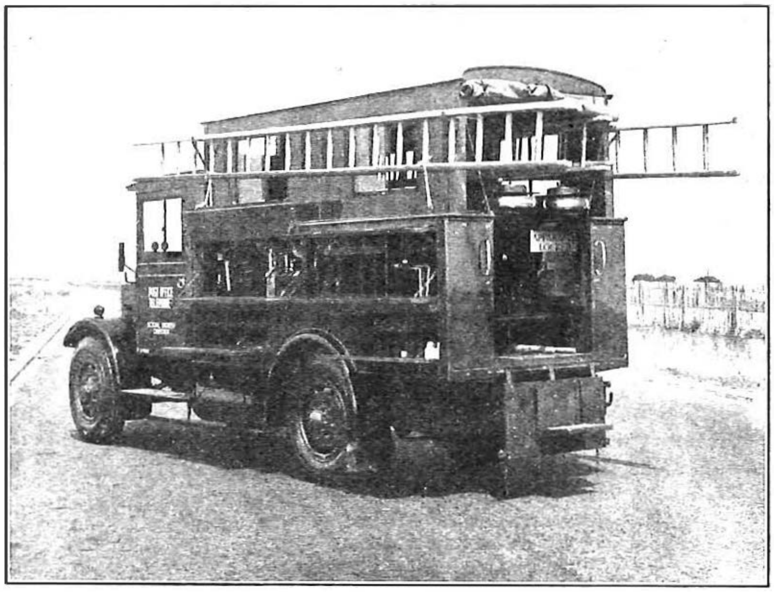


FIG. 1.—THE 30-CWT. UTILITY VEHICLE.

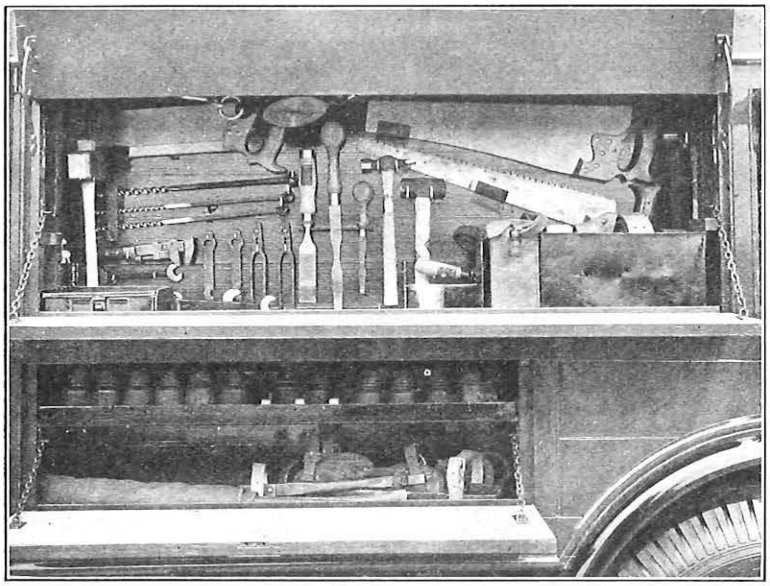


FIG. 2.—NEARSIDE FRONT LOCKERS.

and making a small opening at the front of the body, above the cab, as shown in the top left-hand corner of Fig. 1. The opening is visible through the side window between the rungs of the ladder on the near side of the vehicle. A clearer view of the opening is seen in Figs. 6 and 7.

Since 1925 the fleet has consisted of two distinct classes of vehicles, stores-carrying, which are common service vehicles for conveying men and stores as required; and utility vehicles, which are definitely assigned to a gang or working party, of which the driver is a member. The 30-cwt. utility van was the only type until 1928 when the 10-cwt. type was introduced and the 1-ton a year later. These vehicles provide shelter for the gang in inclement weather while on the work and for meals.

As the load carrying capacity of a utility vehicle is handicapped by the weight of the locker compartments the engineers responsible for their production carefully review the design before placing a new contract, with the object of introducing new methods of construction that will reduce the weight without minimising the strength, bearing in mind that a vehicle of this class is expected to give good service for at least ten years. Recently a considerable reduction in weight has been secured by using lighter framing members of wood reinforced by thin steel plates, and by a modification to the roof. In all, four to five cwts. have been saved during the last two years. The use of the lighter framing members has not increased the cost of the vehicles: although when they were first considered in 1931 the cost was found to be prohibitive.

Tool and Stores Fittings.

When the vehicles were first introduced in 1925, attempts were made to devise suitable fittings for the orderly arrangement of the tools and stores, but in those days gangs were seldom employed on one class of work continuously. The stores used on main trunk lines, e.g., insulators and spindles, arm bolts, wire, etc., are larger in dimensions and heavier than those used on pole lines (minor lines) consisting mainly of subscribers' circuits, hence it was difficult to devise standard fittings that would enable the foreman to take out stores for all classes of work in sufficient quantity for more than one day's work. The tool kit of these mixed work gangs is also much larger than that required for work on minor lines. Gangs working for the most part on main trunk lines use stores-carrying vehicles.

The old Northern Engineering District took particular interest in the development of fittings for utility vehicles, and the volume of work on minor lines having developed by 1928 sufficiently to permit of the work being segregated to a great extent, they devised a layout which is the basis of the present standard scheme. Fittings are being provided locally for all vehicles built before June, 1937.

The recent more rapid growth of overhead subscribers' circuits has made it possible to segregate work still more and to fit up new vehicles before they are brought into service. The equipment costs less and there is no interference with work while vehicles are being fitted up.

There are four lockers on each side of the vehicle. Fig. 1 shows the general layout of those on the near-

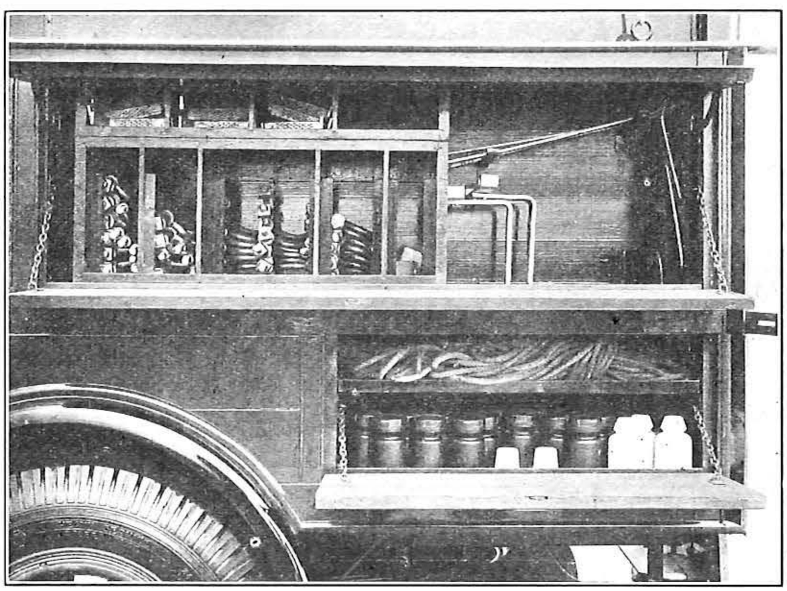


FIG. 3.—NEARSIDE REAR LOCKERS.

side and the individual items in each compartment are more clearly shown in Figs. **2** and **3**.

The tools are neatly spaced out in the upper locker as shown in Fig. **2** and to assist the gang in restoring the tools to their proper place a gummed slip showing a skeleton outline of the tools in position is fixed to the back of the locker. Immediately below the tool locker various types of insulators are kept in position by wooden pegs fixed to the shelf and pole climbers, insulating tails and other items are carried on the floor. In Fig. **3** there are pole steps, brackets and insulator spindles in the upper locker, and sash line and insulators in the lower locker.

Figs. **4** and **5** show the items carried in the offside lockers. These include coils of wire, leading-in cable, various insulator fittings, arm bolts, tension ratchets, draw vices, and small stores.

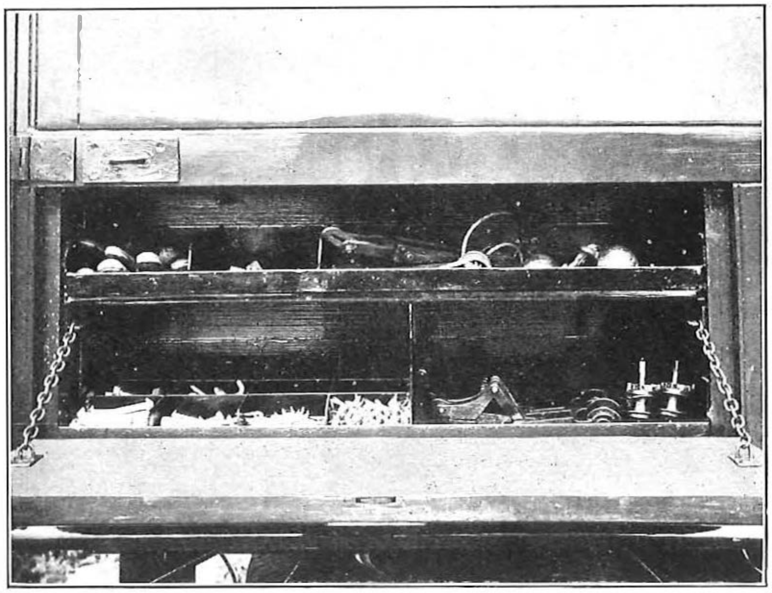


FIG. 5.—OFFSIDE REAR LOCKERS.

Whenever possible a man skilled in fitting up subscribers' apparatus is included in the gang and the items of stores required by him—cords, etc., and apparatus—are carried in the offside locker towards the rear of the vehicle, as shown in Fig. **1**. The purpose for which the other internal lockers are used is shown in Fig. **6**.

Other features shown in Fig. **6** are the ladder hooks, ladder lashing rings, wiring drums for paying out 40 lb. conductors, the opening at the front for the pole heads and the gate at the rear, shown folded back, on which the pole butts are carried. The removable horizontal roller raised above the floor, at the rear of the vehicle, is used to facilitate the loading of poles before the butts are lifted on to the gate.

The writing slope with an adjustable electric light fitting overhead is conveniently near to the locker for the foreman's technical instructions, progress reports, requisition books and other papers. The top of this locker is sufficiently strong to carry a 3-in. parallel bench vice.

Digging tools and stay rods are carried under the seat: arms, stay blocks and other heavy items, such as pole lifting jacks, when required, are carried on the floor in the gangway.

Pole-Carrying Facilities.

Fig. **7** gives two part views of the same vehicle illustrating more clearly the method of loading and conveying the poles. In the back view two poles are shown, one with its head through the opening at the front and its butt resting on the gate at the rear of the vehicle, and the other pole with its head resting on the horizontal roller. The head of the second pole would be supported by the roller until it reached the opening in the front. When the second pole had been pushed forward to the same extent as the other its butt would be lifted off the roller on to the gate. The right hand part of the figure shows the head of the first pole projecting through the opening at the front of the vehicle.

Before the vehicle is moved away from the pole stack the heads of the poles are lashed to the rings provided at the front of the vehicle and the butts to the gate. The head of the first pole has already been lashed. The roller is also removed from its supports and carried on the floor of the vehicle.

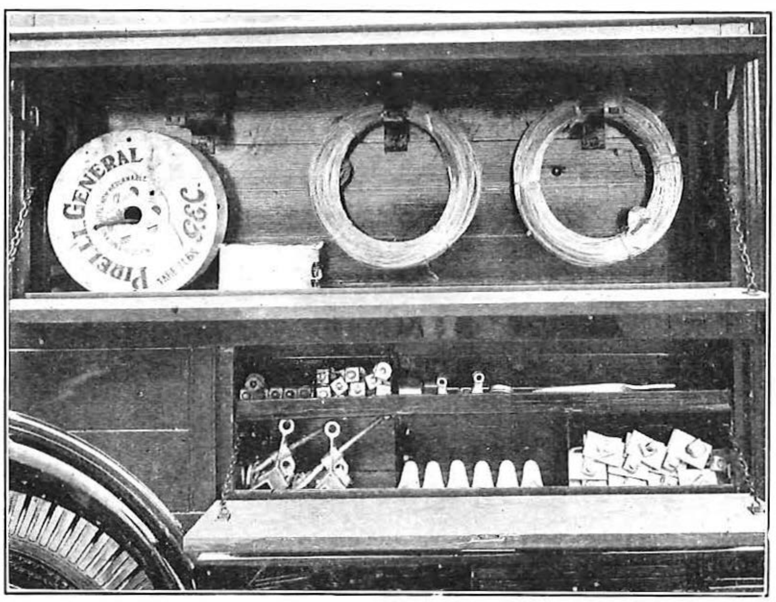


FIG. 4.—OFFSIDE FRONT LOCKERS.

Types of Chassis.

The Albion chassis has hitherto been

used exclusively for this class of utility vehicle. Recently it was decided to make a trial of Morris chassis for this work and 35 are included in the total of 1,305 vehicles at the end of March, 1939.

Staff Accommodation.

The seating accommodation in the body is adequate for five men and since the normal size of a gang is four men including the foreman and driver, both seated in the cab, it is possible to convey other men—for example, a jointer and his mate when their work lies in the same direction—and to hitch their trailer tool-cart to the vehicle. A spare number plate is carried on each vehicle for attachment to a trailer.

Economic Use.

The cost of a utility vehicle is much greater than that of a stores-carrying vehicle of the same load capacity, hence the annual interest and depreciation costs are greater. On the other hand a utility vehicle conveys a gang direct to the job in the morning, and from job to job during the day, and its use does not entail any dead mileage: consequently the cost of transport per subscriber's circuit is less. The radial limit to which gangs are taken out and brought in

FIG. 6.—INTERIOR OF BODY.

is about 15 miles. If the work is beyond this distance the gang usually stays away from its headquarters until the work is finished.

A requirement essential to the economic use of utility vehicles is a well designed system for the rapid replenishment of the stock of stores and apparatus as it becomes exhausted. The locker capacity is sufficient for a three days' supply of all normal items used.

Great attention is being paid at the present time to the development of facilities for rapidly loading utility vehicles. At headquarters where there is a section stock mobile containers are being introduced which will be wheeled to where the vehicle stands in the garage. For vehicles which are stationed at a town where there is no section stock, stores will be left in locked containers or permanent lockups at some convenient place near the garage, to be unpacked by the foreman at his convenience.

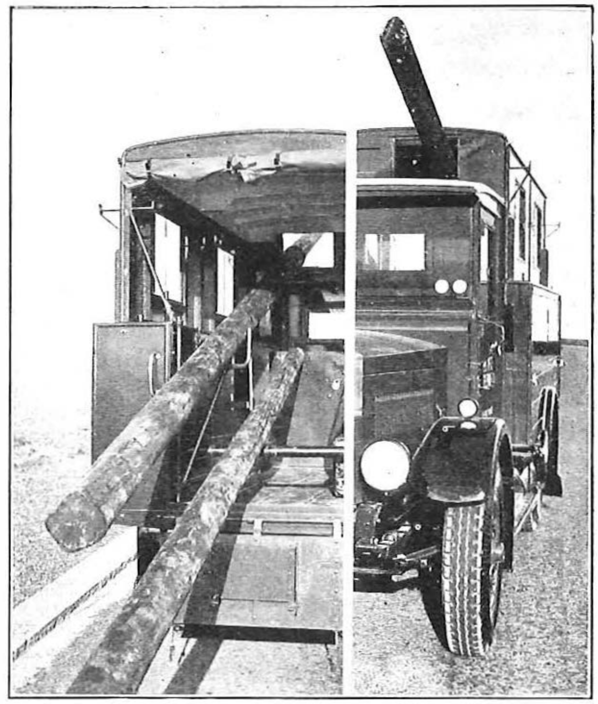


FIG. 7.—POLE-CARRYING FACILITIES.

Conclusion.

Minor adjustments will no doubt be required in the future to suit special conditions, as the character of the work is continually changing. That the 30-cwt. utility vehicle has done much to reduce telephone costs, and that it is an indispensable aid to the development of the telephone service, has been fully recognised; and the consequent growth of the fleet, which has been most rapid in the last few years, is shown in the following table which includes the numbers of vehicles estimated for 1938-39.

Year	30-*cwt. Utility Vehicles*	1-*ton Utility Vehicles*	10/15-*cwt. Utility Vehicles*	*Morris Minor Utility Vehicles*	*All other types of Vehicles*
1925/26	7	—	—	—	1106
1926/27	18	—	—	—	1306
1927/28	39	—	—	—	1443
1928/29	85	—	4	—	1624
1929/30	145	46	60	—	1816
1930/31	16[illegible]	80	71	—	2130
1931/32	246	121	126	12	2439
1932/33	280	137	143	90	2709
1933/34	340	181	202	192	2800
1934/35	468	213	286	438	2963
1935/36	601	336	229	895	2969
1936/37	851	515	202	1669	2831
1937/38	1180	808	183	2765	2882
1938/39 (*forecast*)	1305	953	183	3305	3072

Echo Effects in Relation to the European Trunk Switching Plan

A. C. TIMMIS, B.Sc., A.M.I.E.E.

The problems arising from echo effects on long trans-continental trunk lines have been studied by the various administrations concerned. This article reviews the work done in this country and defines the limits agreed at the recent international conference in Paris.

Introduction.

THE question of the effect of electrical echoes on long lines with or without echo suppressors was dealt with briefly in the course of a recent article on the Trunk Switching Plan[1]. The present article is a more detailed discussion of the question and should be read in conjunction with the article on " A Fast Operating Differential Echo Suppressor."[2]

Circuits Without Echo Suppressors.

Very soon after the introduction of 4-wire circuits electrical echoes were noticed and experiments were made to determine by means of judgment tests the relation between echo time and the overall equivalent* of a line for which the effect was just tolerable to a speaker. The listener also hears an echo at the same time as he hears the speaker's voice, but this listener echo may always be disregarded in practice since, if the echo heard by the talker is tolerable, the listener echo is invariably more so. The results of English, American and Swedish tests were published by the C.C.I.F. in 1926. The curves are shown in Fig. 1.

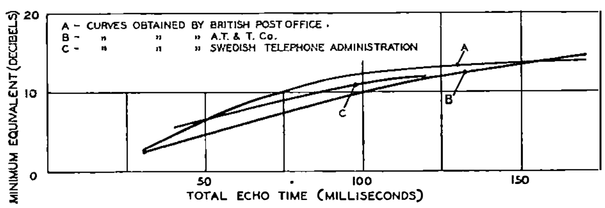


Fig. 1.—Minimum Equivalent limited by Echo.

It will be seen that these curves show the relation between echo time and the equivalent of a trunk under terminal conditions, which were assumed to be the most severe as regards echo, i.e. with a subscriber's telephone and zero local line at each end. The attenuation of the echo path is made up of the trunk equivalent in the go direction, the loss in the reflection from the telephone or other termination, and the trunk equivalent in the return direction.

The echo path attenuation is called echo loss by American writers, and similarly the reflection loss of the telephone or other termination is called the terminal return loss. This quantity is practically identical with the singing point of the termination measured against the compromise balance (usually 600 ohms) at the end of the trunk. The term singing point is not a good one, however, and its use has been discontinued by the C.C.I.F. The terminal return loss may be calculated from an impedance measurement by the usual formula :

$$\text{Return loss} = 20 \log_{10} \frac{Z_a + Z_o}{Z_a - Z_o}$$

where Z_o = impedance of balance
and Z_a = impedance of termination,

or measured directly as the difference in the losses round the echo path of a differential transformer when the 2-wire terminals are (*a*) closed by the telephone or other termination, and (*b*) disconnected or short-circuited. The terminal return loss of a telephone with zero local line, which was used in the first series of judgment tests, varies according to frequency, but its lowest value in the noise range is approximately 7 db. Therefore the total echo path attenuation for a trunk equivalent of, say, 5 db. was $5 + 5 + 7 = 17$ db.

The results of later judgment tests have been plotted to show the relation between echo attenuation and echo time (Fig. 2), so that the curve expresses a psychological relation, namely, the difference in volume between speech and echo which, with commercial telephone instruments, is regarded as tolerable for a certain echo time. The echo curve obtained by the A. T. & T. Co. and plotted on this basis was adopted some years ago by the C.C.I.F.

Recent judgment tests made in this country have given results in reasonable agreement with the curve and an attempt has been made to extend it (as shown dotted in Fig. 2) down to zero time by estimating the tolerable volume of side-tone, regarded as an instantaneous echo, but the curve is of little

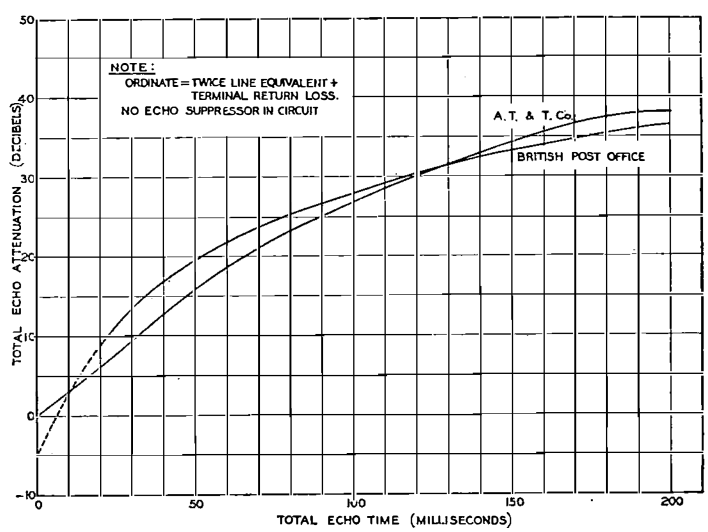


Fig. 2.—Minimum Echo Attenuation—Echo Time.

[1] *P.O.E.E.J.*, Vol. 30, p. 32.
[2] *P.O.E.E.J.*, Vol. 30, p. 186.
* Equivalent or overall equivalent is equal to the net loss.

importance below 20 milliseconds, as then the echo is scarcely distinguishable from side-tone. The American curve was extended to zero as a matter of convenience, but it is recognised that the readings are of doubtful value below 20 milliseconds.

During the judgment tests in this country an ordinary handset telephone No. 162 was used most of the time, but some tests were made with an anti-side-tone handset (Telephone No. 232). The reference equivalents of side-tone, under the conditions of the test, were about 1 and 8 db. respectively. It was found that the tolerable echo attenuation was about 4 db. greater with Telephone No. 232, according to the average of several observers.

As would be expected with the normal or rather loud speech volumes used in these tests, the side-tone, even if it ceases before the echo is heard, reduces the sensitivity of the ear for an appreciable time, and thus tends to make the echo less audible. In practice the echo is likely to be strong when the subscriber's line is short and the side-tone may also be loud. If the subscriber's line is of normal length the echo will be weaker and, in general, the side-tone will also be weaker, but there is no simple relation between side-tone and length of line. The effect of impedance may easily outweigh that of attenuation. Hence it is unsafe to assume that weaker side-tone would compensate for weaker echo and for this reason a very short subscriber's line was used in the echo tests made here.

Telephones with considerable side-tone reduction, such as Telephone No. 232, are not in general use at present, but if their use becomes general it would appear that the ordinates of the C.C.I.F. curve in Fig. 2 should be increased. This would not have any serious economic results as it would merely mean the installation of a few more echo-suppressors.

In an article by Strecker[3] some echo judgment tests made in the laboratory of Siemens & Halske are described. In these tests arrangements were made to adjust the side-tone from a reference equivalent of 7 db. upwards. With a side-tone of 16 db. the tolerable echo attenuation was raised about 5 db., which agrees fairly well with the results obtained in Great Britain when the reference equivalent of side-tone was increased from 1 to 8 db.

It may be mentioned here that side-tone was also found to make a slight difference to the results of the judgment tests made by technical observers on an echo-suppressor circuit, but, in practice, a reduced side-tone would cause a subscriber to speak more loudly and therefore he would speak less often at the very low level required to produce an echo on a trunk equipped with an echo-suppressor. It is, therefore, concluded that side-tone has a negligible effect as regards the echo on echo-suppressor circuits.

Combined Effect of Several Echo Paths.

The object of extending the curve down to short echo times was to verify the assumption, made in the A.T. & T. Co. method of computing echo effects, that a number of intermediate echoes (such as occur on a long 2-wire circuit) could be added on a power basis. This was investigated on an experimental circuit consisting of two London-Leeds 4-wire trunks looped back at Leeds and provided with adjustable echo paths. The general arrangement is shown in Fig. 3. Each of the echo paths A, B, C, D, consisted of an attenuator together with an amplifier. The echo path losses and times were as shown in Table I.

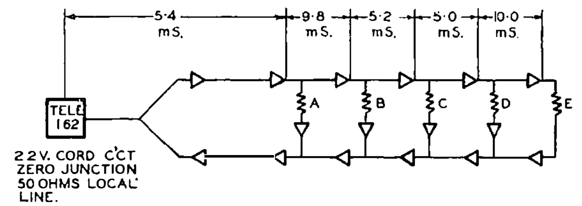


Fig. 3.—Multiple Echo Paths.

Table I.

Path	Echo Loss	Echo Time
	(db.)	(mS.)
A	10	10·8
B	21	30·4
C	24	40·8
D	27	50·8
E	31	70·8

It will be seen that each loss was made 7 db. more than the minimum tolerable loss according to the P.O. curve of Fig. 2.

The method of computing echo effects now being discussed involves two assumptions :—

(1) The audibility of an echo, although a function of time and loudness, can be measured by the difference between the echo path loss and the minimum loss according to the curve, the audibility, or annoyance, regarded as tolerable by the observers being taken as a datum. Thus an echo loss of 7 db. more than the minimum means that the echo is 7 db. below datum.

(2) The effective audibility of a number of echoes may be obtained approximately by adding their powers, expressed as fractions of the datum. When the sum equals unity the total echo effect is just tolerable.

The second assumption means that the echoes combine, in their psychological effect, according to a random addition law.

Since each of the five echo paths A to E has a margin of 7 db. (a power ratio of 1/5) the sum of the powers is unity, and the total echo should be just tolerable. In order to eliminate differences of individual judgment a rapid comparison was made by several observers between the combined echo and a single echo path (E) adjusted to a loss of 24 db., the value according to the curve. It was agreed by all observers that the combined echo and the single echo were equally tolerable in so far as two psychological effects, of somewhat different characters, can be equated. Hence the two assumptions are justified.

[3] Investigations on intermediate and terminal echo-suppressors for trunk lines, *T.F.T.*, August, 1937.

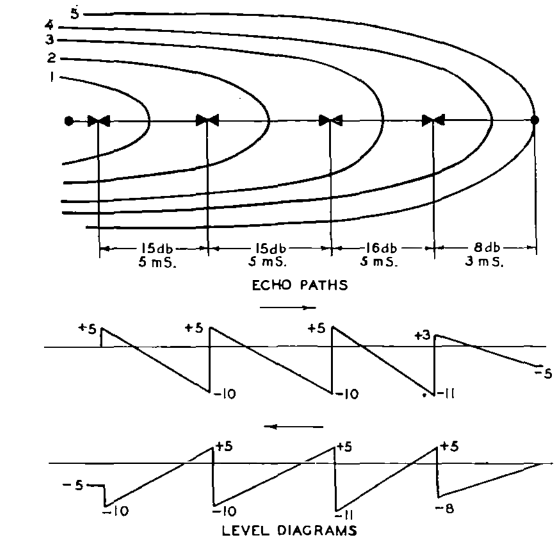


FIG. 4.—ECHO PATHS—2-WIRE TRUNK.

In applying the method to a long 2-wire circuit the times and losses for each echo path are calculated and set out in tabular form in Table II, which relates to the typical 2-wire trunk, loaded with 176 mH at 2,000 yards, shown in Fig. **4**. The five echo paths are shown at the top of the figure. Since reflections (due to impedance irregularities) actually occur throughout a repeater section, it is assumed that the effective echo time is that corresponding to the middle of the section.

The echo loss, in each path, is most conveniently obtained from the level diagram.

Cols. 1, 2 and 3 of Table II are self explanatory. Col. 4 shows the minimum tolerable echo loss, according to Fig. **2**, and col. 5 is the difference between cols. 2 and 4, i.e. the margin of echo loss in each path.

TABLE II.—TYPICAL ECHO COMPUTATION

1	2	3	4	5	6
Path No.	Echo Loss db.	Echo Time milli-secs.	Minimum Echo Loss db.	Margin of Echo Loss db.	Power Ratio
1	18	5	0	18	0·02
2	18	15	6 (5)	12 (13)	0·06 (0·05)
3	17	25	11 (8)	6 (9)	0·25 (0·13)
4	22	33	14 (10)	8 (12)	0·16 (0·06)
5	18	36	15 (11)	3 (7)	0·50 (0·20)
					Total 0·99 (0·46)

Minimum equivalent limited by echo to approximately 5 db. for which the total of the power ratios=0.99 (0.46).

The method of computation is practically that used by the A.T. & T. Co., but the column headings are paraphrased. Moreover, it makes a considerable difference whether the A.T. & T. Co. or the P.O. curve of Fig. **2** is used. Figures corresponding to the former have been inserted in brackets in the table, and it will be found that the equivalent must be reduced to 3 db. to make the total of power ratios equal to one.

There was some difference between the methods used in obtaining the English and the American curves. In both countries most of the speakers were experts who tried to maintain a uniform criterion of the magnitude of the echo effect at various echo times, but the English speakers admitted the effect as tolerable when they could just notice it, whereas the American experts asked themselves whether the effect would be tolerable in conversation, and afterwards checked the results by observations on speakers who did not know they were the subject of experiment.

The amount of echo which subscribers may reasonably be expected to tolerate is very much a matter of opinion, however, and it may be said that the P.O. curve agrees as well as can be expected, in view of the nature of the problem, with the American curve adopted by the C.C.I.F.

Terminal Return Loss.

In computing echo effects on 2-wire and on 4-wire circuits the terminal return loss is generally the dominant factor. On a 4-wire circuit, of course, the echo comes only from the terminal.

The value of terminal return loss to be used in calculations depends on the chance of occurrence of various values (which can be determined as closely as desired by statistical methods), and on the percentage of calls in which one is prepared to take the risk of echo being noticed. This percentage depends on economic and psychological factors and is therefore a matter of experienced judgment.

Return loss measurements were made from the international trunk exchange on forty-six typical London subscribers' connections. Each result was "weighted" in accordance with the amount of international trunk traffic at the exchange concerned, and percentage distribution curves were plotted.

When a quantity which varies in a more or less random manner between certain limits is plotted the curve always has two bends as in Fig. **5**. The present problem is concerned with the upper bend only, for

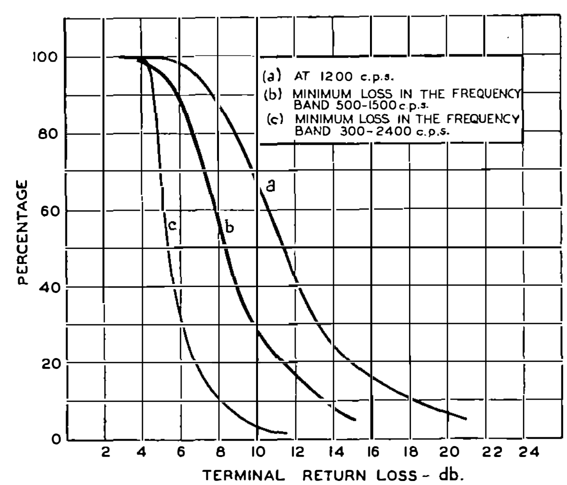


FIG. 5.—PERCENTAGE OF CALLS HAVING TERMINAL RETURN LOSSES EQUAL TO OR GREATER THAN THAT SHOWN.

it is obvious that a low terminal return loss must be chosen for design purposes and this will be exceeded by the majority of connections. The shape of the curves gives some help in deciding on the percentage to be taken, since they bend over in the neighbourhood of 90 per cent. The return loss for 90 per cent., curve (a), is about 8 db. If a value of 6 db. were selected it would be exceeded in almost 100 per cent. of calls, which would be too much on the safe side. On the other hand, if 10 db. were adopted it would be exceeded in only 65 per cent. of calls. This is hardly a safe majority. Hence it is a reasonable compromise to take the 90 per cent. value.

The reasons for plotting curves (b) and (c) are the following :—It was assumed by the A. T. & T. Co. that the loudness of an echo depended on the minimum return loss in the frequency range from about 500 to 1,500 c.p.s. To check this assumption, and compare the terminal return losses measured here and in America, (1) the return loss measurements were made over the range 200 to 2,400 c.p.s., and (2) a direct measurement was made of the distribution of energy with frequency for typical echoes heard in an ordinary telephone, the frequency response of the echo path being flat. Two typical return loss curves are shown in Fig. **6** and curve (b) of Fig. **5** was obtained from the minima between 500 and 1,500 c.p.s.

It will be seen that the 90 per cent. value is 6 db., the same figure as obtained by the A.T. & T. Co. This agreement was not unexpected, for subscribers' line impedances are very similar, here and in America.

The energy-frequency characteristic of an echo was determined by means of a telephone and an artificial ear connected to a Siemens & Halske " sound spectrograph." Various words were spoken into the transmitter and, as expected, the spectrum was found to be

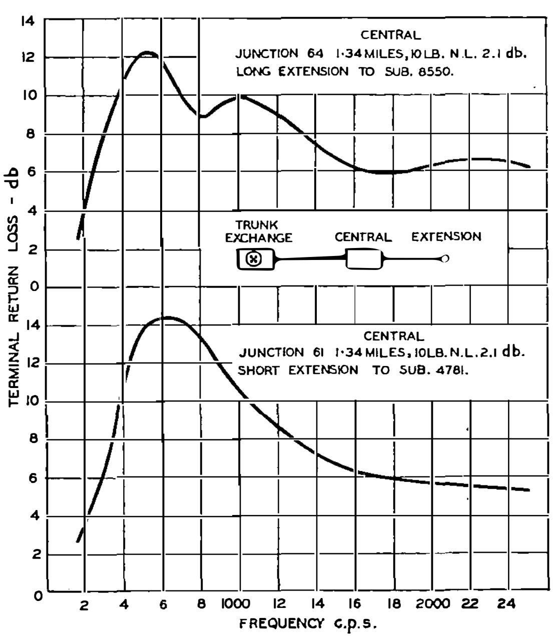


FIG. 6.—TERMINAL RETURN LOSS OF EXTENSIONS ON CENTRAL EXCHANGE.

very variable, but a peak always occurs about 1,200 c.p.s. and the power falls off rapidly on both sides, being negligible above 2,000 and below 600 c.p.s.

In the course of these tests weak syllables such as fifty, six, etc., were also recorded, and gave a similar peak in the neighbourhood of 1,200 c.p.s. These weak sounds are important on circuits equipped with echo-suppressors and will be dealt with later.

It will be seen that the terminal return loss curves in Fig. **6** fall about 2 db. between 1,200 and 1,500 c.p.s., but the energy-frequency curve of the echo falls more rapidly and, as stated above, the energy is negligible at the lower frequencies where the return loss falls again. Hence the loudness of the echo depends mainly on the echo path attenuation at or about 1,200 c.p.s. The equivalent of the trunk being constant over the range of frequencies considered, the echo attenuation takes its shape from the terminal return loss. In the P.O. telephone No. 162 (hand micro-telephone) the transmitter and receiver combine to produce a peak at about 1,200 c.p.s. If, as seems very probable, transmitters and receivers are improved during the next few years the peak will be flattened out and the appropriate return loss will be the minimum between 500 and 1,500 c.p.s. (curve (b)), or possibly over a wider range. But, before high quality telephones have become general, improved echo-suppressors will be available for those trunks which need them. It is therefore convenient and reasonable to assume that these two tendencies will neutralise each other, and that for this country the terminal return loss could be taken as 8 db.

At the recent Paris meeting of the commission dealing with the European plan, however, other administrations also submitted data regarding terminal return losses. In France and Germany the 90 per cent. value is decidedly lower than 8 db., and the response frequency of the microphones differs from 1,200 c.p.s. In Sweden, on the other hand, the terminal return loss is generally higher, about 9 db., but for calculation it is evidently necessary to take the lowest value likely to occur in Europe, namely 6 db.

Listener Echo and " Near Singing."

The phenomenon of " near singing " was briefly discussed in the previous article and it was pointed out that an echo-suppressor prevented near singing and thus allowed the circuit to be adjusted to a somewhat lower working equivalent. The matter is now discussed in more detail.

When a circuit is adjusted to an equivalent only 2 or 3 db. above the value at which it is just stable, in the talking condition every pulse of speech current circulates back and forth over the circuit several times before dying away, and is heard by the listener as a multiple echo, mixed up with the received speech. As stated earlier in this article, listener echo has always been regarded as less troublesome than talker echo, at least on loaded lines, but, with the introduction of unloaded carrier systems, the question arose whether the irregular frequency response obtained when a circuit is near to singing would have any influence on speech quality apart from the effect of circulating (echo) currents. On a loaded trunk of

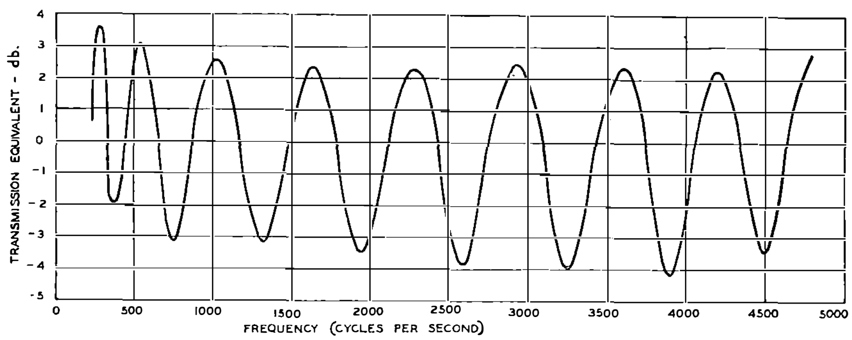


FIG. 7.—FREQUENCY RESPONSE OF CIRCUIT WITH STABILITY MARGIN 4·5 db.

moderate length the spacing of the peaks in the frequency response curve is very close, so that they would be expected to have no effect on articulation. Actually, the frequency difference between peaks equals 0·5/transit time. Hence, for an unloaded circuit about a hundred miles long the peaks may be 600 c.p.s. apart, as in the example in Fig. 7. Speech tests were made with this circuit, using ordinary and high quality instruments, but no effect on articulation or quality could be detected.

This result suggests that the irregular frequency response of a circuit having a small margin of stability has no a preciable effect by itself.

The circulating currents which give rise to the "near singing" effect differ from listener echo in that their frequency is the frequency at which the circuit would sing, determined chiefly by the terminal conditions; whereas the dominant frequency of a talker echo and the listener echo which is derived from it is always in the neighbourhood of 1,000 or 1,200 c.p.s. because of the receiver and transmitter characteristics. On a circuit having a long transit time both the talker and listener echoes may be noticeable, although at a low level. Conversely, if the transit time is very short the echoes will not be noticeable even though the level is high, but the circulating currents in any circuit which is near to singing are liable to be noticed since they may traverse the circuit several times before being damped out and thus produce an effect similar to that of an echo on a long line. It will be evident that the proper value of terminal return loss to be used in calculating the margin of stability is the minimum value within the ordinary equalising range of trunk circuits, i.e. 300-2,400 c.p.s.

The percentage distribution curve of terminal return losses on this basis is shown as curve (c) of Fig. 5.

On a 4-wire circuit, or a 2-wire circuit with moderately good repeater balances, the terminal return loss is always the deciding factor as regards both stability and echo.

CIRCUITS PROVIDED WITH ECHO-SUPPRESSORS.

As explained in the previous article, echo-suppressors do not completely eliminate echo effects, because their sensitivity is limited on account of false operation by line or switchroom noise.

The three types of suppressor now widely used in Europe are:—

(1) The valve type (bothway) suppressor patented by Robinson and Chamney, used principally here and in Germany.

(2) The Siemens & Halske terminal (one-way) suppressor used in Germany and other Continental countries.

(3) The (bothway) metal rectifier suppressor with differential action, invented by Ryall and now standardised by the Post Office.

In all three types a tuned input transformer is used, making the suppressor most sensitive in the region of 1,000 c.p.s. Below this frequency the sensitivity falls rapidly to reduce the risk of operation by line noise. At higher frequencies the sensitivity falls off much less rapidly.

The administrations represented on the mixed commission were asked to supply operating data of their echo-suppressors in order that the sensitivity could be standardised. Definitions of operating time, hang-over time, etc., were agreed and measurements made with steady tone, and with noise.

When considering the limitations imposed by echo effects on trunk equivalents, the operation of suppressors by noise is of major importance. Noise can enter the trunk from other lines such as aerial routes subject to power induction, or radio links, but generally comes from the operator's transmitter which picks up switchroom noise while a call is being set up. The noise on a trunk fitted with an echo-suppressor is almost invariably too slight to affect the suppressor.

Since the noise enters the trunk at a zero level point the sensitivity of the suppressor is measured by the level of pure tone (of that frequency for which it is most sensitive) applied at the end of the trunk which just operates the suppressor. This level is known as the "zero-level sensitivity" and is about 30 db. below 1 milliwatt for the three types of suppressor mentioned above. A series of measurements was made at London Trunk Exchange, using an echo-suppressor of which the sensitivity could be varied, to find the safe limit under working conditions. A psophometer, having an instrument the time constant of which is roughly that of the Western Electric volume indicator, was connected across the input of the suppressor so that the noise voltages could be correlated to some extent with the operation of the suppressor. This was of the metal rectifier type, normally adjusted to give a suppression loss of 30 db. with a zero-level input of 30 db. below 1 milliwatt, i.e. the sensitivity was 30 db. The suppressor was considered to be operated sufficiently to break an incoming conversation when a certain value of (D.C.) control current was reached in the rectifier networks.

The results fall into three groups:

(*a*) Inland and continental trunks never produced sufficient noise to operate the suppressor unless they were too noisy for service.

(*b*) Radio links, when so noisy as to be only just workable, would operate the suppressor at a zero-level sensitivity of about —25 db.

(*c*) Switchroom noise picked up by a trunk operator's telephone would operate the suppressor, at times, when the sensitivity was —35 db.

It was, therefore, decided that the normal figure of —30 db. used in this country was safe and convenient, since the normal sensitivity of the German suppressors is —29 db. Incidentally the sensitivity of the relay type suppressors used in America is —31 db., so that a sensitivity of —30 db. has been standardised by the C.C.I.F. except where noisy radio links are concerned. In such cases it may be necessary to devise means for cutting out suppressors or reducing their sensitivity to, say, —20 db. The question is now being studied separately from the preparation of the European switching plan, on which it has no direct bearing.

Relation between Attenuation and Time for Echoes which Escape the Suppressor.

The sensitivity of echo-suppressors for the European system being fixed, the next step is to decide upon the allowable echo loss for weak sounds which fail to operate the suppressor. This can only be done by a large number of judgment tests, similar to those used in making the curves of Fig. 2, except that the observers use phrases containing very little energy, such as "fifty-six, not sixty-six," or "My goodness, my Guinness," and talk quietly. By carefully adjusting the speech to a level low enough not to operate the suppressor, but not so low that the very faint echo is masked by line or room noise, it is possible to get a fairly consistent relation between echo loss and echo time. The upper three curves in Fig. 8 were obtained in this way and agree reasonably well with the results obtained by the French administration. The curve for —20 db. sensitivity is only of interest in connection with radio links.

But the condition of test is somewhat artificial and the chance of its occurring in practice very small.

Probability of Occurrence of Syllables which fail to operate a Suppressor.

An attempt has been made to estimate the probability from the available data as regards talking volume and the occurrence of weak syllables in ordinary speech. For an audible echo the following conditions must occur at the same time:

(1) Attenuation of talking subscriber's line and trunk junction must be less than, say, 3 db., and the receiver of normal efficiency; otherwise the echo will not be heard. The probability is, say, 1 in 8, based on 1 in 2 for short subscribers' lines and 1 in 4 for short junctions.

(2) The talking volume must be weak enough not to operate the suppressor, but not so weak as to be masked by noise. It was noticed in making the judgment tests that the allowable range of volume was only about 6 db. The echo is noticed only on weak sounds, which are about 12 db. below the loud parts of speech by which volume is measured. (This figure was obtained as the mean of five observers, using a volume indicator.) Hence weak syllables 35 db. below "reference volume," which just fail to work the suppressor, correspond to a talking level of —23 db. This level may, as explained above, fall to —29 db. From the curve of talking volumes observed

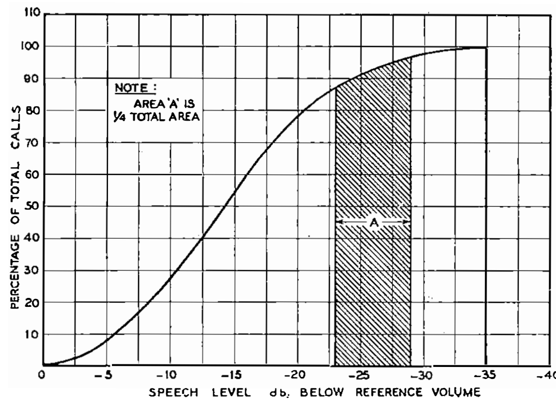


FIG. 9.—RELATIVE SPEECH LEVELS.

at London Trunk Exchange (Fig. 9) it will be seen that the chance of this range of volumes occurring is 1 in 4.

(3) Terminal return loss at distant end must be as low as in the judgment tests, i.e. 7 db. The chance of this (from Fig. 5, curve (a)) is 1 in 20.

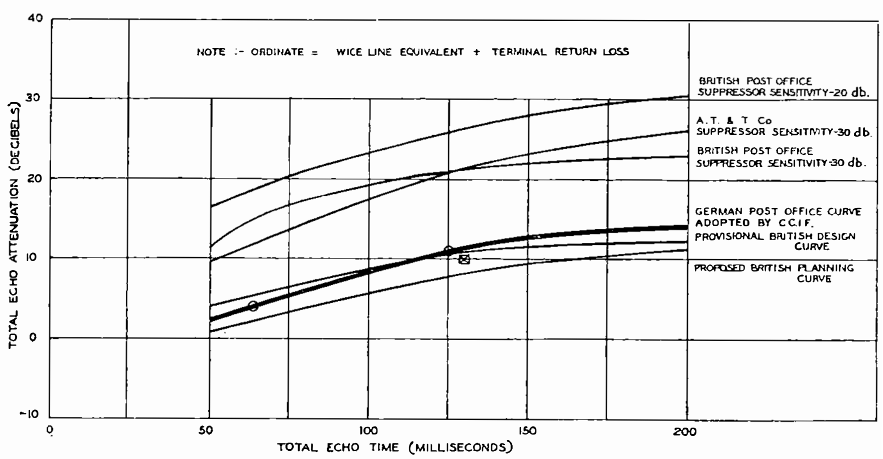


FIG. 8.—MINIMUM ECHO ATTENUATION *v*. ECHO TIME.

(4) Weak sounds capable of producing an echo must occur at least every 10 words (say 50 times in a call) if they are to be noticed by a subscriber. A fairly good estimate of this probability was obtained from an analysis of English speech made in connection with articulation testing. The weak sounds occur about once in four words. Hence the probability is 10/4.

The total probability is the product of (1), (2), (3) and (4), namely

$$\frac{1}{8} \times \frac{1}{4} \times \frac{1}{20} \times \frac{10}{4} = \frac{1}{256}.$$

Such a chance would appear to be negligible.

This calculation, however, will not serve to decide the curve of echo loss to be adopted for design purposes. As for circuits without echo-suppressors, the amount of echo which the subscribers can be expected to tolerate is a question of experienced judgment, but we are now concerned with an effect which only occurs very rarely in contrast with an ordinary echo which is heard when the subscriber is talking at a normal volume.

Experience gained in the operation of zero loss trunks in this country has suggested an upper limit for the design curve, and there is reason to assume that the shape of the curve should be the same for ordinary conversation as for the special phrases used in the judgment tests. The curve marked Provisional British Design Curve in Fig. 8 was drawn on this basis. Later the results of judgment tests made in Berlin by members of the Reichpost staff, using ordinary conversation, were found to agree very closely. The two points obtained as the means of a large number of observations are shown on the German Post Office Curve in Fig. 8. The German observers were perhaps somewhat more critical than a non-technical subscriber would be, even if an habitual user of the international telephone service. Hence, after discussion of these results, the C.C.I.F. requested certain administrations to arrange for judgment tests by senior members of their technical and traffic staffs who would be in a position to make a compromise between expense on the one hand, and risk of complaints on the other.

More than twenty members of the engineering and traffic staffs made conversation tests in London on a line specially set up, with an echo time of 70 milliseconds. The echo attenuation was adjusted to three values :—

Value (1) Infinite—i.e. no echo at all.

Value (2) 6 db.—the appropriate value for this echo time according to the tentative design curve proposed by the writer and confirmed by tests made in Berlin.

Value (3) 1 db.—corresponding to a line equivalent 2½ db. lower than would be given by the design curve.

Opinion was practically unanimous that value (3) represents an amount of echo which might be noticed very occasionally but would involve no risk of complaint, while value (2) gives an echo which is quite unnoticeable by a subscriber.

It was impracticable to obtain a longer loop when these tests were in progresss, but the shape of the curve had already been well established by previous judgment tests. The main question at issue was whether the curve should be moved bodily up or down. It appeared from the tests that the design curve could safely be lowered 2 or 3 db. Hence the proposed planning curve in Fig. 8, which was recommended to the C.C.I.F.

The practical effect of this curve taken in conjunction with a terminal return loss of 6 db. is that an overall equivalent of 1 db. between exchanges, corresponding to the zero loss trunks used in Great Britain, would be safe as regards echo up to an echo time of 130 milliseconds.

Taking the German curve, the echo time for the same ordinate of 8 db. is 100 milliseconds, which corresponds to 1,000 miles of 44 mH loading.

After considerable study the mixed commission decided to adopt, for use in calculations, the German curve which ensures that echo would practically never be noticed by a subscriber.

In making these calculations the A.T. & T. Co.'s method of computing echo effects, which applies both to circuits with and without echo-suppressors, was used, with the appropriate judgment curve for those echo paths which contain the suppressor. For example, suppose a long 2-wire trunk, AB is connected through a 4-wire circuit, BC, provided with an echo-suppressor, to another long 2-wire trunk, CD. When the subscriber at A speaks at normal volume the suppressor will be operated and the only echoes heard will arise in AB. On the other hand, if the subscriber speaks too quietly to operate the suppressor echoes will be heard from all echo paths between A and D. But the faint echoes from AB, having relatively short times, may be neglected in comparison with those from CD. Two calculations are therefore made by the method already described : one for AB, using the curve of Fig. 2 ; and the other for BD, using one of the curves in Fig. 8. Whichever calculation gives the greater total echo power is taken as the limiting condition and the equivalents of the three circuits must be adjusted accordingly.

Later echo calculations were made for various extremely long international calls, such as from Londonderry to Gävle (Sweden).

Two important results emerged from the calculations. First, international trunks may be worked at zero equivalent in the transit condition (that is, when connected to other trunks at each end) without risk of echo or instability. Secondly, international trunks could not safely be adjusted to zero equivalent in the terminal condition (that is, when connected to local lines at each end) until the variations of equivalent which now occur have been brought within the recommended limits. When this has been done it should be practicable to introduce the system of zero loss trunk working, which is used in Great Britain with complete success, to those parts of the European network where traffic is heaviest and where, consequently, its advantages in speed and simplicity would be most valuable.

The author wishes to acknowledge the assistance of Mr. R. E. Jones, who was responsible for the measurements and echo judgment tests carried out in this country.

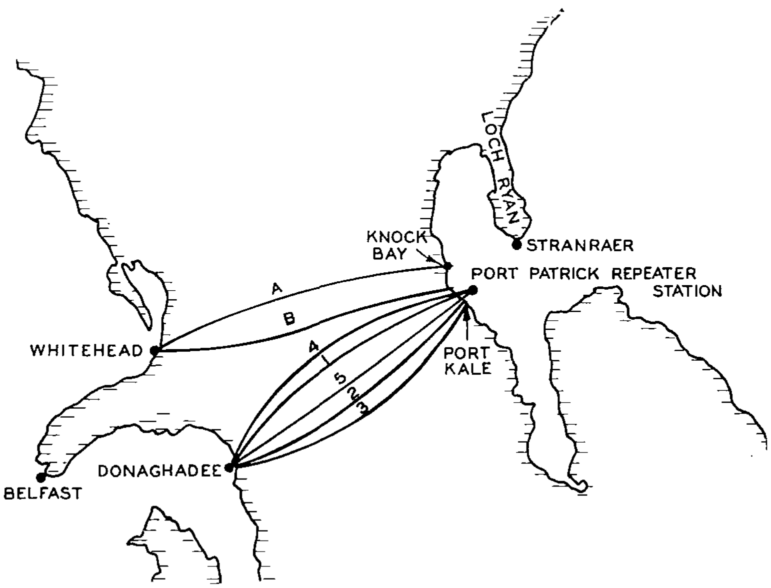
The Belfast-Stranraer Cable Carrier System

E. M. RICHARDS, B.Sc., A.C.G.I., M.I.E.E.
and F. J. D. TAYLOR, B.Sc.

The recent rapid growth of trunk telephone traffic, aided by the removal of the special cable charge over this route, has necessitated the provision of additional circuits to Northern Ireland. This article describes two new concentric submarine cables which have been laid to cater for this traffic and gives details of the associated land lines and carrier equipment. Initially a 1 + 3 and one 12-circuit carrier equipments have been installed and further circuits over the same cables will be provided by the addition of further 12-circuit systems, as required, to give a maximum of 100 circuits.

Introduction.

SIMULTANEOUSLY with the development of multi-channel carrier systems on underground cables, this method of obtaining larger numbers of circuits is also being adopted for main submarine cables. It has been employed on the Anglo-Dutch, the Port Kale (Scotland)—Donaghadee (Northern Ireland), and the North Wales—Ireland submarine cables, all of which were laid during 1937 and are of the same detailed design. The Anglo-Dutch 1937 cable has already been described[1]. This article gives details of the submarine cables, the land cable extensions and the equipment employed on the Belfast–Stranraer system. Both the Dutch and Northern Ireland schemes utilise P.O. carrier equipment Nos. 4 and 5 (audio + 4 carrier circuits and 12 carrier circuits respectively).



Cable	Date of Laying	Number of Cores	Conductor Weight lbs. per Naut.	Dielectric Weight lbs. per Naut.	Length Nauts.	Remarks
A	1879	4	107	150	23·5	Telegraph Gutta-percha
B	1888	4	107	150	25·6	Telegraph Gutta-percha
1	1870	4	107	150	22·0	Telegraph Gutta-percha
2	1893	4	160	300	24·4	Telegraph Gutta-percha
3	1921	4	169	195	21·7	Balata Insulated and continuously loaded, for Telephone working
4	1937	1	508	690	21·0	Paragutta Insulated. Concentric type
5	1937	1	508	690	21·3	Paragutta Insulated. Concentric type.

FIG. 1.—SUBMARINE CABLES BETWEEN SCOTLAND AND NORTHERN IRELAND.

CABLES

Fig. 1 shows the cables between Scotland and Northern Ireland. The four cables laid in 1870, 1879, 1888 and 1893 are 4-core telegraph gutta-percha cables, but have been utilised for telephone working. The 1921 cable was laid for telephone working, being balata-insulated and continuously loaded. Part of the telephone traffic between Great Britain and Northern Ireland is also carried by the Blackpool–Isle of Man–Ballyhornan cables, and by a radio link between Ballygomartin near Belfast, and Port Patrick. The five pre-1937 cables shown in Fig. 1 have recently been operated so as to provide nine telephone circuits and one 18-channel V.F. telegraph system.

During the period September 7th to 14th, 1937, the cable ship "Faraday" laid between Port Kale, Wigtownshire and Donaghadee, County Down, two concentric type, paragutta dielectric submarine cables, and the acceptance tests made immediately after laying proved the cables to be satisfactory. One of the cables (No. 4) follows fairly closely the route of the No. 1 cable laid 67 years ago, and the other one (No. 5) is a little to the south. The No. 1 cable is still working, but should it become faulty it may not be possible to repair it.

The No. 4 and No. 5 cables land in Scotland at the somewhat rock-strewn beach known as Port Kale. Owing to the difficulty in obtaining an electric power supply at the Port Kale hut, the cables are continued overland for about 0·9 nautical mile, in separate trenches 6 feet apart to a new building near Port Patrick, which will later contain repeaters when additional circuits are provided at higher carrier frequencies

[1] *P.O.E.E.J.*, Vol. 30, p. 222, October, 1937.

than those employed in the initial stages. In order to protect the dielectric from the deleterious effects of exposure to the atmosphere, the land sections have a lead sheath 0·04 inch thick and are armoured with steel tapes.

A cable having a solid dielectric is essential on the route between southern Scotland and northern Ireland owing to the depth of water, which exceeds 140 fathoms in parts. Although, for the comparatively short submarine route of approximately 21 nautical miles between Port Kale and Donaghadee (about one-quarter the length of the Anglo-Dutch cables), satisfactory transmission over a fairly wide frequency range could have been obtained by the use of a much smaller gauge conductor than one weighing 508 lbs. per nautical mile, the necessity for keeping to a minimum the number of types of submarine cable which must be stocked for repair purposes, combined with the low attenuation, were determining factors. Advantage of the low attenuation of the heavy gauge conductor will be taken by using the cable over a wide frequency range, probably up to about 450 kc.p.s. eventually. Furthermore, no repeaters will be required at the submarine cable terminals until carrier frequencies above 60 kc.p.s. are used, and since the land section between Port Patrick and Stranraer is only about 8 miles no repeaters will be required at the former place until carrier frequencies higher than 156 kc.p.s. are used, i.e. until 44 circuits have been provided on the two cables. The low attenuation length of the submarine section, combined with the high singing points obtainable due to the uniformity with which this type of cable can be manufactured, also increases the number of channels because several stable duplex circuits can be worked.

Fig. 2 is a cross section of the cable and indicates clearly the make-up of the main submarine portion, the shore end and the land section. Fig. 3 is a photograph of the bays containing the hybrid transformers, balance filters, cable terminations, and system and directional filters at Donaghadee. The submarine cable terminating panel, which can be seen at the bottom of the bay, contains three terminals to which are connected the centre core, the six copper return tapes and the armouring. The U-link box used to terminate the balanced-pair land cables, referred to later, can be seen at the top of the bay.

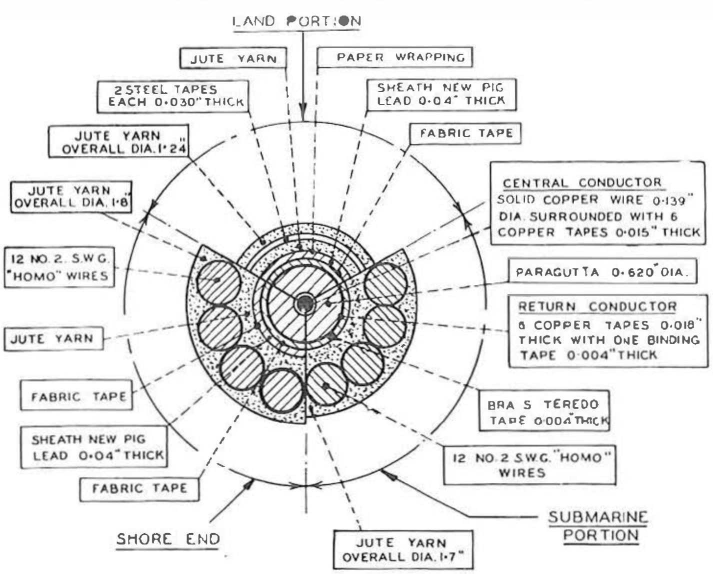


FIG. 2.—CROSS SECTIONS OF THE CABLE.

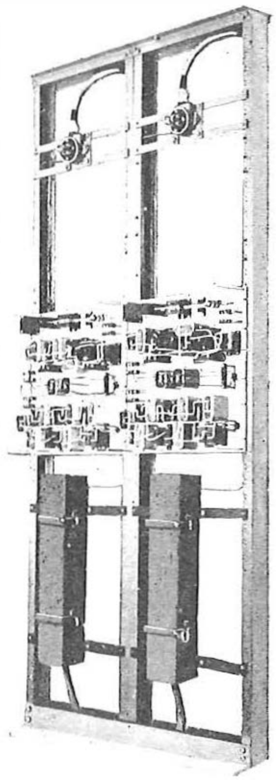


FIG. 3.—CABLE TERMINATIONS AT DONAGHADEE.

The attenuation-frequency characteristics of the submarine cables are very closely the same as those shown for the Anglo-Dutch cables[2] up to 70 kc.p.s. Fig. 4 gives the attenuation values measured on a short length up to 2,000 kc.p.s. and also shows the contribution of the dielectric losses to the total attenuation. As an interesting comparison, the total attenuation per nautical mile at 2,000 kc.p.s. and 60° F. is 10·7 db., whereas the value for the London–Birmingham coaxial cable in which the dielectric is mainly dry air, is 7·1 db.

The comparable diameters (i.e. over the dielectric) for these two cables are 0·62 in. and 0·45 in. respectively; hence, although the paragutta cable has the larger diameter, its attenuation is greater, due to the use of a solid dielectric. Nevertheless the dielectric losses which result from the use of paragutta are considerably smaller than those which would be given by the earlier types of gutta, particularly at the higher frequencies.

Other constants of the submarine cables, including the results of electrical measurements made after laying, are as follows:

	No. 4 Cable	*No. 5 Cable*
Length (nautical miles)	21·04	21·31
D.C. resistance of central conductor at 57°F. (ohms per naut.)	2·261	2·260
Capacitance (microfads per naut.) . .	0·202	0·202
Insulation resistance after electrification for one minute (megohms per naut.)	67,000	70,000
Total weight of central conductor (lbs. per naut.)	508	
Weight of return conductor (lbs. per naut.)	852	
Weight of paragutta dielectric (lbs. per naut.)	690	
Diameter of "Homogeneous" iron armouring wires on submarine sections and shore ends	0·276 in.	
Weight of complete cable (wet):		
Submarine section (tons per naut.)	9·6	
Shore end (tons per naut.) . .	11·0	

[2] *Loc. cit.*

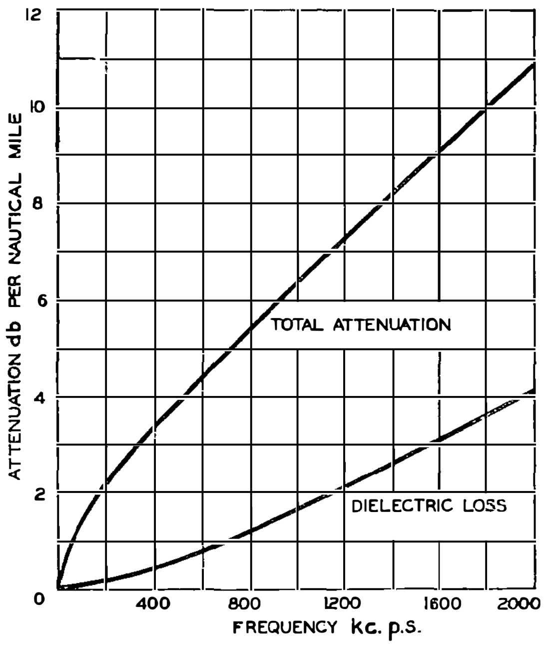


FIG. 4.—ATTENUATION CHARACTERISTICS OF SUBMARINE CABLE.

Impedance-Frequency Characteristics.

In order to permit of duplex or " 2-wire " working on the cable, thereby providing the maximum number of circuits, the specification required each cable to have, between 0·3 and 16 kc.p.s., a singing point against its own smooth mean curve of at least 10 db. more than the cable attenuation. This allows the construction of 2-wire balances to give a sufficient margin of stability to avoid any tendency to " sing." It is interesting to note that the specification covered the impedance-frequency characteristics of the cable up to 400 kc.p.s. These stringent requirements entailed careful selection for jointing of the manufacturing sections, each of which was approximately one nautical mile in length. The worst singing point realised between 0·3 and 400 kc.p.s. was about 36 db.

Utilisation of Frequency Band.

The 1 + 3 type carrier equipment (audio + three-carrier circuits) uses the frequency band from 0·3 to 16 kc.p.s. with carrier frequencies of 6·0, 9·2 and 12·5 kc.p.s. The P.O. No. 5 type carrier equipment (12 carrier circuits) uses the frequency band from 12 to 60 kc.p.s., with carrier frequencies of 16, 20, 24, etc., to 60 kc.p.s. Lower sidebands only are transmitted in each system. There was already existing between Stranraer repeater station and Port Patrick, and also between Belfast repeater station and Donaghadee, a 38 pair 40 lb. paper-core quad trunk cable containing eight pairs loaded with 18 millihenry coils spaced at 0.284-mile (500 yards) intervals. These pairs, as will be seen from Fig. **5**, are divided into two groups and were balanced during laying for 4-wire working, one group constituting the " Go " circuits and the other the " Return " circuits. The two main groups of the cables are separated in a rather unique manner by the use of diametrical screening fillets of metallised paper. The metal used is aluminium, and the screening paper is wrapped in plain paper to avoid the risk of contact with the conductors.

The theoretical cut-off of the 18 mH loaded pairs is 17·5 kc.p.s., and taking 0·75 of this as the upper working limit of frequency gives approximately 13 kc.p.s. It was therefore decided to use in the submarine cable the audio and three carrier circuits of the No. 4 type carrier system (requiring a nominal range of frequencies from 0·3 to 12·5 kc.p.s.) and to extend these four circuits from Port Patrick and Donaghadee to Stranraer and Belfast respectively on the 18 mH loaded pairs.

Assuming an audio frequency range of 0·3 to 2·7 kc.p.s., the maximum frequency required to be transmitted is 12·2 kc.p.s. The lowest channel of the 12-circuit carrier equipment has a carrier frequency of 16 kc.p.s. and a nominal band of 12·0 to 16·0 kc.p.s. but, as the lower sideband only is transmitted, the lowest frequency required to be transmitted is 16·0—2·7=13·3 kc.p.s. Hence there is the frequency band from 12·2 to 13·3 kc.p.s. between the two systems which may be used to allow the separating filters to develop sufficient attenuation. These system filters are installed at the submarine cable terminals, and the 12-circuit system carrier circuits are extended at each end on two " balanced-pair " cables laid especially for the purpose to both Belfast and Stranraer. One of these balanced-pair cables carries the " Go " circuits and the other the " Returns."

Fig. **6** shows the scheme at the Belfast end in block schematic form and illustrates the position of the " emergency " filters.

The arrangement at Stranraer is similar to that at Belfast with the following exceptions :

(i) The 2-wire–4-wire terminations are omitted and half repeaters are also fitted in the transit direction of all channels.

(ii) The audio change-over " U " links are fitted on the receive side of the 12-channel equipment.

(iii) The "receive" channels on the voice circuits are equipped with half repeaters No. 25A.

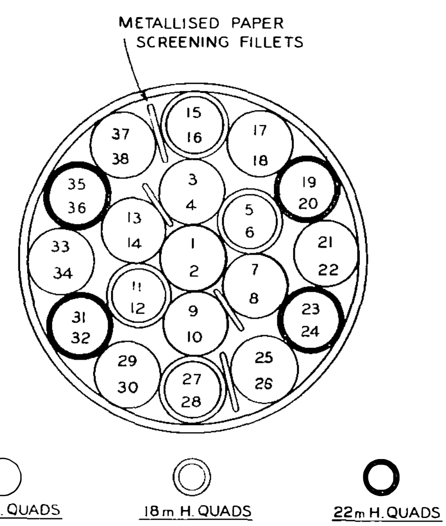


FIG. 5.—PORT KALE—STRANRAER COIL-LOADED CABLE.

It will be seen that the 1 + 3 type equipment works on a 2-wire basis in each submarine cable and 4-wire on the land sections, and that the 12-circuit carrier system equipment is 4-wire throughout between Belfast and Stranraer. At the submarine cable terminations (Port Patrick and Donaghadee) specially constructed hybrid transformers and balances designed to match the cable impedance up to 12·5 kc.p.s. are provided to permit the conversion from 2-wire to 4-wire working. The arrangement gives a total of 20 circuits in the frequency band from 0·3 to 60·0 kc.p.s.

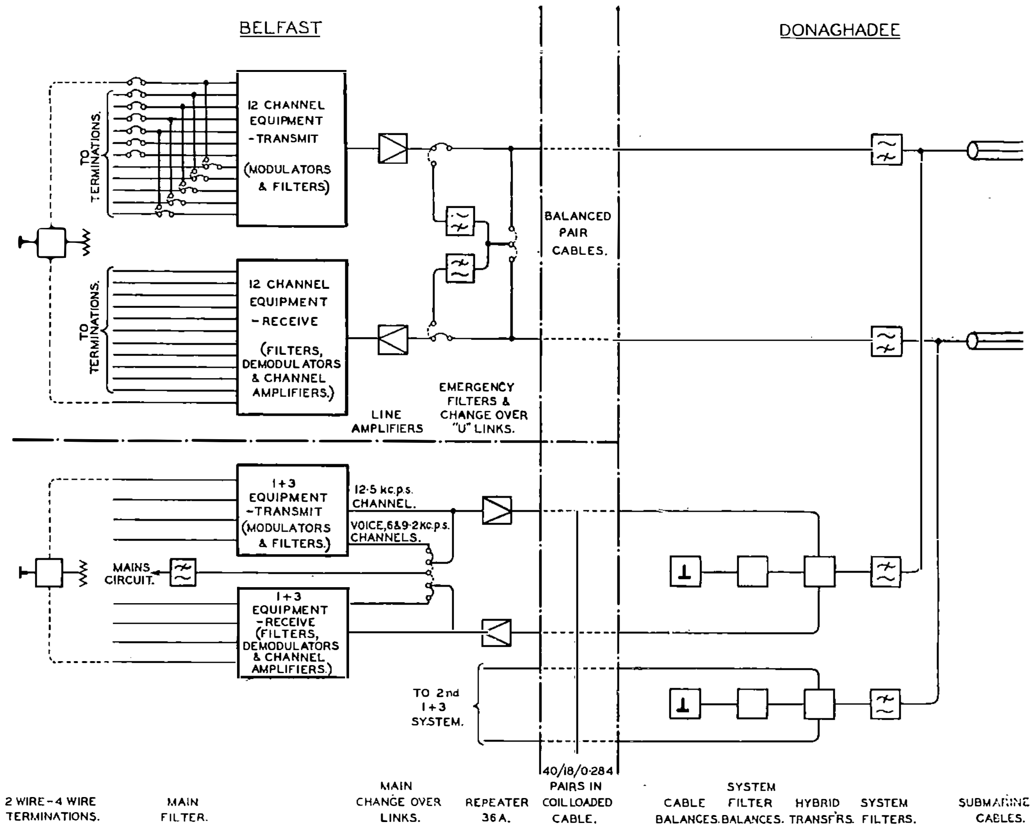


FIG. 6.—SCHEMATIC DIAGRAM SHOWING INITIAL CIRCUIT PROVISION.

Emergency Conditions.

A breakdown of one of the submarine cables would cause a complete failure of the 12-circuit equipment, but only one of the audio + 3-circuit carrier systems would be affected. Hence, in order to avoid the loss of 16 circuits due to a submarine cable fault, emergency filters are provided at the carrier terminal stations. Their function is to divide into two parts the frequency spectrum normally occupied by the 12-circuit system so as to provide 5 " Go " channels in the lower portion of the spectrum (12 to 32 kc.p.s.) and 5 " Return " channels in the upper portion (40 to 60 kc.p.s.). Although the frequency band from 32 to 40 kc.p.s. is more than sufficient to permit the emergency filters to develop sufficient attenuation to separate satisfactorily the frequencies of the two directions of transmission, it is not wide enough to provide, in addition, two more channels for another 4-wire circuit. This arrangement provides on one submarine cable 4 duplex circuits and 5 circuits working on a 4-wire basis during breakdown conditions, a total of 9 circuits.

The change-over to the emergency condition is effected as shown in Fig. **6** by removing U-links on the change-over field, fitted on each cable terminating bay at Belfast and Donaghadee, from the normal to the emergency position. The changes which it is necessary to make on the audio side of the 12-circuit equipment are also indicated in Fig. **6** ; the U-links required are fitted on the repeater test rack.

Music Circuits.

Since it is desirable that the systems should be capable of transmitting music, arrangements have been made for the portion of the frequency spectrum occupied by the voice and lowest two carrier circuits on each cable system (i.e. up to about 9 kc.p.s.) to be used for single-channel transmission in either direction. This is effected by replacing, when necessary, the band filters of the bottom three circuits by a single low pass filter with a nominal cut-off of 9·2 kc.p.s. ; the arrangement is included in schematic form in Fig. **6**. The repeaters 36A give satisfactory transmission down to 50 c.p.s. It will be appreciated that the use of a music circuit means the loss of three telephone circuits, but that the fourth circuit of the system concerned is not affected.

Balanced Pair Cables.

The cable pairs on which the 12-circuit system carrier circuits are extended from the submarine cables to the repeater stations at Stranraer and Belfast (which are the terminals of the carrier portions of these circuits) must be capable of satisfactory operation from a frequency of about 12 kc.p.s. up to the highest frequency which can be employed on the submarine cable. Briefly, the requirements of the cable pairs are an attenuation at the highest frequency which can be dealt with by the amplifiers in the circuit, and satisfactory immunity from cross-talk and external interference at all frequencies. The cross-talk between coaxial type cables in which one conductor is at earth potential becomes rapidly worse at lower frequencies. The reverse is experienced with pair-cable in which each conductor of the pair has approximately the same impedance to earth. A pair-cable, being balanced or symmetrical with respect to earth and other circuits, is also very much less susceptible to external interference. Hence it was necessary to employ pair-cables, each pair having sufficient screening to make cross-talk satisfactory at higher frequencies. The type of cable chosen was the balanced-pair cable with self-locating conductors which is illustrated in Fig. **7**.

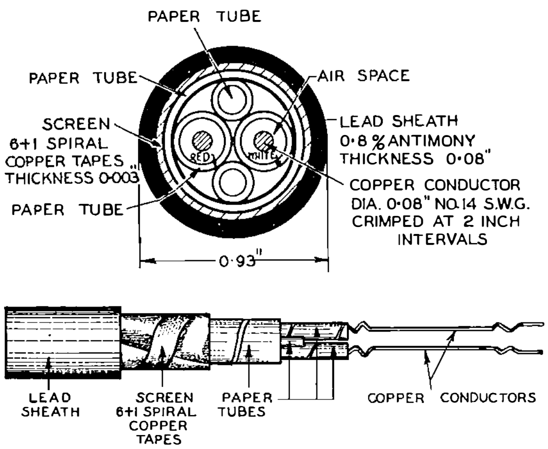


FIG. **7**.—TWIN CABLE WITH SELF-LOCATING CONDUCTORS.

This cable is of the twin or pair type and has two conductors of 0·080 in. diameter (102 lbs./mile) which are self-locating in the paper sheaths. The " crimps " or waves in the conductor which support it in the paper tube are 2 inches apart and have an amplitude of approximately 0·13 in. from the mean position. Successive crimps are in planes at angles of 90°. The two cores are twinned together with two paper wormings, lapped with paper and then with seven copper screening tapes 0·003 inch in thickness, and finally sheathed with a ternary lead alloy to an overall diameter of approximately 0·93 in. The two cables are drawn into the same duct-way and the joints, made at intervals of about 250 yards, are filled with a compound which has a low dielectric loss. This will effectively prevent any moisture which may enter due to a fault in the lead sheath, from travelling far along the cable. The side separation between the two conductors gives a low mutual capacitance and a correspondingly low attenuation.

It was this type of cable which was laid in London during early 1937 for television purposes.[3] Its transmission characteristics are shown in Fig. **8**. It will be observed that the velocity of propagation approaches very closely to that of light and is practically constant from about 10 kc.p.s. upwards. The mean modulus of the impedance at higher frequencies is 186 ohms.

[3] *P.O.E.E.J.*, Vol. 30, p. 215.

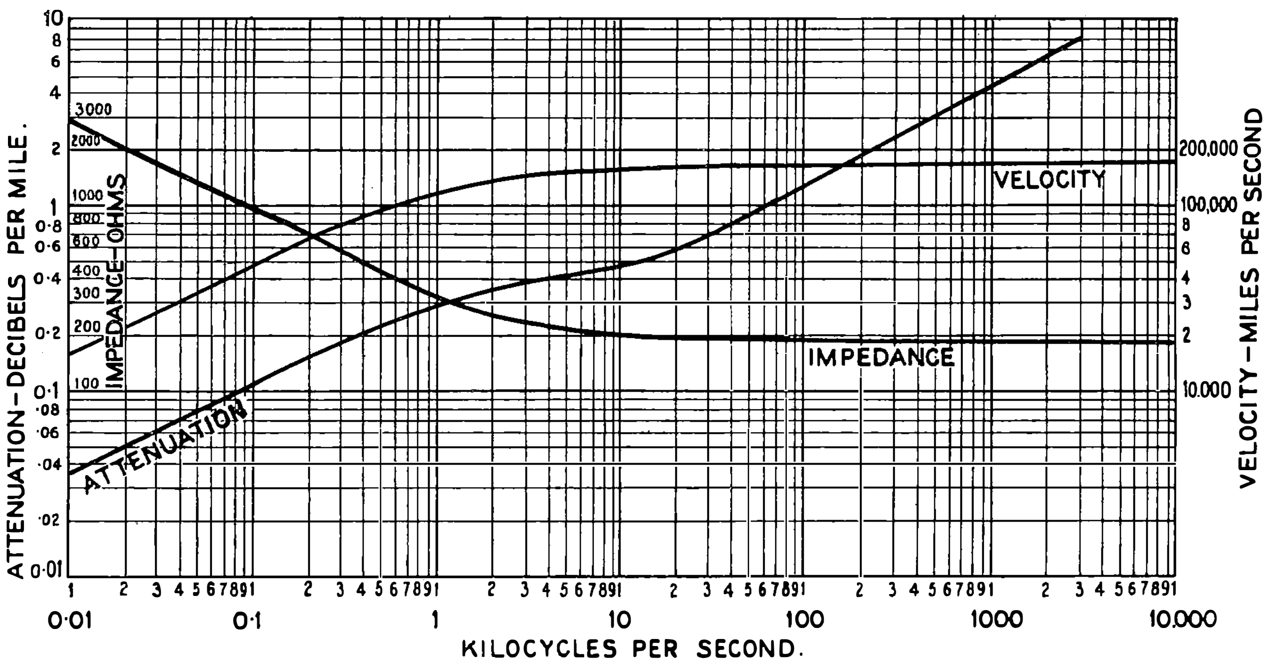
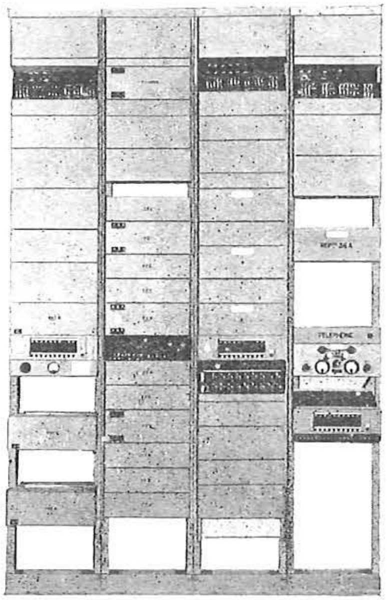


FIG. 8.—TRANSMISSION CHARACTERISTICS OF BALANCED PAIR CABLE.



Bay 1 2 3 4

FIG. 9.—1 + 3 CARRIER EQUIPMENT.

Other constants (average of the two cables), measured after laying, are as follows :—

	Belfast-Donaghadee.	Stranraer-Port Patrick.
Length (Statute miles) ..	18·14	7·18
D.C. resistance (ohms per loop mile)	17·31	17·32
Mutual capacitance (microfarads per mile)	0·0333	0·0332
Insulation resistance, wire-to-wire, after electrification for one minute (megohms per mile)	220,000	750,000

Manufacturers.

The paragutta submarine cables were manufactured by Messrs. Submarine Cables, Ltd., and laid by the cable ship " Faraday." Messrs. Siemens Bros. & Co., Ltd., were awarded the contracts for the manufacture and installation of the audio + 3-circuit carrier equipment and for the balanced-pair cables and Messrs. Standard Telephones & Cables, Ltd., provided and installed the 12-circuit carrier equipment.

1 + 3 TYPE CARRIER EQUIPMENT

General.

In principle the 1 + 3 type equipment used in this instance is similar to the 1 + 4 type equipment (Carrier system No. 4) described by Messrs. Halsey and Millar in this JOURNAL[4]. The equipment differs in the following details :

(*a*) Carrier frequencies of 6, 9·2 and 12·5 kc.p.s. only are required.

(*b*) When there are only two systems to be fed with the carrier voltages the use of amplifiers between the carrier generators and frequency changers is unnecessary.

(*c*) The frequency changers, filters and repeaters differ in circuit details.

A photograph of the equipment is shown in Fig. 9 and the components will now be considered individually.

Carrier Frequency Generators (Oscillators No. 17A, B and C).

Three oscillators generating frequencies of 6·0, 9·2 and 12·5 kc.p.s. are provided on each side of the carrier generator bay (Bay 1). These oscillators work continuously and circuit arrangements are such that, in the event of a breakdown of any oscillator, the change-over of a " U " link on the affected oscillator transfers the load to the corresponding " spare " oscillator on the opposite side of the bay.

It is, of course, essential that the oscillators shall maintain a frequency close to their nominal frequency and that the corresponding oscillators at the ends of the systems shall be as nearly as possible in synchronism. As two of the carrier frequencies concerned are not harmonics of 1·0 kc.p.s.—an accurate source of which is available in London—a check against this frequency is impossible ; it is therefore necessary, from time to time, to check the carrier frequencies against a variable frequency oscillator the performance of which is accurately known. The synchronism of the oscillators at the distant ends of the systems may readily be checked by beating them together, or by using other well-known methods which do not involve the direct application of the carrier frequencies to line.

When the system was designed it was thought that, in order to provide the necessary frequency stability, it would be necessary to enclose the oscillating circuits (condenser and inductor) of each oscillator in a temperature-controlled oven, and space for such ovens is available on the oscillator bay. Experience has shown, however, that the oscillators so far are reasonably stable without these precautions.

Fine control of the oscillator frequency is provided by a variable condenser which may be adjusted and clamped from outside the oscillator cover with the aid of a screwdriver.

The output voltage, normally 2 ± 0·2 V, of any of the oscillators may be checked by voltmeters, mounted one on each side of the bay, and which may be associated by switches with the oscillators. Adjustment of the output voltage is made by varying the tapping on the feedback resistance to the oscillator valve and, if necessary, by adjusting the setting of the coupling unit.

In form, each oscillator consists of an electron coupled oscillator circuit with a pentode buffer amplifier stage, negative feedback being employed to give stability. The output of an oscillator with an anode supply voltage of 130 and with a load of 50 ohms is 360 mW.

Modulators and Demodulators (Frequency Changers No. 2).

The frequency changer units, which are combined modulator and demodulators, are identical for all channels, except, of course, that different carrier frequencies are applied to the individual units. A

[4] *P.O.E.E.J.*, Vol. 29, pp. 226 and 294.

spare frequency changer is provided and the circuit is arranged so that, in the event of a failure of any unit, the three "U" links on that unit are moved from the "normal" to the "spare" position, the correct carrier frequency is applied to the spare unit, and the circuit restored to service. The carrier frequency is connected to the spare frequency changer by plugging a cord into sockets on the frequency changer bay to connect the carrier output terminals of the frequency changer to the carrier frequency required.

As excessive modulation of the carrier may involve interference, speech voltage entering a modulator circuit must not exceed a predetermined figure. The "limiting" of the applied voltage is effected in a manner identical with that employed in the 1 + 4 type equipment. After being subjected to "limiting," speech frequencies pass via a low-pass filter to the modulator; the sidebands produced are applied to a band filter which accepts the lower sideband only and passes this via the line amplifier to line.

Sideband frequencies received from line are equalised, amplified and passed via the receive band filters to the demodulator side of the frequency changers. The audio frequency output from the demodulators is at a level of approximately —15 db.; hence channel amplifiers are required to bring the speech frequencies to a level suitable for application to the line or terminations.

As in the original design, the modulators and demodulators employ copper oxide rectifiers arranged in a bridge formation. The arrangement of the bridge used in this equipment is illustrated in Fig. **10**.

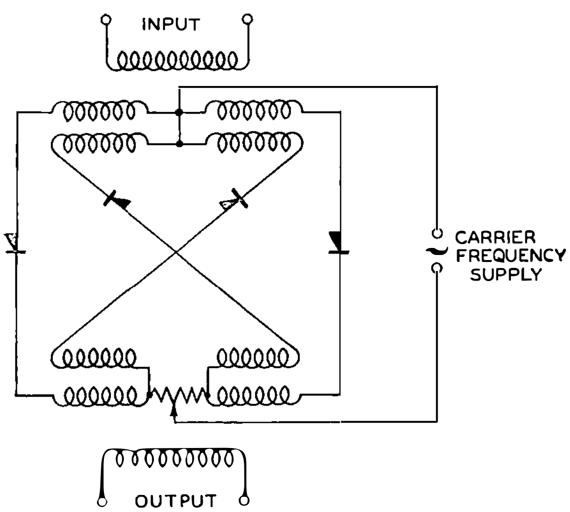


FIG. **10**.—SCHEMATIC CIRCUIT OF MODULATOR.

The degree of carrier suppression is, of course, dependent upon the degree of balance of the bridge, and this is controlled in the modulator by a potentiometer as shown in Fig. **10**. There is no such potentiometer in the demodulator network. In practice the degree of carrier suppression is such that the level of leak of each carrier frequency obtained at the common point of the band filters is of the order of —75 to —80 db.

Channel Filters (Filters Frequency Nos. 30 *and* 24).

The band filters have a performance similar to those of the No. 17 type; they have the same number of sections and the same "m" values were used in their design. The filter components are built in units, each unit being enclosed by a screening can; there are three such cans in each carrier channel band filter and two in those of the voice channels. After assembly each can is filled with wax and the lid soldered in position. This construction tends to ensure stability of the filter characteristics with time and change of humidity.

In addition to the filter proper, the audio channel transmit filter (Filter Frequency No. 24) carries the voltage limiting transformer and rectifier unit.

Line Amplifier (Repeater No. 36A).

Valves V.T. 113 and 114 are being used in place of the valves V.T. 106 and 107 employed in the original design; otherwise the unit as used in this equipment is identical with that described in Messrs. Halsey and Millar's article.

One repeater per station is required for each system, and an additional unit is provided as spare. In the event of a breakdown of one repeater the spare unit may be brought into use by patching cords between the relevant "U" link sockets on the repeater bay.

In addition to the repeaters, the repeater bay (Bay 3, Fig. 9) carries the line equalisers, one of which is associated with the incoming cable pair of each system. The equalisers which were used when the systems were first brought into use were designed prior to the laying of the submarine cables, and did not, therefore, take into account any discrepancies between the calculated and realised performance of the cables, or effects due to the presence of hybrid equipment at the cable huts. From insertion-loss measurements made after the laying of the submarine cables, new equalisers have been designed and will subsequently replace the temporary equalisers. It may be mentioned, however, that the performance of the temporary equalisers would have been adequate had it not been desired to make possible the transmission of music with a minimum of frequency distortion.

Test Equipment.

A bay of test equipment (Bay 4, Fig. 9) is situated adjacent to the carrier equipment bays. The equipment provides the following facilities:

(i) Valve rejection test.
(ii) Measurement of levels in the range —40 to + 15 db., i.e. all input and output repeater levels likely to be met with in practice.
(iii) Speaking and listening facilities on the voice channels.
(iv) Exceptionally, the levels at various points in the carrier channels may be measured.

The test bay equipment comprises a milliwatt oscillator (Oscillator No. 13C), two low-pass filters (Filters Frequency No. 29) the function of which is to separate the voice channels for measuring and monitoring purposes, a Repeater 36A which amplifies low-received levels to a degree suitable for application to the decibel meter, a valve tester (Tester R.P. 471) which is used for testing the valves used in the Repeater No. 36A, a decibel meter, telephone circuit equipment and minor apparatus.

Circuit arrangements are such that a test circuit having zero loss may be set up and applied to the points of which the level is required. The tapping loss of the test circuit at a 150 ohm point is negligible. Should the level to be measured be lower than the minimum measurable by the decibel meter the test circuit may be given a calibrated gain until the range of the decibel meter is reached. Speech in either direction is possible by tapping at the repeater input and output " U " links; this facility is, of course, available only when the voice channel is not actually in traffic.

The valve tester is essentially a Repeater No. 36A without feedback, and the normal gain of such a unit is of the order of 70 db.; a pad of 65 db. is, therefore, inserted in the input circuit to reduce the overall gain to about 5 db. One of each type of valve to be tested is inserted in the tester and heater currents adjusted to normal. The overall gain is then indicated on the decibel meter connected to the output of the tester. By means of a key the heater current in either valve may be reduced by 10 per cent.; the change of gain under these conditions is then noted. As the change of gain will depend upon the condition of the emission of the valve a change larger than a predetermined normal figure will indicate that the valve concerned has reached the end of its efficient life.

It is generally found that the measurement of levels on the audio channel will provide sufficient indication that all is, or is not, normal in the equipment as a whole. Exceptionally, it may be found desirable to measure levels on the carrier channels; if this is necessary the whole of the system under test must be taken out of service and measurements made on each channel individually. This facility is provided for on the test bay by a key which cuts out of circuit the low-pass filter which normally excludes carrier frequencies from the measuring circuit.

Performance of the 1 + 3 Type Carrier Equipment.

Measurements made on the cable circuit and temporary equaliser showed that, with an input level of + 10 db., the output measured as a level across a termination of 1,000 ohms varied from 30·8 db. at 100 c.p.s. to 35·4 db. at 12 kc.p.s. When the permanent equaliser is available the overall characteristic will be considerably flatter than this and will remain reasonably flat down to a frequency of 50 c.p.s. Typical channel characteristics are shown in Fig. 11. Speech over the circuits is of excellent commercial quality.

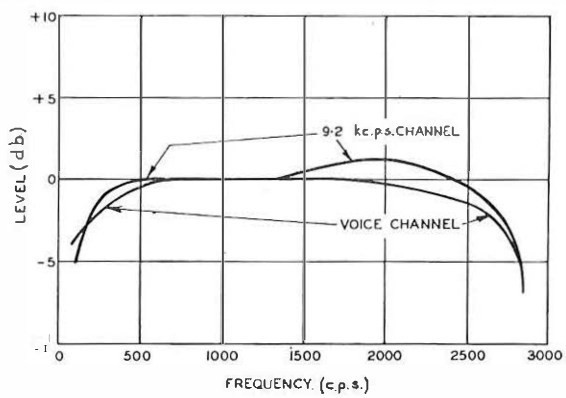


FIG. 11.—OVERALL FREQUENCY RESPONSE RELATIVE TO 800 C.P.S., 1 + 3 TYPE EQUIPMENT.

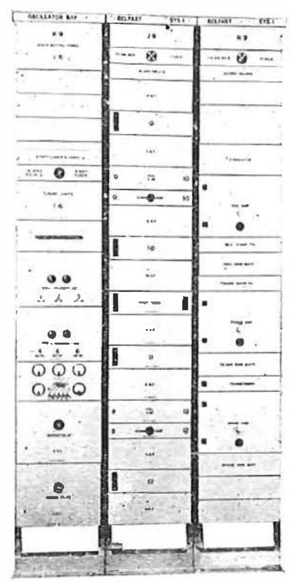
Due to the facts that the overall cable insertion loss (including equaliser) was not constant with frequency and that, owing to the shortness of the distance between Stranraer and Port Patrick, the cable impedance at Stranraer was very irregular, it was necessary on some channels to adjust the equipment to give levels differing somewhat from those dictated by a consideration of the ideal conditions, i.e. amplifier and demodulator outputs are not the same for all channels. This, however, does not affect the performance of the equipment to any extent and the audio levels at Belfast are those applicable to circuits having an overall equivalent of 3 db.

It is perhaps of interest to note that the use of repeaters having such a high basic gain (i.e. the gain without feedback) as that of the Repeater 36A made necessary the employment of special construction to reduce cross-talk. It was found necessary to provide the individual anode alarm relays with screens and to screen the high-level links on the repeater " U " link panel from the low-level links.

12-CIRCUIT TYPE CARRIER EQUIPMENT (P.O. CARRIER SYSTEM No. 5)

General.

This equipment is similar to that installed on a number of routes in other parts of the country. The principles underlying the operation of the equipment have been described in this JOURNAL[5], and a general description of the apparatus as manufactured by Messrs. Standard Telephones & Cables, Ltd., follows. A detailed description is outside the scope of this article.



Bay 1 2 3

FIG. 12.—12-CIRCUIT CARRIER EQUIPMENT.

A photograph of the equipment installed at Stranraer is shown in Fig. 12, and the apparatus may conveniently be divided into three groups:

[5] *P.O.E.E.J.*, Vol. 29, Part 3, p. 220.

(i) Carrier generating equipment (Bay 1).
(ii) Channel equipment (Bay 2).
(iii) Amplifier equipment (Bay 3).

Carrier Generating Equipment.

This apparatus, which is mounted on a double-sided bay (Bay 1) comprises two master oscillators (one working and one spare), four multi-frequency generators and associated equipment. The master oscillators generate a frequency of 4 kc.p.s. which is stable to within narrow limits. The working master oscillator controls the frequency of the four multi-frequency generators, each of which has three output frequencies, i.e. one oscillator has output frequencies of 16, 20 and 24 kc.p.s., the next 28, 32, 36 kc.p.s., and so on. The twelve carrier frequencies produced by the multi-frequency generators are passed through tuning units before being applied to the channel bays. The function of the tuning units is to ensure a good wave form in the carrier supplies. The loads offered by the frequency changers are such that twelve systems can be driven from one set of multi-frequency generators. Normally a duplicate set of multi-frequency generators is provided on a separate bay, and these can quickly be brought into use by the aid of keys if required; in this particular instance, however, the relatively small number of circuits concerned does not warrant the provision of the duplicate equipment.

Channel Equipment.

This comprises transmitting and receiving band filters, frequency changers, voltage limiters, and channel amplifiers. The operation of the equipment is similar to that described briefly for the 1 + 3 equipment.

Speech frequencies received from the 2-wire termination or 4-wire circuit are applied, as is usual in carrier systems, to the modulator via a voltage limiter. The limiter is of the transformer and neon tube type, the tube striking with an applied level of the order of + 3 db. Attenuating pads are provided prior to the modulator proper and these are brought into circuit as required in order that the correct working level may be applied to the modulator. On either side of the modulator, and on the carrier frequency side of the demodulator, networks are provided, the function of which is to assist, by impedance mismatch reflections, in the overall equalisation of the circuits.

After passing through the low-pass filter on the output side of the demodulator, speech frequencies are amplified by a single-stage amplifier and applied to the termination or to the transmit line.

The transmit and receive band filters are unbalanced. It is of interest to observe that each combined inductor and condenser unit is built into an airtight can; this form of construction gives a very stable filter characteristic as the units are independent of changes of humidity, and external fields cannot affect the resonant frequency of the units.

Amplifier Equipment.

The system is equipped with a transmit and receive line amplifier (with a spare if required), line equaliser, and grid battery supply panels. These units are fitted on one side of a bay as illustrated in Fig. **12**, Bay 3.

The line equaliser consists of a number of sections which, being of the constant impedance type, may be connected in series to provide the total line equalisation required. Approximately 32 db. of equalisation over the range of 12–60 kc.p.s. can be provided. The line amplifiers are of the negative feedback type and have three stages of amplification giving a maximum gain of about 65 db. The design of the inter-stage coupling units is such that a very flat gain-frequency characteristic is obtained and phase change kept to a small value. Pentode valves are used except for the last stage in which a co-planar grid valve is employed. The use of the co-planar grid valve gives the amplifier a large power-handling capacity with the relatively low anode voltage (130 volts) available and helps to keep harmonic distortion to a minimum. The large amount of negative grid bias required (approximately 50 volts) is obtained from a dry-cell battery mounted adjacent to the repeater.

As the band filter impedance is 600 ohms and that of the line usually approximates to 138 ohms, the transmitting and receiving amplifiers are designed to have corresponding input and output impedances. In order that the spare unit may be used in either capacity, an impedance transforming network is provided adjacent to the unit and is brought into circuit when required.

Normally, intermediate amplifier stations are required between the system ends. The amplifiers employed at these stations are similar to those used at the terminal stations.

12-Circuit Carrier Equipment Installed at Stranraer and Belfast.

As no intermediate amplifier stations are involved the equipment consists simply of one oscillator bay and two channel and repeater bays at each of the terminal stations.

At Belfast the equipment is adjusted so that input and output levels (audio) are those applicable to 3 db. circuits. At Stranraer the level presented to the modulators is − 4 db., while the output from the channel amplifiers is + 6 db., a level which is suitable for direct application to line.

The frequency response curves of three typical channels are shown in Fig. **13**. Speech over all channels is of excellent quality and is free from cross-talk and noise.

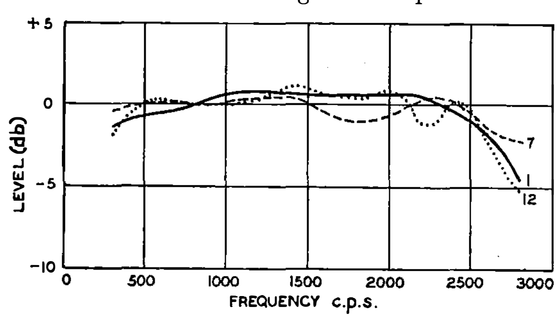


FIG. **13**.—OVERALL FREQUENCY RESPONSE RELATIVE TO 800 C.P.S. 12-CIRCUIT CARRIER EQUIPMENT.

Equipment at the Cable Huts.

Each submarine cable is terminated on a separate bay at the cable huts. These bays carry, in addition, the terminations of the balanced pair cables, system filters, hybrid transformers and balance equipment. The filter, hybrid and balance equipment were designed and constructed by the Research Branch of the P.O. Engineering Department.

The high-pass and low-pass system filters are on the submarine cable side of the hybrid transformer. It is, therefore, necessary that the filter equipment be reproduced in the balance, which thus consists of a network simulating the submarine cable together with two filters similar in construction to the actual system filters. The performance of this equipment is such that, over the whole of the frequency range concerned, a singing point between line and balance of not less than 35 db. is obtained.

Circuits Provided.

The manufacturers' 30 days' maintenance period for the submarine cables expired in the middle of September, 1937, and four temporary circuits, two on each cable, were put into service early in October. These circuits were as follows :—One London–Belfast, one Glasgow–Belfast and two Liverpool–Belfast. The permanent 1 + 3 circuit equipment providing eight duplex circuits was tested and accepted by the Post Office Engineering Department during the first week in November and the circuits were put into service. The 12-circuit carrier equipment was also accepted during November, 1937, and is in service.

Future Developments.

With the added impetus given by the recent removal of the special submarine cable charges for telephone calls on this route, considerable increase in the traffic is anticipated, far beyond that which can be catered for by the 20 new circuits already provided. Further circuits will be obtained by providing additional 12-circuit terminal equipments at Belfast and Stranraer in the normal range of 12 to 60 kc.p.s. ; a group of 12 such circuits will then be " group-modulated " so as to occupy the frequency band from 60 to 108 kc.p.s. : a second 12-circuit carrier system will be group-modulated to the frequency band 108 to 156 kc.p.s. ; this process will be repeated in a similar way to that in which the groups of 10 circuits on the London–Birmingham coaxial cable are translated to higher frequency bands.[6]

The following schedule shows the frequency bands to which 12-circuit type equipment will be " group-modulated " and the corresponding group carrier frequencies which will be employed for a range of transmitted frequencies up to 300 kc.p.s. The total number of circuits thereby provided on the two cables will be 80, including the eight duplex circuits. It is possible that other means may be adopted to provide circuits at frequencies above 300 kc.p.s.

[6] *P.O.E.E.J.*, Vol. 30, p. 206.

12-Circuit Equipment	Nominal Transmitted Frequency Range	Group Carrier Frequency
	kc.p.s.	kc.p.s.
No. 1	12 to 60	—
No. 2	60 to 108	120
No. 3	108 to 156	168
No. 4	156 to 204	216
No. 5	204 to 252	264
No. 6	252 to 300	312

The circuits will pass over the balanced-pair cables at each end and the submarine cables on a 4-wire basis (i.e. " Goes " will be on one cable and " Returns " on the other), and group-demodulators at Belfast and Stranraer will translate the frequencies back to those of the normal 12-circuit carrier range, whence they will pass to the carrier terminal equipment for conversion to audio frequencies.

Equipment has already been ordered to provide 24 additional circuits by this means. The valve type group-modulators and demodulators, and the intermediate line amplifier at Donaghadee rendered necessary by the increased attenuation at the higher frequencies, will be provided by the Research Branch of the P.O. Engineering Department. The intermediate line amplifier will be designed to pass the initial 12-circuit carrier band as well as the two additional bands, thus operating over a frequency range of 12 to 156 kc.p.s. No intermediate amplifier will be required at Port Patrick until still higher frequencies are employed, as the distance to Stranraer is only 7·2 miles whereas Donaghadee is 18·2 miles from Belfast. The existing cable termination building at Donaghadee has been considerably enlarged and improved to provide for the equipment and power plant. The new Port Patrick repeater station is also designed to accommodate the line repeaters and power plant which will ultimately be required. With the addition of each block of circuits the emergency arrangements may be revised so as to split the total frequency band in use into two approximately equal portions and so provide, in the event of a submarine cable breakdown, about half the normal number of circuits on one cable. This would entail replacing the emergency filters by others having the appropriate cut-off frequencies.

The ultimate limit to the total number of circuits obtainable is governed mainly by the power level of the resistance noise inherent in the cables. As this is of the order of 140 db. below a milliwatt and as a signal-to-noise ratio of at least 55 db. is required, with normal transmitted levels the limit is reached at a frequency corresponding to a submarine cable attenuation of about 85 db. This attenuation will be reached (see Fig. 4) at a frequency of about 450 kc.p.s. Hence it is anticipated that a total of approximately 100 telephone circuits can be obtained on the two submarine cables.

The authors are indebted to Mr. F. S. Hudson for the photographs of the equipment.

The Belfast-Stranraer 9-Circuit Ultra-Short Wave Radio Telephone System

D. B. Mirk, B.Sc., M.I.E.E.
(Standard Telephones & Cables, Ltd.)

Details of the equipment and performance of the recently installed ultra-short wave radio link between Scotland and Northern Ireland are given. The system is novel in that nine telephone channels are provided on one carrier in each direction.

Introduction.

THE attention of engineers has been directed for a considerable time to the possibilities of transmitting more than one communication on a single radio carrier frequency. This problem raises many considerations such as the availability of the necessary bandwidth in the ether, the elimination of intermodulation difficulties between the channels, and the obtaining of a sufficiently high signal-to-noise ratio for each individual channel when the available transmitter power is divided between the channels.

The long and medium waveband did not appear promising for multi-circuit use in view of the first consideration, and in 1931 experiments were made in the short waveband on the circuits between Madrid and Buenos Aires. In 1932 experimental two-way working was carried out over a lengthy period on this circuit employing one telephone and one telegraph circuit, operated simultaneously. At that time the short wave communication bands were not so crowded as they are at present and, during normal ether conditions, the signal-to-noise ratio was sufficiently high to permit simultaneous operation on the two circuits.

The problem of elimination of intermodulation was solved by the use of the displaced sideband system[1]; it permits placing a number of channels on a single carrier, the relationship between the channels and the carrier being such that intermodulation products between channels are eliminated. The combined band, which included the telegraph and the telephone circuit, occupied approximately 3,000 c.p.s. bandwidth, and it was displaced from the carrier by an equal amount. Thus the two-circuit system occupied 12 kc.p.s. of ether space. The trials, lasting several months, were extremely satisfactory.

Due to the increasing use of the short waveband for long-distance broadcasting, it was nevertheless felt that, unless the total bandwidth of the carrier and two sidebands could be reduced, multi-circuit working in the short wave field would not be of great interest. Based on the short wave single sideband work done by the Le Matériel Téléphonique (L.M.T.) laboratories[2], the Dutch P.T.T. developed a system based on the single sideband principle, comprising three telephone circuits and one telegraph circuit for operation between Holland and the Dutch East Indies. This system halves the ether space required by the Madrid-Buenos Aires system.

The bandwith limitations imposed by the use of short waves led the L.M.T. laboratories to investigate even shorter wavelengths in the ultra-short wave range (1–10 metres) and in the micro-ray range (1 centimetre to 1 metre) with a view to ascertaining the requirements for multi-channel operation and the limitations of the system.

In the years 1932 to 1936 considerable work was carried out in the 1–10 metre band by the British Post Office, although in the present paper we can do no more than briefly mention the results. In 1932 a single-circuit equipment was put in operation by the Post Office between Cardiff and Weston-super-Mare on a wavelength of 5 metres. This was followed in 1935 by the operation of six single-circuit equipments between Scotland and Ireland operating on twelve frequencies between 4 and 6 metres, and in 1936 by the installation of an ultra-short wave link between Guernsey and Chaldon giving two circuits on wavelengths between 5 and 8·5 metres. This work together with the advice and co-operation of the British Post Office engineers has been of very great assistance in the production of the 9-circuit ultra-short wave equipment which forms the subject of the present article.

Although micro-ray wavelengths undoubtedly provide the necessary bandwith for multi-circuit operation, micro-ray as compared with ultra-short wave technique is relatively less developed. Consequently the practical development of multi-circuit radio communication has taken place in the ultra-short waveband and has resulted in the production by Standard Telephones and Cables, Ltd., of the 9-circuit equipment now in service between Belfast and Stranraer.

Belfast–Stranraer System.

The 9-circuit ultra-short wave equipment provides nine 4-wire telephone circuits between two points which are separated by about 35 miles, and between which optical visibility exists. On the Irish side, the radio station is at Ballygomartin, about five miles from the Belfast exchange ; the Scottish station is at Enoch Hill, about five miles from Stranraer repeater station.

The system is designed for operation on wavelengths between 60 and 85 Mc.p.s., limits which are most suitable for high grade telephone circuits.[3] A carrier frequency of 76 Mc.p.s. is used in one direction and 83 Mc.p.s. in the other.

The system operates on a 4-wire basis from the input to the transmitters to the output of the receivers. Feedback between the " Go " and " Return " paths is eliminated by the use of different wavelengths, and polarisations in the two directions of transmission, as well as by adequate shielding of the circuits, at voice and intermediate frequencies, in the equipment.

[1] "The Spread Sideband System on Short Wave Telephone Links," by L. T. Hinton, *Electrical Communication*, October, 1931.

[2] " The Single Sideband System Applied to Short Wavelengths," by A. H. Reeves, *Electrical Communication*, July, 1931.

[3] " Ultra-Short Wave Communication," by E. H. Ullrich, *Electrical Communication*, July, 1937.

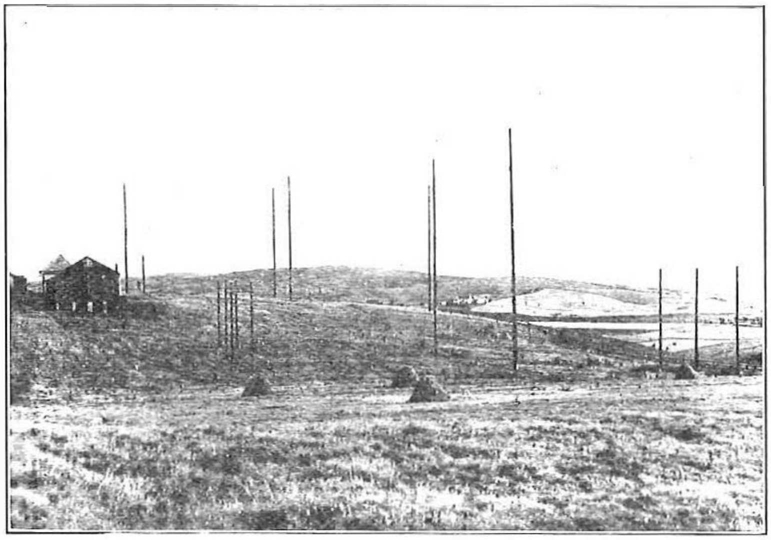


Fig. 1.—The Aerials and Station Building at Stranraer.

The 4-wire terminating sets can be located at the radio stations, but on this system are placed at the Belfast and London trunk exchanges. From these exchanges the circuits are connected by regular 4-wire repeatered cables to the radio stations at Ballygomartin and Stranraer, respectively.

The equipment is designed for unattended operation and is capable of complete remote control from the nearest telephone exchange. Spare equipment is provided, part of which is brought automatically into operation on the occurrence of any abnormal condition, and the whole apparatus is protected by safety circuits from the possibility of damage due to breakdown. Both transmitting and receiving equipments derive their whole power supply from the public supply mains, the only battery used in the equipment being that for the operation of the remote control relay system.

A Diesel electric power plant is arranged so that, in the event of failure of the public supply, it will automatically take over the load approximately one minute after such failure and thus avoid serious interruption of the service.

The transmitting, receiving and power equipment for the whole system is housed in one small frame building (Fig. 1). The Diesel power plant is located in a separate brick building close to the radio building.

The area occupied by the station is quite small, being mainly taken up by the antenna arrays. In choosing the sites, particular attention was paid to the proximity of sources of electrical interference as well as the question of available power supply and optical visibility of the complementary station.[4]

General Principles of Operation

Transmitters.

The transmitter, shown schematically in Fig. 2, is of the multi-channel type transmitting all nine channels on a single radio carrier frequency. Each incoming conversation passes through its own channel producer and buffer stage to the intermediate frequency busbars. From the busbars the whole nine channels modulate either the service or reserve ultra-short wave transmitter, and thence pass through a changeover switch to the transmitting antenna. The system of transmission is shown in the right-hand column of Fig. 3.

Let it be assumed that the input of channel No. 1 is supplied with a sinusoidal tone of frequency f_1 kc.p.s. This tone modulates a channel-producer having a frequency of, say, 155 kc.p.s., resulting in a carrier frequency of 155 kc.p.s. together with upper and lower sidebands of $(155+f_1)$ and $(155-f_1)$ kc.p.s

If channel No. 2 be supplied with a sinusoidal tone input of frequency f_2, this will modulate a channel-producer frequency of, say, 165 kc. p.s., resulting in a carrier frequency of 165 kc.p.s., and upper and lower

[4] "Ultra-Short Wave Communication," by E. H. Ullrich *Electrical Communication*, July, 1937.

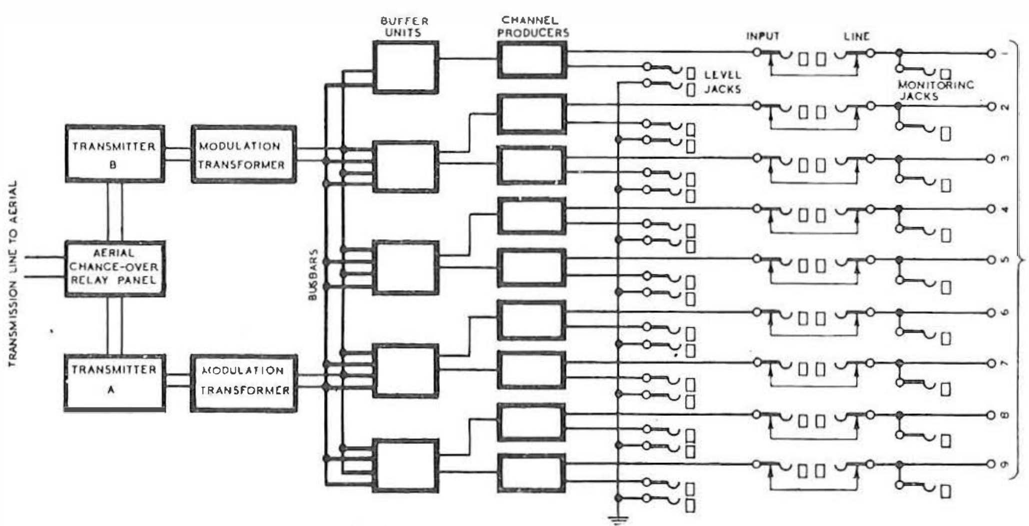


Fig. 2.—Block Schematic of Transmitter.

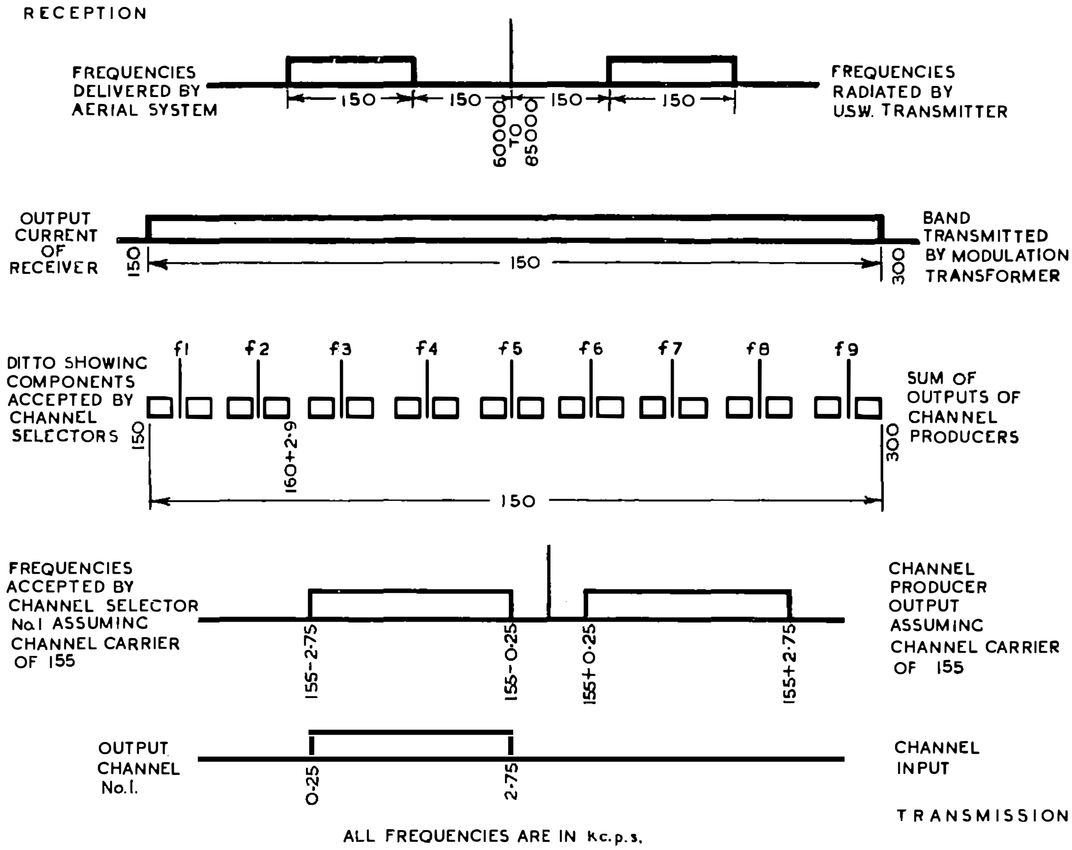


FIG. 3.—FREQUENCY SPECTRUM.

sidebands of $(165+f_2)$ and $(165-f_2)$ kc.p.s. Similarly, channel No. 3 may have a carrier frequency of 180 kc.p.s., and so on to the ninth channel, of which the carrier frequency might be 280 kc.p.s.

The bands of frequencies derived from the nine channel producers, after passing through the buffer stage are added together on the busbars, producing in total a frequency band extending from $(155-f_1)$ to $(280+f_9)$ kc.p.s. This total frequency band is now used to modulate the output of the ultra-short wave transmitter having a carrier frequency of, say, 76,000 kc.p.s. and therefore produces a lower sideband extending from 76,000 — $(280+f_9)$ to 76,000 — $(155-f_1)$ kc.p.s., the carrier wave of 76,000 kc.p.s.

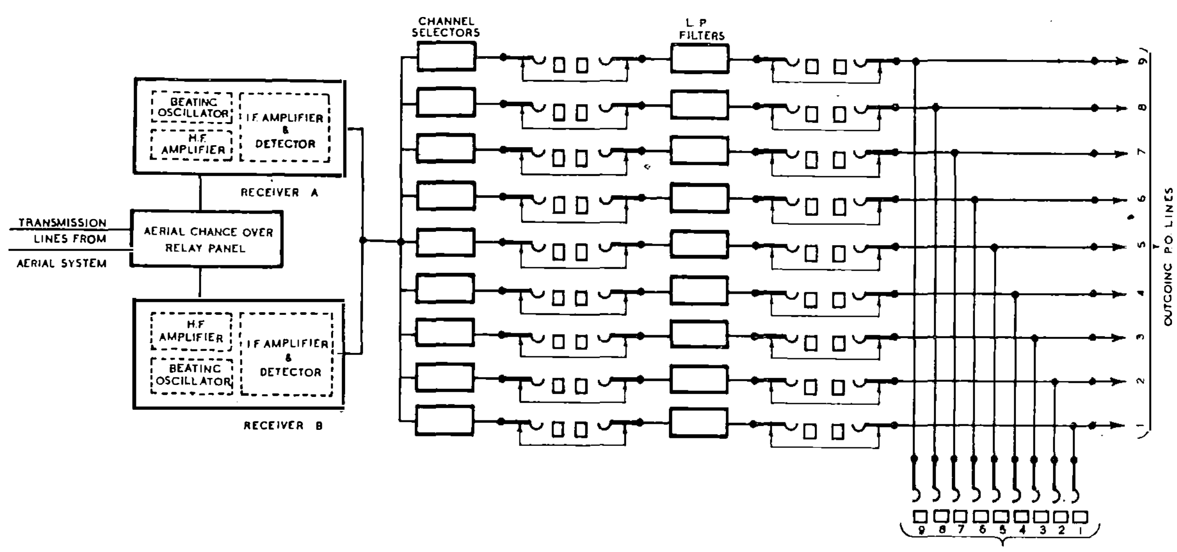


FIG. 4.—BLOCK SCHEMATIC OF RECEIVER.

and an upper sideband extending from 76,000 + $(155-f_1)$ to 76,000 + $(280+f_9)$ kc.p.s. This band of frequencies, about 600 kc.p.s. in width, is radiated by the antenna system and transmitted along the ultra-short wave path.

Receivers.

At the receiving end the incoming band of frequencies described above passes from the antenna through the changeover switch to either the service or reserve ultra-short wave receiver as will be seen by reference to Fig. **4**. The system of reception is shown in the left-hand column of Fig. **3**.

The superheterodyne type receiver amplifies and steps the carrier frequency down to an intermediate value which is fed to the second detector. The second detector reproduces the original sideband extending from $(155-f_1)$ to $(280+f_9)$ kc.p.s. This band of frequencies is then applied to a bank of nine selecting circuits operating as band-pass filters. The currents of frequency $(155-f_1)$, 155 and $(155+f_1)$ kc.p.s. are passed by the first selector circuit to a third detector and amplifying circuit, which delivers the original frequency of f_1 kc.p.s. to the first channel. Similarly, the frequencies of $(165-f_2)$, 165 and $(165+f_2)$ kc.p.s. are passed by the second filter to a detecting and amplifying circuit, which delivers the original frequency f_2 to the second channel. In this manner, the whole band of frequencies delivered by the second detector is split up, detected, amplified and delivered to the appropriate channel.

The carrier frequency of the ultra-short wave transmitter and the beating oscillator frequency of the superheterodyne receiver are both crystal-controlled and maintained constant to within very close limits. Thus a high degree of selectivity is attained in the receiver without the necessity of frequent retuning.

Antenna System.

In order to minimise interference between the transmitting and receiving waves, the plane of polarisation of the waves emitted at the transmitting aerial is at right angles to that of the waves received by the receiving aerial. At one terminal, therefore, the transmitter is equipped with an aerial system designed for vertical polarisation, whereas the receiver is fitted with an aerial designed for horizontal polarisation. At the other terminal, the receiving aerial is vertically and the transmitting aerial is horizontally polarised. The foreground of Fig. **1** shows a vertically polarised array consisting of eight inverted "**V**" aerials arranged side by side. The horizontally polarised array is in the background and consist of four horizontal Rhombic aerials stacked one above the other.

The gain of each of the arrays is approximately 18 decibels in the direction of propagation over a vertical or horizontal dipole. This means that the directive antennæ contribute some 36 db. gain to the circuit. If this gain were concentrated at the transmitting end, a 300 kilowatt transmitter would be necessary to give the same receiver input with dipole antennæ at both ends.

The aerials are connected to the station by means of overhead 2-wire transmission lines.

General Performance.

Before describing the apparatus in detail, some of the performance figures of the Belfast–Stranraer system are given. These show that the design of the system permits adaptation to the regular long-distance telephone networks. Overall circuits which include a 9-circuit link, can, therefore, be treated in exactly the same manner as any other long-distance wire or cable circuit.

For any individual "Go" or "Return" channel operating as part of a 4-wire system, the transmission performance is:

(*a*) Within the frequency range of 250 to 2,750 c.p.s. the transmission equivalent of any one channel does not depart by more than 2·5 db. from that at 800 c.p.s.

(*b*) Each transmitting channel may be adjusted so that normal modulation is obtained for any given level between zero and −20 db. referred to 1 mW.

(*c*) Each receiving channel may be adjusted so that normal modulation gives an output of any given level between zero and + 15 db. referred to 1 mW.

(*d*) The transmitting and receiving equipments on the Belfast-Stranraer link normally operate at a gain of zero from the transmitter input of any channel to the receiver output of the same channel. The possibility of using the maximum overall gain of 35 db. depends, of course, on the layout of the overall circuit.

(*e*) With the transmitter adjusted for maximum modulation and with the receiver adjusted to give an output of approximately zero (1 milliwatt), the tone/noise ratio is of the order of 45 db.

(*f*) When the equipment is adjusted as described under (*e*), the crosstalk due to any other channel is practically non-existent and certainly not detectable by ear.

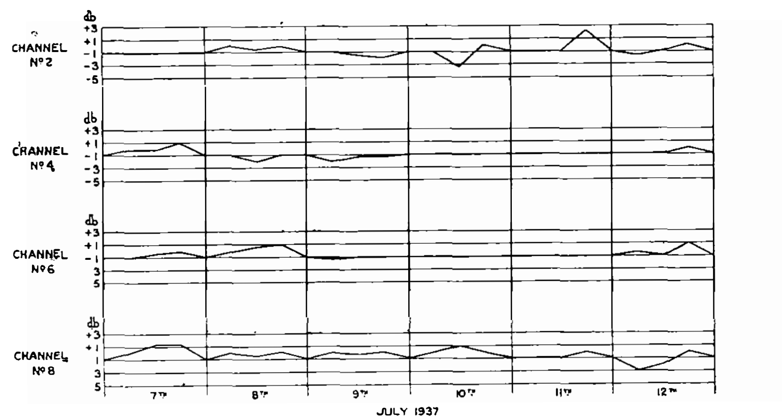


Fig. **5**.—Channel Selector Output Levels measured at Ballygomartin. Normal operating level—1 db.

(*g*) The transmission equivalent of any channel at 800 c.p.s. does not normally vary by more than ± 3 db. A typical level diagram showing the variation of level over seven consecutive days for several channels is shown in Fig. 5.

(*h*) The equipment is designed to match incoming and outgoing lines of 600 ohms impedance.

(*i*) The power consumption of the complete set, including that of the 9-channel transmitting equipment and of the 9-channel receiving equipment, is less than 4 kW.

Description of Transmitter

Radio Channels.

The nine incoming circuits from the local telephone exchange are taken to triple jacks on a line jack panel so that connection may be made by plugs to the incoming line, or to the transmitter input circuit, or the line may be bridged.

From these jacks each incoming circuit is taken through a potentiometer to the input transformer of a 2-stage audio frequency amplifier, the output of which modulates the channel-producer carrier. A portion of the output of this amplifier is led back for monitoring purposes to level jacks mounted on the line jack panel. The channel-producer high stability oscillator, giving the appropriate channel frequency, drives a screened pentode amplifier which is suppressor grid-modulated by the audio output of the amplifier.

The modulated carrier at the channel frequency thus obtained is passed through a low impedance transmission line to a network which presents a high attenuation to currents of any frequency outside the band of this channel. These "buffer networks" reduce the coupling between the channel-producers to zero, thus preventing intermodulation in the producer output pentodes. The buffer units are assembled in pairs, each panel carrying the buffers corresponding to two channels, the fifth panel carrying one buffer only. Each buffer is connected by a switch to common busbars which thus carry the total frequency band obtained by adding the outputs of all nine channel-producer panels. This switch is so arranged that, for testing purposes the buffer may be disconnected from the busbars and a non-inductive resistance connected across its output to simulate the normal operating load. The output of a diode rectifier connected across this resistance is led back for monitoring the depth of modulation on the channel producer.

The busbar output is fed to the modulation transformer designed to pass the necessary wide frequency band and to plate-modulate the ultra-short wave transmitter.

The carrier frequency on the ultra-short wave transmitter is controlled by a specially cut, quartz crystal with an exceedingly small temperature co-efficient. The crystal oscillator output drives a screened pentode valve at a frequency twice that of the oscillator. This pentode amplifier excites a frequency multiplying stage which drives the push-pull output stage of the transmitter.

The latter is modulated by the combined outputs of the channel-producer units from the modulation transformer. Two sections of the modulation transformer carry the plate currents of the two push-pull amplifier valves.

The transmitter unit contains filter circuits which not only prevent ultra-high frequencies from entering the channel-producers but also prevent radiation of the channel frequencies by the antenna system. Incorporated in this circuit are the necessary networks for matching the impedance of the balanced output stage to that of the 600 ohm transmission line. The output leads of the transmitter unit include thermo junctions connected through suitable filters to a pair of ammeters which indicate the feeder line currents.

The modulation transformer panel also carries filter equipment and meters indicating the plate currents of the final stage ultra-high frequency amplifying valves.

In addition to duplication of the ultra-short wave transmitter—common to all nine channels—two modulation transformers are provided for convenience, one for each transmitter. Arrangements are such that the service transmitter and its modulation transformer are automatically replaced by the reserve transmitter and its associated transformer if certain faults occur. The transmitters are connected to the 600 ohm feeder line by an aerial changeover relay panel containing relays which connect the transmission line to the service transmitter or to the reserve transmitter as determined by the control circuits. The arrangement of the control circuits is described below in detail.

Monitoring and Testing Circuits.

Two sets of facilities are available for monitoring the operation of the transmitter:

(*a*) The incoming line level may be monitored at the line level jacks;

(*b*) The audio output of each channel modulator can be adjusted to a standard level by means of level jacks and a volume indicator.

Testing facilities are provided to line up independently any channel-producer unit for the correct output level, percentage modulation, etc., thus

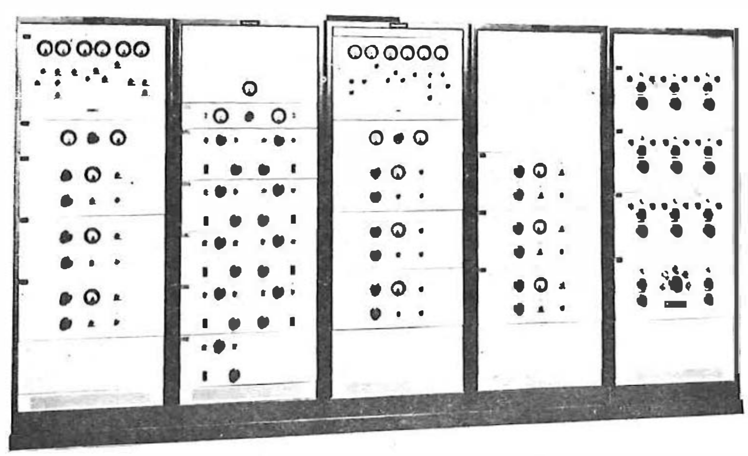


Fig. 6.—The Transmitter Bays.

ensuring the highest transmission efficiency for the equipment as a whole.

Mechanical Construction.

The various panels of the multiplex transmitter are mounted in five steel cabinets (Fig. 6). Reading from left to right: bay No. 1 contains the ultra-short wave transmitter, modulation transformer panel and three channel producers; bay No. 2, the aerial changeover relay panel, monitoring panel and five buffer units; bay No. 3, the spare ultra-short wave transmitter and spare modulation transformer panel together with three channel producer units; bay No. 4, the three channel producer units; and bay No. 5, the three power distribution switching panels and the main power isolation switch panel.

All five transmitter bays are protected by a lock safety system, which is interlocked with the four transmitter power bays described below in the section "Transmitter Power Supply."

Description of Receiver.

Radio Circuits.

The ultra-high frequency currents delivered by the receiving antenna system to the 600 ohm transmission line are brought first to an aerial changeover relay arranged to connect the incoming line to either the service or reserve receiver.

The received currents are amplified by an ultra-high frequency pentode and then pass to a frequency changer valve. The beat frequency oscillator is controlled by a quartz crystal with a very low temperature coefficient, the fourth harmonic of this oscillation being amplified by a screened pentode stage and applied in the cathode circuit of the frequency changer. The intermediate frequency output passes to the I.F. amplifier, which contains three indirectly heated screened pentode amplifying valves operating as a wide band amplifier designed to pass the intermediate frequency carrier wave and the lower side-band only. This sideband lies from 150 to 300 kc.p.s. below the intermediate carrier frequency. The amplifier has a highly linear characteristic in order to minimise the possibility of crosstalk between the nine channels which it amplifies.

After rectification, the frequency band of approximately 150–300 kc.p.s. is fed to nine channel selector units connected in parallel. Ahead of each selector unit is a filter offering high attenuation to any frequencies of the other eight channel bands. Thus, for channel No. 1, this filter passes only frequencies from (155+2·75) to (155−2·75) kc.p.s.; and, similarly, the input filter of channel selector No. 2 passes without attenuation only frequencies between (165−2·75) and (165+2·75) kc.p.s., and so forth. For each channel the output of the filter is passed to the grid of a screened pentode, the output circuit of which contains a second highly selective filter of similar characteristics. This filter feeds a dry rectifier, and, by the usual process of rectification, the outputs of the dry rectifiers in the respective channels duplicate the voice frequencies originally supplied to the input circuits of the transmitter channel producers.

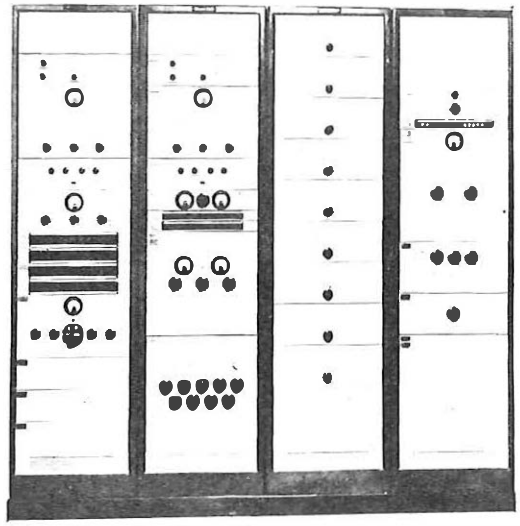


FIG. 7.—THE RECEIVER BAYS.

The output of each rectifier is passed through an impedance-matching device and a variable attenuator to a voice frequency amplifier, and thence through a high and a low pass filter to the outgoing telephone lines.

Monitoring and Testing Circuits.

Level jacks are provided to facilitate observation of the receiver output during operation by high resistance telephones or the volume indicator panel without causing interruption of the service.

Means are provided for routine testing both the service and reserve receivers while the equipment is in operation.

When the receiver is withdrawn from service it is possible, with the facilities provided, to analyse the performance of the whole receiving system.

Mechanical Construction.

The receiver units are assembled in the four bays illustrated in Fig. 7. Reading from left to right bay No. 1 contains the aerial changeover relay panel: the H.F. amplifier and the I.F. amplifier; bay No. 2, the spare H.F. amplifier, the spare I.F. amplifier, and spare oscillator panels, together with the meter panel, jack panel, power control and distribution panels; bay No. 3, the nine channel selector panels together with the L.F. oscillator panel; bay No. 4, the remote control relay panel, auxiliary power supply unit No. 1, auxiliary power supply unit No. 2, the power supply unit, and the rectifier unit.

Control Circuits

The station is designed for unattended operation, and full control facilities can be transferred to the distant exchange by means of a remote control panel containing two 3-position switches and three control lines.

The distant exchange is thereby enabled to: (1) switch the whole equipment on or off; and (2) use either the service or reserve receiver with either the service or reserve transmitter.

If, by chance, the control lines from the exchange are interrupted, both transmitter and receiver remain switched on so that a control line fault cannot put the radio link out of service.

Any overload occurring on the ultra-short wave transmitter automatically effects the switching-over of all appropriate supplies and of the transmitting aerial to the spare transmitter. When a fault occurs in the ultra-short wave receiver, the reserve receiver may be switched in by using remote control equipment which then connects the receiving aerial to the latter.

The remote control facilities are duplicated in the station so that the equipment can be locally controlled if required. The local control is interlocked with the remote control so that if, for example, one of the transmitters is switched off locally by hand and the distant control operator attempts to switch on this transmitter, an alarm indication is given and the transmitter is not switched into service.

Power Supply

General.

A service of the nature of Belfast–Stranraer, in which the stations are located at points remote from towns and in which the equipment is designed to be non-attended and to be operated by remote control, needs careful study of the power supply circuits. In addition, the use of plate voltages of 500 and 1,250 V makes it necessary to interlock the transmitter supplies for the protection of the staff when making routine and maintenance tests.

Power for the station is derived from a 230 volt single phase, 50 c.p.s. supply, which should not be subject to voltage variations greater than ± 5 per cent. or frequency variations greater than ± 1 per cent.

The power consumption of a 9-circuit terminal (transmitter and receiver), as previously mentioned, is approximately 4 kW.

Transmitter Power Supply.

The transmitter power equipment is shown in Fig. 8 and is contained in four bay frameworks similar to those housing the transmitter. The bays are arranged as follows:

Bay 1. Control and alarm circuits and power distribution;

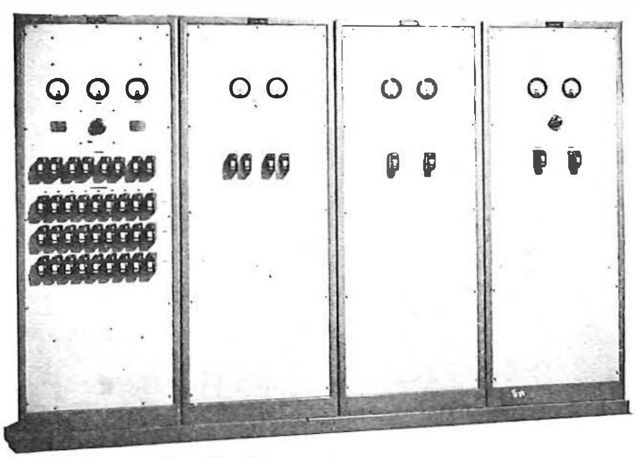


Fig. 8.—Power Supply Panels.

Bay 2. Transmitter filament supply with overload relays, battery with charging rectifier and overload relays, and half of the 1,250 V supply rectifier units;

Bay 3. Half of the 1,250 V supply rectifier units with overload relays, and channel producer grid bias supply—smoothing gear and overload relays;

Bay 4. Rectifier, smoothing circuit and overload relays for 500 V supply and transmitter grid biases 1 and 2.

The incoming power supply for the ultra-short wave transmitters is brought straight to the isolation switch panel on transmitter bay No. 5 (Fig. 6). A multi-point switch fitted with keys ensures that none of the power supply bays (Fig. 8) can be opened until the power has been switched off and the apparatus earthed. Each bay is fitted with a Yale lock which cannot be opened until the corresponding key has been turned in a lock forming part of the multi-point switch and withdrawn from the isolation switch panel. The multi-point switch must be in the "off" position before it is possible to withdraw any key, and it is impossible to restore the multi-point switch to the "on" position until all keys have been replaced and turned.

The isolation switch panel also contains one pair of switches for each ultra-short wave transmitter unit. When any pair of switches is in the "off" position, it is impossible to apply power to the corresponding transmitter. The two switches of each pair are so interlocked that when power is applied it must follow the necessary sequence, i.e. power is first applied to the filaments and, after a 50-second delay, the H.T. is applied.

When the switch of the transmitter in use is thrown to the "off" position, either by hand or from the distant exchange, the automatic changeover relay removes the power from the transmitter in service and applies it to the reserve transmitter which is then brought into service and connected to the antenna.

Re-set push buttons are provided to prevent power from being re-applied in any circumstances to a faulty transmitter until the operator decides it may be safely done and deliberately operates the push button. A special push button is included for actuating an A.C. operated emergency relay for applying power to the control circuits in the event of a control battery failure.

Since each ultra-short wave unit is locked, as described, it is impossible to obtain access to either transmitter until the power has been switched off and the transmitter earthed.

Power supplies to the channel-producer units are furnished through the distribution switching panel (Fig. 6). By closing and locking a given channel-producer unit, the key can be withdrawn and inserted in the distribution switching panel, thus unlocking the switch which controls the filament heating circuits and the grid bias circuit for the output stage. When this switch is unlocked, it is possible to rotate a second mechanically interlocked switch which applies plate and screen voltages to the output stage of the channel-producers. When the latter switch is in the "off" position, the lighting of a lamp shows that power is removed from the channel-producer unit; access thereto may then be obtained by withdrawing the key from the distribution switching panel.

The following supplies are generated in the power equipment and applied to the transmitter:

Description	*Voltage*	*Approx. Current*	*Used for*
H.T.1	1,250 V D.C.	0·48-0·8 A	(*a*) Transmitter Anodes (*b*) Channel Output Anodes
H.T.2	500 V D.C.	1·08-1·5 A	(*a*) Transmitter Screens (*b*) Channel Output Screens (*c*) Channel Anodes
G.B.1	−180 V D.C.	15-25 mA	Transmitter Grid Bias
G.B.2	−240 V D.C.	15-25 mA	Transmitter Grid Bias
G.B.3	−40 to −120 V D.C.	5 mA per channel	Channel Producer Grid Bias
U.S.W. Trans. L.T.	7·6 V A.C.	13.·8 A	Transmitter Valve Filaments
Channel Producer L.T.	230 V A.C.	0·35 A per Channel	Primary Supply to Filament Transformer on Channel Producer Panels.
Battery	33 V D.C.	3 A	Relay and Alarm Circuits
Monitor	4 V A.C.	1 A	Filament Supply for Monitoring Detector Valves

Receiver Power Supply.

The incoming receiver power supply passes through a filter which isolates the mains from the radio frequency equipment. It then divides into two branches, the first of which normally feeds the service receiver while the second provides power for the test oscillators and the reserve receiver. Each supply provides all the filament, anode, grid and screen voltages required on the units served. A high degree of smoothing is provided in order to ensure the highest signal-to-noise ratio in the received signal.

The supplies to the receivers are fed through two multi-point changeover switches, one for each receiver. When either of these switches is thrown to the "hand" position, the corresponding receiver derives its power from the second power supply. When the switch is thrown to the "automatic" position, the receiver derives its power through a changeover relay from the first power supply. This changeover relay is connected in parallel with the receiver aerial changeover relay and is remotely operated from the telephone exchange, so that when the receiving aerial is changed over from Receiver "A" to Receiver "B," the power supply system is also changed over.

Power for the channel selector panels is supplied from the distribution panel, which carries nine quick-break switches each feeding one channel selector unit. Suitable load resistances are provided so that when a channel selector unit is switched off, a corresponding amount of power is absorbed, thus avoiding the possibility of change in individual channel voltage with the number of channels in use. The receiver power supply enters the power supply bays direct without passing through an isolator switch panel since high voltages are not involved.

Power Failure Alarm and Stand-by Power Plant.

Care has been taken in the design of the power circuits to ensure, as far as possible, that a failure of any kind is immediately brought to the notice of the operator by means of a bell and an alarm lights.

The alarm circuits for the transmitters consist of six power failure relays, the operation of any one of which switches in the reserve transmitter and also lights its appropriate alarm lamp.

A similar system of alarm circuits in the receiver switches in the reserve receiver and provides suitable visual and aural indications.

A Diesel electric emergency power plant is provided. Upon failure of the public electricity supply it starts up automatically within a period not exceeding 60 seconds and furnishes power to the radio equipment, thus preventing any serious interruption of the service.

When the public supply is re-established, the emergency set stops automatically and returns the radio mains to the incoming public supplies. When, however, the public supply is re-established after a short time interval, the automatic control will not reconnect the radio mains to the public supply until sufficient time has elapsed to enable the engine starter battery to be fully recharged, thus ensuring operation of the emergency supply in the event of repeated short-interval failures.

Inauguration

The 9-circuit ultra-short wave radio link between Belfast and Stranraer was inaugurated by Sir. Walter J. Womersley, M.P., Assistant Postmaster General, on August 31st, 1937, from the Ballygomartin station at the Irish end. Four circuits were provided, one for the use of Sir Walter Womersley, and the other three for Press representatives. These circuits functioned as ordinary 2-wire connections from Ballygomartin to the Belfast exchange, and were there connected by the regular operators to four Belfast-London circuits using four of the nine channels on the radio link.

The three circuits turned over to the Press representatives for simultaneous conversations demonstrated conclusively that the claims made for the equipment are fully justified, and that this system is ready to take its place in regular long-distance telephone service.

Acknowledgment.

The system herein described was developed by Les Laboratoires, Le Matériel Téléphonique, and in this connection special mention is due to Messrs. E. H. Ullrich, R. E. Gray and A. H. Reeves. The author is indebted to Dr. R. C. Turner, of Standard Telephones and Cables, Ltd., for his valuable assistance in the preparation of this article.

The Unit Automatic Exchange No. 14

A. J. C. HENK
and W. CLAYTON

This article gives details of the construction of and facilities given by the U.A.X. No. 14. A maximum of 800 subscribers' lines can be accommodated in this type of exchange and provision for junction equipment is, in general, limited only by the available accommodation in the exchange building.

Introduction.

THE U.A.X. No. 14, which supersedes U.A.X. No. 7, has been designed for exchanges where the ultimate requirements exceed 200, but are less than 800 subscribers' lines capacity. The U.A.X. No. 14 functions similarly to the U.A.X. No. 13[1], in regard to acting as a switching centre for other smaller unit automatic or manual exchanges.

Facilities.—The general facilities are similar to those given by the U.A.X. No. 13. Major exceptions are that the incoming junctions are routed direct to 1st selectors instead of via linefinders and that forced releasing under permanent line loop or earth (P.G.) and called subscriber held (C.S.H.) conditions is not provided. Additional facilities include P.B.X.2-20 groups, service interception and changed number equipments, service and meter observation, traffic recording and the extension of urgent alarms. Test selectors and test final selectors are provided for testing subscribers' circuits from a remote exchange when required; these selectors are also employed during subscribers' meter-testing operations.

Subscribers' Numbering Scheme.—A 4-digit numbering scheme is employed for the subscribers, 400 lines being provided in each of the "2" and "3," thousand groups giving a numbering range of 2,000–2,399 and 3,000–3,399. P.B.X. facilities for groups of 2–10 lines are provided throughout the multiple, and P.B.X. facilities for groups of 2–20 lines can be provided, subject to a maximum of one such group in a 100-line multiple.

Trunking.—For the purpose of simplicity the trunking diagram has been drawn in three parts. Although in some instances bothway junction equipments are used, unidirectional junction working is shown in the diagrams. The types of junction equipments employed are described later in this article.

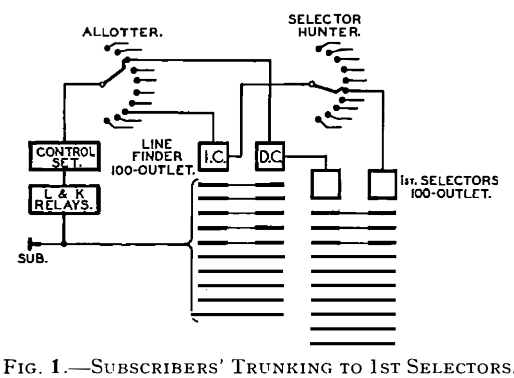


FIG. 1.—SUBSCRIBERS' TRUNKING TO 1ST SELECTORS.

Fig. 1 shows the trunking scheme between the subscribers and the 1st selectors. Normally the allotter is resting on a free directly connected (D.C.) linefinder, so designated because an individual 1st selector is directly associated. Should all directly connected linefinders be engaged, an indirectly connected (I.C.) linefinder is employed and the associated selector-hunter finds a 1st selector while the linefinder is operating to find the calling subscriber.

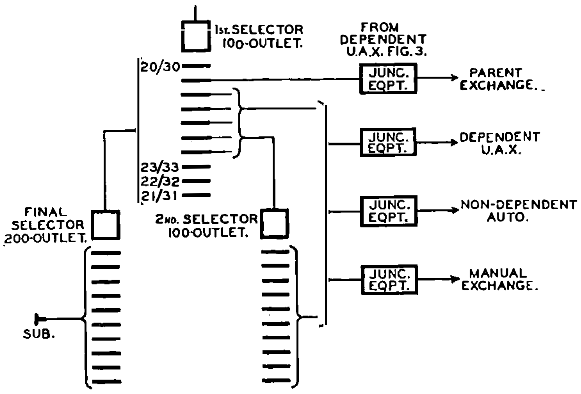


FIG. 2.—TRUNKING FROM 1ST SELECTORS.

On referring to Fig. 2, it will be seen that only a 1st selector and a final selector are employed on a call to a local subscriber, arrangements being made for the absorption of the digits "2" or "3." Levels 1, 2, 3 and 0 of the selector multiple serve as outlets to the final selectors for the hundreds digits. Levels 4–8 may be routed either direct or via 2nd selectors to various exchanges other than the parent. Level 9 carries the traffic to the parent exchange, except where a separate junction routing to the auto plant is required, when level 7 will be used for this purpose. The tenth impulse of an "0" call is absorbed and the call is routed via level 9, thus utilising one group of junctions for both manual board and automatic traffic.

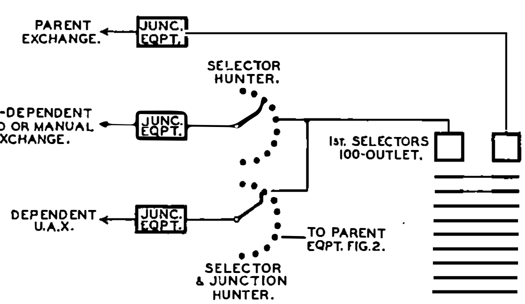


FIG. 3.—INCOMING JUNCTIONS, TRUNKING TO 1ST SELECTORS.

Fig. 3 shows the trunking arrangements for the incoming junction traffic. It will be seen that junctions from the parent exchange have individual 1st

[1] *P.O.E.E.J.*, Vol. 29, p. 141.

selectors at the U.A.X. whereas junctions from non-dependent exchanges employ selector-hunters. Junctions from dependent U.A.X.'s employ a combined junction and selector-hunter ; access is obtained to either the parent junction route or a selector depending on the signals over the junction.

Construction and Equipment

General.

The racks used in U.A.X.'s No. 14 have been designated according to whether they are used solely in U.A.X.'s No. 14 or not. If used solely in U.A.X.'s No. 14 the racks are designated Units Auto No. 14A, B, C, D, E, but if they can also be used in main exchanges the racks are given a descriptive title such as meter rack, etc.

The apparatus is assembled on five types of units and two types of racks as follows :

Designation.	*Apparatus fitted.*
Unit Auto No. 14A ..	Line Equipment
Unit Auto No. 14B ..	1st and 2nd Selectors
Unit Auto No. 14C ..	Junction Equipment
Unit Auto No. 14D ..	Miscellaneous Equipment (M.A.R.).
Unit Auto No. 14E ..	Auxiliary Equipment for junctions working into Director Areas.
Unit Auto No. 14 Meter Rack ..	Subscribers' and Traffic Meters.
Unit Auto No. 14 Meter Pulse Machine Rack	Meter Pulse Machines.

Trunk distribution frames, a traffic recorder rack and a test rack are also employed, but it is not proposed to describe them in this article as these items follow main exchange practice. The test rack is fitted only when the number of calling equipments exceeds 500.

Provision of Units and Racks.

An exchange designed to cater for a maximum of 800 subscribers' lines would require the following units and racks :

A Units	1–8 (1 per 100 subscribers).
B Units	1–4 (fitted as required).
C Units	1–33 (fitted as required).
D Units	1
*E Units	0, 1 or 2 (fitted as required).
Meter Rack	1
Meter Pulse Machine Rack	1
Trunk Distribution Frames	1 or 2 (fitted as required).
Traffic Recorder Rack	1
Test Rack	1

* E Units are required only at exchanges which have routes to director areas.

The units and racks are all 8 ft. $6\frac{1}{2}$ in. in height and are normally arranged in suites as shown in Fig. 4. The suites are arranged with the apparatus sides facing each other.

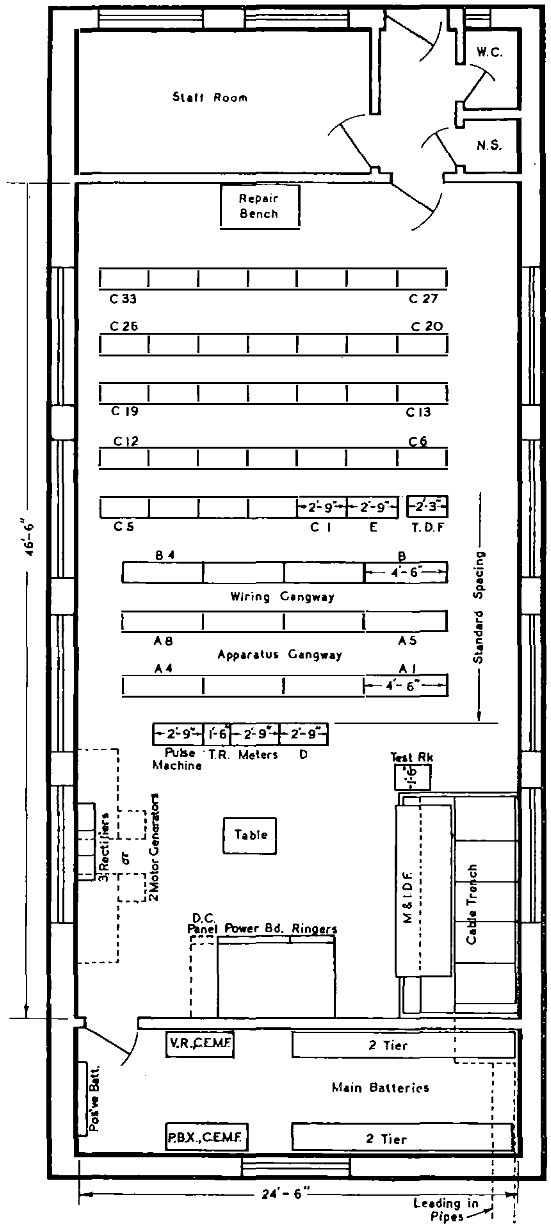


FIG. 4.—TYPICAL LAYOUT USING THE D OR E TYPE BUILDING.

General Rack Construction.

Exchanges of the smaller type, i.e. U.A.X.'s No. 12[2] and No. 13, have been designed for use in unheated buildings, and in order to prevent dampness from affecting the apparatus, the racks are totally enclosed in sheet steel cavity cabinets with special sealing arrangements for the cabinet doors and the cable runs. In buildings housing exchanges of over 200 lines multiple, heating is provided and cavity cabinets have therefore been dispensed with.

Open type construction has been adopted in the design of the racks and they have been arranged as far as possible in accordance with the P.O. standard 2,000-type equipment. As constructional details of the 2,000-type equipment have already been described

[2] *P.O.E.E.J.*, Vol. 28, p. 105.

in the JOURNAL[3], it is not proposed to give any description of the construction of the U.A.X. No. 14 racks.

Apparatus Details.

The selectors and relay sets are of the P.O. 2,000 type and incorporate ballast transmission bridges and balanced tone feeds.

The P.O. 3,000-type relay is used for all circuits other than the subscribers' line circuits (L and K relays) in which the P.O. 600-type relay is used. The meters are of the 100-type. A relay switch of the P.O. 3,000-type having one 6 amp. mercury tube, is used in the P.G. milliammeter circuit.

The miscellaneous equipment associated with a particular rack is mounted on the right-hand upright of the rack concerned.

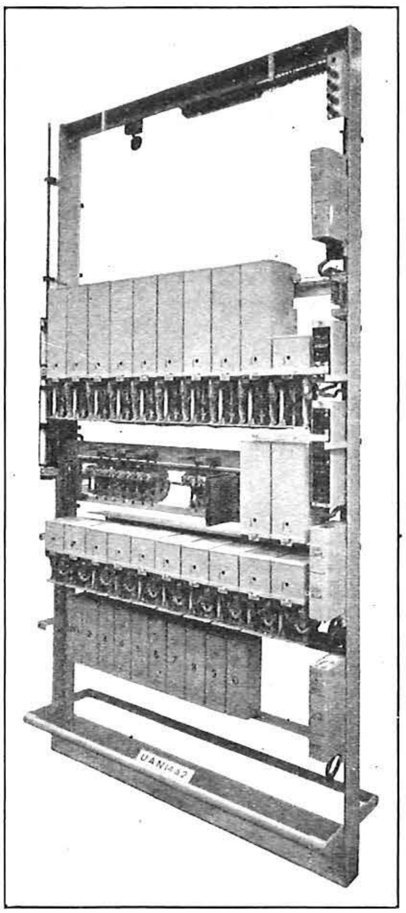


FIG. 5.—UNIT AUTO NO. 14A.

Unit Auto No. 14A (Fig. 5).

This unit accommodates 100 subscribers' calling and answering equipments which are mounted on four shelves as follows:

Shelf D. 9 P.B.X. Final Selectors and 1 Test Final Selector†, or 10 P.B.X. Final Selectors.

Shelf C. 7 Selector Hunters, 2 Allotters and 2 Control Relay Sets.*

Shelf B. 10 Line Finders.

Shelf A. 100 Subscribers' Line Circuits.

Unit Auto No. 14B (Fig. 6).

This unit accommodates the 1st and 2nd selectors, which are mounted on five shelves, each accommodating ten selectors.

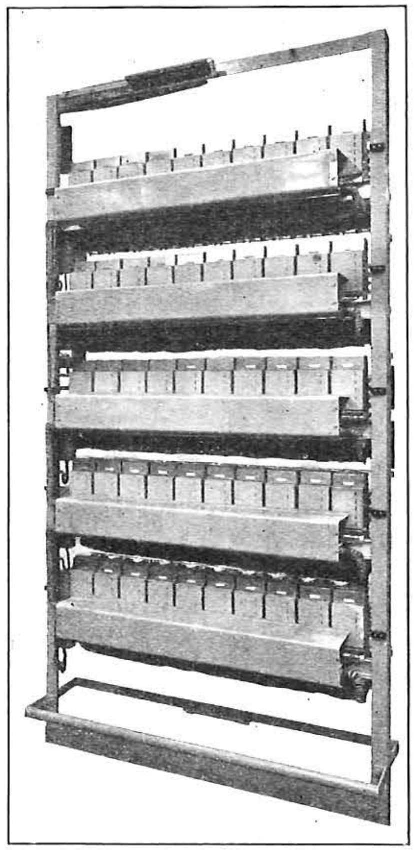


FIG. 6.—UNIT AUTO NO. 14B, REAR VIEW.

Second selectors are provided only when the number of junction codes exceeds five, or where it is necessary to employ 2-digit junction codes.

Unit Auto No. 14C

This unit accommodates strip-mounted equipment required for junction working. Common route discriminating relay sets used on junctions to non-director exchanges, when required, are also fitted on this unit. These relay sets are mounted at the bottom of the 1st C unit accommodating the associated junction equipment for that route. A rolled steel channel shelf is fitted to mount this equipment and arrangements have been made to use existing drillings in the uprights.

[3] *P.O.E.E.J.*, Vol. 28, pp. 249, 257.

† A test selector is provided on the basis of 1 per 2 A units.

* Where an odd number of A units is installed, the last unit is equipped with two control relay sets each serving 50 subscribers. Sufficient spare space exists for fitting an additional shelf of 10 final selectors (Shelf E) if required.

Unit Auto No. 14*D*

This unit is the equivalent of the miscellaneous apparatus rack (M.A.R.) as used in main automatic exchanges. There are seven shelves on which provision is made to mount the following apparatus :

- Shelf G. 1 Service Observation equipment.
- Shelf F. 4 Test and Plug Up Line equipments.
- Shelf E. 4 Changed Number equipments and 1 Alarm Delay equipment (6 seconds).
- Shelf D. 1 Service Interception Finder, 1 Howler and 1 P.G. milliammeter.
- Shelf C. 4 N.U. Tone Relay Sets.
- Shelf B. 1 Test Number, 3 Service Interception and 1 Alarm Extension Relay Sets.
- Shelf A. 1 Test Selector, 3 Alarm Delay Relay Sets and 1 Howler Relay Set.

A connection strip for terminating the test selector banks is mounted at the rear of shelf A. A tone and pulse distribution jack panel is mounted between shelves C and D.

To facilitate the subsequent installation of the service observation equipment in exchanges where it is not installed initially, the equipment has been assembled on the strip-mounted principle, i.e. relays, condensers, etc., are mounted on standard flange-type mounting plates. These plates, together with a unit amplifying and testing equipment, are assembled on a framework, thus making a complete and self-contained unit which is bolted direct to the uprights. A connection strip on which the internal and external wiring is terminated is also mounted on the framework.

Unit Auto No. 14*E*

This unit accommodates the auxiliary route discriminating equipment for use on junctions to director areas. There are 8 shelves on which provision is made to mount the following apparatus :

- Shelves H to C. Route Discriminating (Junction) Relay Sets (5 per shelf).
- Shelf B. 5 Route Discriminating (common) Relay Sets.
- Shelf A. 5 Route Discriminating (common) Selectors.

The selectors are of the 8-level, 2-motion type, and function in a similar way to the " BC " selectors as used in directors (see circuit notes).

The method of mounting the code or translation field is of particular interest and is described in some detail. The assembly is divided into two sections : (*a*) an individual translation field mounting on which are mounted the banks of each " BC " selector and the associated connection strips for its translation field, and (*b*) a common support-assembly framework on which the individual frameworks are mounted. The support-assembly has a capacity for five translation field mountings and projects to the rear of the unit.

Each translation field mounting accommodates four 200-point heavy duty selector banks and 8 connection strips. Each connection strip has 10 horizontal rows of 10 tags (bank outlets) and 5 horizontal rows of 4 tags (meter fee relay leads), the selector bank contacts being permanently wired to the connection strips. The complete assembly is arranged to jack-in on the support assembly and a locking device secures the mounting. Covers to protect the tags of the connection strips are provided.

A jumper field to provide facilities for connecting any route discriminating junction relay set to any particular common equipment is mounted at the top of the unit.

The method of connecting the meter fee relay to its associated selector bank contact is shown in Fig. **7**.

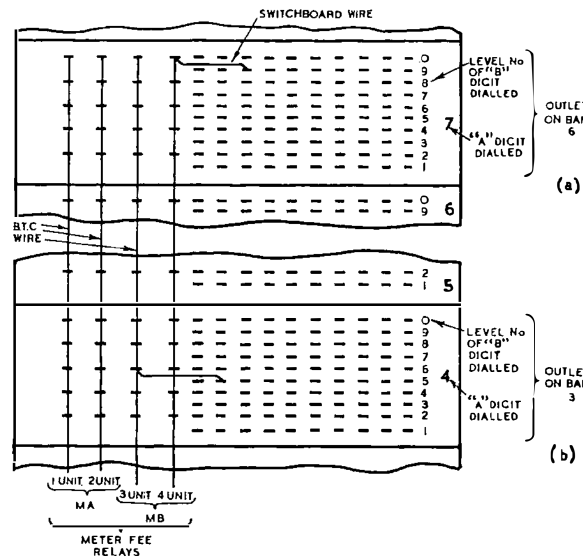


FIG. **7**.—TYPICAL STRAPPING OF METER FEE RELAYS.
(*a*) 4-UNIT FEE ROUTE SYD (793)
(*b*) 3-UNIT FEE ROUTE GLA (452)

Meter Rack

This rack is similar to the meter racks used in main automatic exchanges and accommodates 800 subscribers' meters (Meters No. 100A), 80 traffic meters (Meters No. 100C) and a meter routine test circuit. Standard flanged-type mounting plates are used for mounting this equipment.

A meter reading circuit is also provided and is mounted on the right-hand upright.

Meter Pulse Machine Rack (*Fig.* **8**).

This rack accommodates the meter pulse machines, pulse distribution jacks and the fuses providing the meter pulse distribution, i.e. S, Z, and 1-, 2-, 3- and 4-unit meter pulses.

The meter pulse machines and their associated equipment are assembled as jacked-in items and are mounted on two channel-type shelves at the bottom of the rack. The reserve machine is mounted on the lower shelf and the regular machine on the upper shelf.

The pulse distribution panel consists of a group of 8 switchboard jacks (Jacks No. 510 BO), and each meter pulse supply is fed through a main distribution and a suite distribution jack. One jack per pulse is provided for each suite of 6 units and one is provided for the 4-unit pulse supply to unit D.

The total number of fuses on a fully equipped rack is as follows :

6 3·0 amp.—S, Z, and 1-,2,-3- and 4-unit pulses (Main Supply).
42 1·5 amp.—S, Z, and 1,-2,-3- and 4-unit pulses (Suite Distribution Supply).
249 0·5 amp.—S, Z, and 1, 2,-3- and 4-unit pulses (Individual Supply).

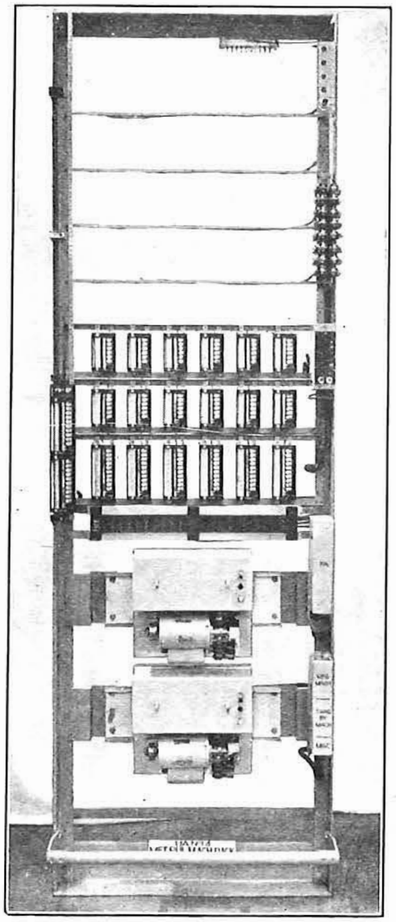


FIG. 8.—METER PULSE MACHINE RACK.

The 3·0 amp. fuses are accommodated on fuse panels mounted on the left-hand upright in the standard manner. Special arrangements were developed for mounting the 1·5 and 0·5 amp. fuses as these are not directly connected to battery. For this purpose, two frameworks, one with a capacity of six 10-way standard fuse mountings, and the other with a capacity of six 6-way standard fuse mountings which accommodate the 1·5 amp. (suite distribution supply) and 0·5 amp. (individual supply) fuses respectively, were designed.

The framework, on which the 10-way fuse mountings are accommodated, is arranged on the basis of one per rack and is mounted immediately above the regular pulse machine. The other frameworks, each of which accommodates sufficient fuses for each pulse supply to 6 units, are provided as required and are mounted between the rack uprights on existing drillings, commencing immediately above the suite distribution supply framework. Two of these frameworks are usually fitted initially.

Cabling and Wiring.

In earlier types of unit automatic exchanges it was found essential, in order to retain a high insulation resistance value, that the wiring should be carried out with enamelled wire. As, however, U.A.X. No. 14 buildings are heated, it has been found possible to dispense with the enamelled wire and the types of wire and cable used are identical with those used in 2,000-type main exchanges.

Typical cabling arrangements (main circuits only) are shown in Fig. 9.

Power Plant.

The provision of power plant of the parallel battery float type has been standardised for all U.A.X.'s No. 14 irrespective of the load requirements.

The power switchboard accommodates the apparatus for automatically controlling the charging equipment, which will be either rectifiers for A.C. supplies or motor generators for D.C. supplies, and also apparatus which functions to maintain the voltage of the battery within the prescribed limits.

The positive battery, which is used in connection with route discrimination supply, is obtained from 37 leclanche cells, type D.S.5.

The ringer panel accommodates the ringing machines, ringing change-over equipment, ringing distribution circuit breakers, tone chokes and transformers, and miscellaneous equipment.

Where the public power supply is A.C., a mains-driven ringer (Motor Generator No. 15) and a battery-driven ringer (Dynamotor No. 23) are used ; where, however, the public supply is D.C., both machines are of the battery-driven type. Each type of machine is fitted with an inductor tone generator instead of the high-speed interrupter drum formerly used for tone generation.

Heating.

Heating is provided by electric tubular heaters with a consumption of 60 watts per foot run, and is controlled by a mercury relay switch and a hygrostat which is adjusted to operate at a humidity of 70 per cent. or over.

The tubular heaters are mounted immediately above the guard rail on the wiring side of the units and racks ; a bracket for fixing these heaters to the rack, utilising the rear guard rail fixing bolts, has been designed.

Lighting.

Standard rack lighting as used in main exchanges is provided.

Building and Site.

There are three types of P.O. buildings available for the installation of U.A.X. No. 14 equipment, i.e. Types D, E and F, each of which has the cavity wall construction. The internal dimensions are as follows :

Type	*Length*	*Width*	*Height*
D and E	63 ft. 0 in.	24 ft. 6 in.	10 ft. 0 in.
F	55 ft. 0 in.	24 ft. 6 in.	10 ft. 0 in.

Each type of building provides accommodation for staff welfare and the dimensions shown above for the D and E type buildings include a staff room, normal stock room and W.C. In the type F building the staff accommodation is not catered for in the dimensions shown above, but consists of a building of 17 ft. by 11 ft. 6 in. by 8 ft. internal dimensions which is attached to the front of the main building.

The D type building is not extensible, but the E and F types are extensible vertically and laterally respectively. Fig. 4 shows the layout of the units and racks in the D and E type buildings.

The buildings are of brick construction and the internal walls are lined with "Insul wood" to prevent rapid heat dissipation.

Typical sizes of sites are as follows:

D and E Type. Frontage 50 ft. with a depth of 85 ft. behind the building line.

F type. Frontage 70 ft. with a depth of 120 ft. behind the building line.

Circuit Notes

It is not proposed to describe in detail the operation of the various portions of the apparatus, but to give a brief description of the functions of the equipment with outlines of circuit controls which are special to U.A.X. No. 14 design.

Subscribers' Calling Equipment.

The line and cut-off relays, associated with the subscribers' calling equipment, serve to bring into operation the control set, allotter and linefinder. The

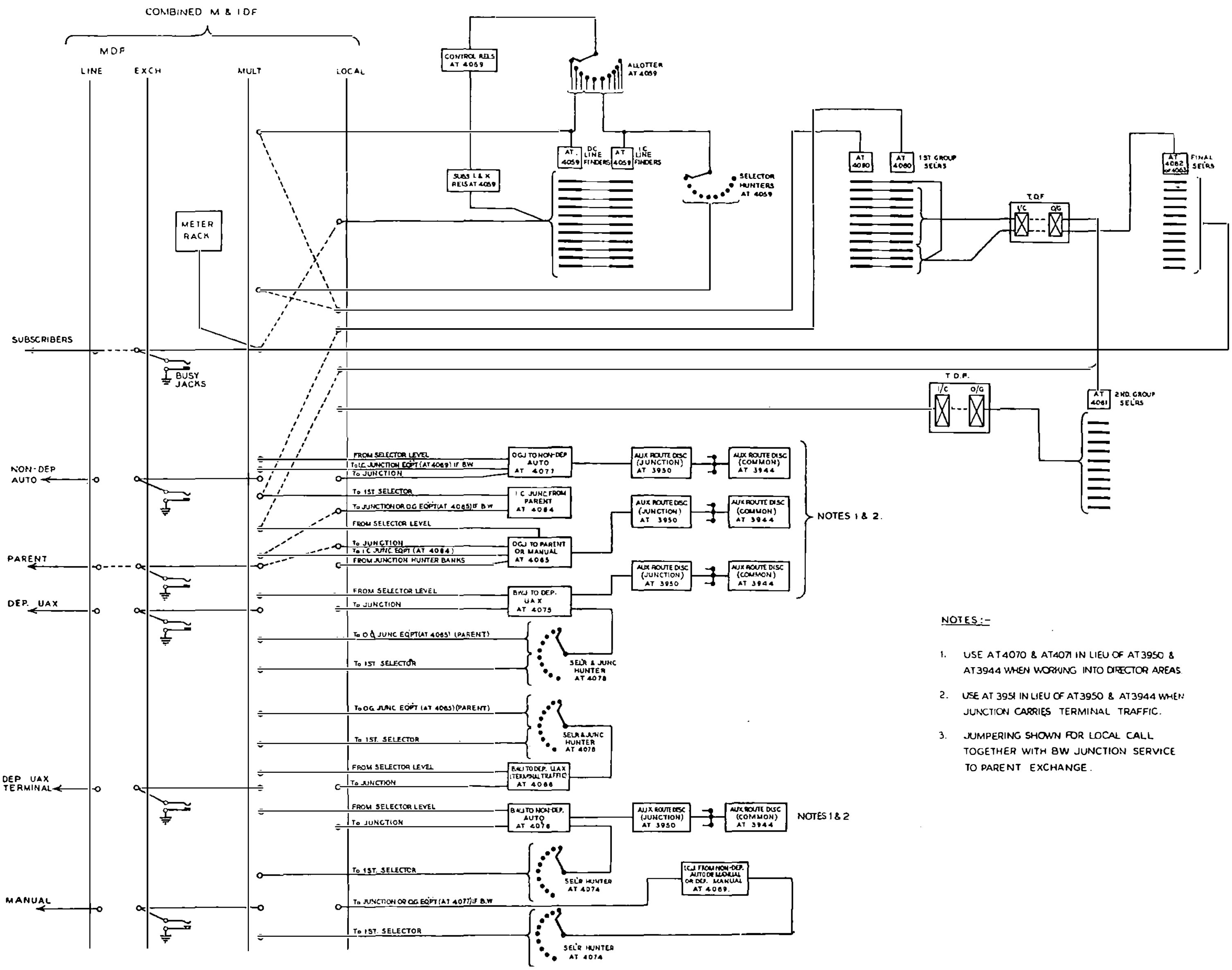


Fig. 9.—Typical Cabling Arrangements.

vertical and rotary bank positions on the linefinder multiple are marked by contacts of the line relay.

The Control Relay Set functions to cause the allotter to connect a " free " linefinder and to control the vertical-rotary action until the calling subscriber's line is found. One control relay set on each unit normally serves the 100 subscribers associated with a particular unit. Fig. **10** depicts the arrangements. S relay is operated by the earth (L contact) on the start lead. HX relay tests the outlets and operating to a free linefinder cuts the allotter drive circuit. The scheme embodies an automatic change-over to a partner control set in the event of the normal control set being rendered out of order. This is arranged by

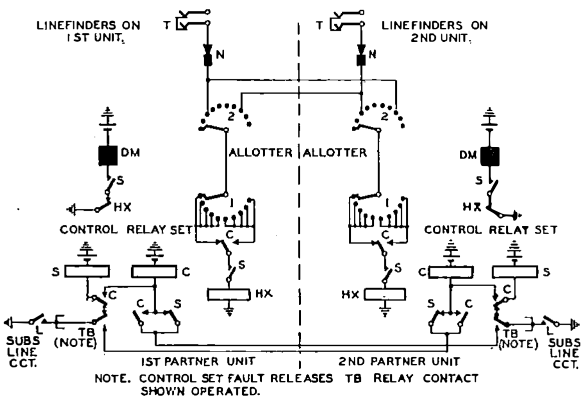


Fig. **10**.—Partner Controls.

pairing the units, units 1 and 2 (3 and 4), etc., acting as partners. TB relay, releasing under fault conditions, transfers the start lead to the partner unit. C and S relays operate and HX relay tests in the portion of the allotter bank for a linefinder on the unit serving the calling subscriber. The faulty control set is locked out of service and an alarm given. In the event of the second control set being rendered out of order, both controls are restored to service. In the event of the last-fitted unit being an " odd " unit (e.g. 3, 5 or 7), two control sets are fitted, each taking a load of 50 subscribers' lines and acting as partners to each other.

Allotter. The allotter is released when the linefinder finds the calling subscriber's line and it has pre-selected a free directly connected linefinder. Should, however, a directly connected linefinder not be available, the allotter rests on bank contact 1 in order to make a complete search on the following call. Three directly and seven indirectly connected linefinders are connected to the allotter banks. In the event of all the linefinders being engaged the allotter rotates to the last bank position, group occupancy time metering continuing until a linefinder becomes available. Access is also given to the linefinders on the partner unit to cater for the failure of the control set, as shown in Fig. **10**.

Linefinders.—These selectors are of the 2-motion type and serve the 100 subscribers' lines connected to the multiple. Coin box subscribers may be allocated to any position on the bank multiple, an additional I.D.F. connection (CB) only being necessary.

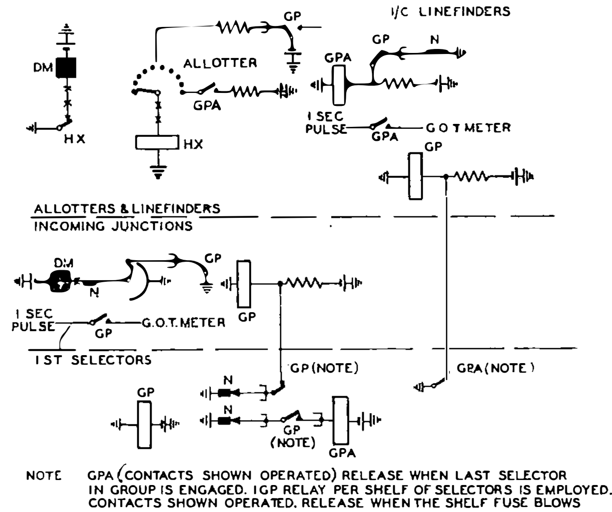


Fig. **11**.—Group Control Scheme.

Group Control of 1st Selectors.

Fig. **11** gives an outline of the control scheme. All 1st selectors, except those serving parent junctions and directly connected linefinders, are employed in a common pool system. The selectors may be connected in one or more groups.

The 1st selector GP relays, one per shelf of selectors, are held operated to their associated shelf fuses, releasing only when the fuse blows. GP relay contacts, in series with the earthed N springs of the free selectors, cause the operation of GPA relay and the extension of the earth to the group control (GP) relays serving the junctions.

The GPA contacts extend an earth to the group control relays on the A units.

In the event of a 1st selector shelf fuse blowing, the associated GP relay is released and its contacts disconnect the selectors on that shelf from the group control scheme.

When the last selector in a group is engaged, the group control relays for linefinders and junctions operate, and the selector-hunters and the allotters are prevented from further rotation.

1st Selectors, 100 Outlet.

As described under the trunking section of this article, digit absorption occurs when " 2 " or " 3 " is dialled as the initial digit and also on the 10th impulse of an " 0 " call. Fig. **12** shows the impulsing circuit arrangement. If the initial digit is " 2 " or " 3 " the selector has to restore to normal during the inter-train period, and in order to reduce the restoration time to a minimum, the release time of relay C is kept as low as possible since rotary restoration, following the release of relay C, adds considerably to the overall release time of the selector.

The next important point is the preparation of the vertical magnet circuit for the 2nd digit. Arrangements are made for the re-operation of relay C (when the vertical-marking bank wipers V.M. restore to normal) during the rotary restoration period. N springs release W relay and the selector is then available for further impulses. During this restora-

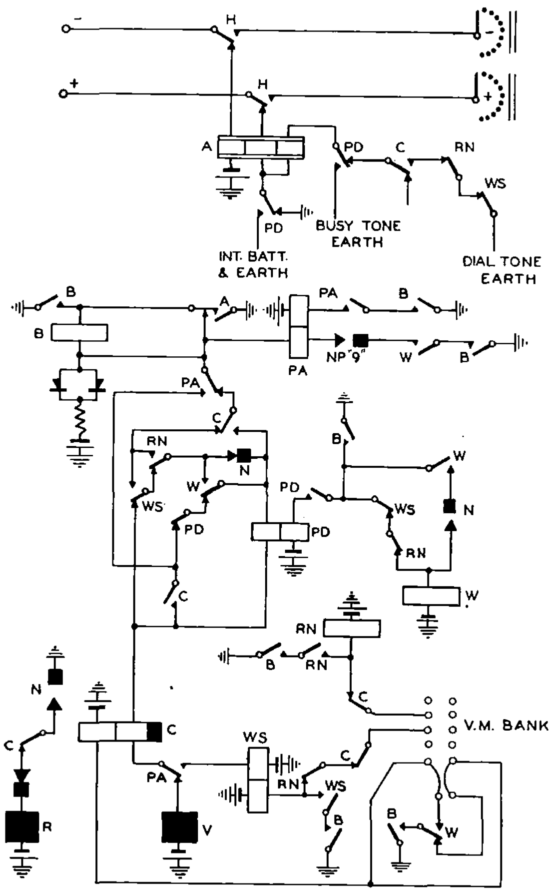


FIG. 12.—1ST SELECTOR IMPULSING CIRCUIT.

tion period, the short-circuit is removed from PD relay to allow the relay to operate should further impulsing occur before the selector has restored. Busy tone would then be returned to the caller and further vertical action prevented.

The absorption of the 10th impulse (" 0 " call) is provided by the operation of PA following the re-operation of A relay after the 9th impulse—the 10th impulse is routed to WS relay. The operation of WS relay provides a discriminating signal to the junction equipment to provide manual board call signals; in addition, should the call be originated from a coin box line, a discriminating signal is given to the junction. Arrangements are made to bar access to coin collecting box (C.C.B.) subscribers on any junction level as required, other than level 9 (for " 0 " call). The operation of RN relay provides a discriminating signal to the final selector to denote that the 3000 group is required.

2nd Selectors, 100 *Outlet.*

The 2nd selectors employ the usual principles of group selectors ; access is prevented (C.C.B. Subscribers' call) to barred levels.

Final Selectors.

Two types of final selectors have been designed, the 2-10 P.B.X. type catering for single line and groups of 2-10 P.B.X. subscribers. A second type is available where a P.B.X. of 2-20 lines is required. The facilities for 2-20 P.B.X. groups are limited to one such P.B.X. in a 100-line multiple. Access is given to 200 subscribers' lines by the bank multiple—100 lines in each of the thousands " 2 " and " 3." A wiper switching scheme is arranged to change over from the wipers giving access to the 2000 group, to the wipers giving access to the 3000 group, on receipt of a discriminating signal from the 1st group selector. Trunk-offering facilities are also given to calls from the parent exchange.

Outgoing Junction Services.

Unidirectional junction equipments have been developed for parent and non-parent routes, but these can be combined for bothway working. Bothway equipments are designed for routes to dependent U.A.X.'s, i.e. exchanges which communicate with their parent exchange via the U.A.X. No. 14. A bothway equipment is also available for routes to non-dependent auto exchanges. For the purpose of simplicity the outgoing and incoming features will be described separately.

Parent Exchange Route.—This equipment functions similarly to the U.A.X. No. 13 parent exchange equipment. Discrimination is given to the manual board between calls originating from ordinary and C.C.B. subscribers when " 0 " has been dialled. When " 9 " has been dialled, auto-auto working within the parent auto-network is permitted. Standard control facilities are afforded, i.e. manual hold, re-ring, busy tone and flash, etc.

Dependent U.A.X. Junctions.—Two types of equipment have been designed, one type for use when access to subscribers only on a U.A.X. (Nos. 12 or 13) is allowed, the necessary restricting equipment being part of the junction equipment. The other type caters for through traffic via a U.A.X. No. 13 and auxiliary equipment for route discriminating is necessary. Trunk offering over the junction to the dependent U.A.X. is provided on calls from the parent exchange operator.

Non-dependent Auto Routes. — The equipment designed for these routes may be used for all auto exchanges, including U.A.X.'s which are not dependent on the U.A.X. No. 14 for direct " 0 " level traffic. Auxiliary equipment is necessary for route restriction or route discrimination purposes.

Manual Exchange Routes.—Identical equipment with that used on the parent route is employed on junctions between the U.A.X. and all types of manual exchanges. Coin-box lines are barred access to the selector levels serving routes to adjacent manual exchanges.

Auxiliary Equipments used in conjunction with outgoing junction equipments are divided into three classes :

(1) Route discrimination on U.A.X. and non-director routes.

(2) Route restriction on U.A.X. and non-director routes.

(3) Route discrimination on director routes.

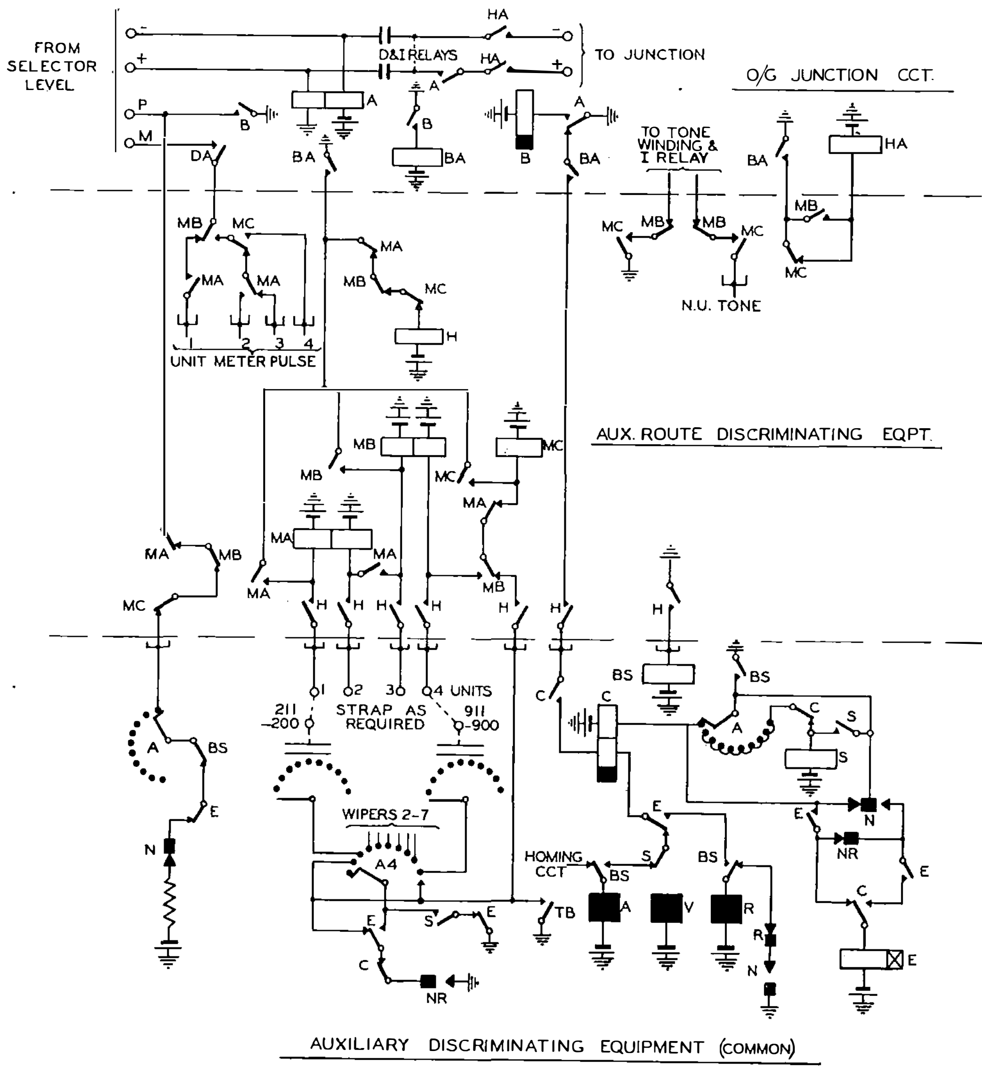


FIG. **13**.—800 CODE MULTI-METERING ON JUNCTIONS TO DIRECTOR AREA.

The first two classes are identical with those employed in U.A.X.'s No. 13 and cater for multi-fee metering, manual hold (non-metering calls) and route-barring on calls in the U.A.X. or non-director auto network.

In order to cater for calls into a director area, equipment capable of discriminating on 800 codes is necessary. Fig. **13** gives an outline of the circuits. A uniselector is employed to receive the 1st code (" A " digit) train and a 2-motion selector accepts the " B " and " C " digit trains simultaneously as the digits are repeated over the junction to the director exchange. Assuming a CENtral number is being dialled, the uniselector would be stepped to contact " **2** " and the **2**-motion selector to level " **3** " and rotary bank outlet " **6**." On completion of these " code " digits, C relay releasing, extends an earth via wiper and arc A**4**, wiper and bank 1 to the requisite meter-fee relay and the common equipment is released. Should a spare code be dialled (C and E relays releasing) earth is extended on the spare lead, and N.U. tone is given to the caller; the junction is disconnected and the common equipment is released. Should the caller fail to complete the code trains, forced release of the common equipment is arranged by a time pulse—TB applying spare code conditions.

Incoming Equipments.

All incoming junction equipments cater for premature dialling. In the event of dialling occurring before a group selector has been connected, busy tone and flash are returned to the caller. On tandem calls, the incoming junction equipment gives a discriminating signal to the outgoing junction equipment associated with the route dialled in order that operators or subscribers on other automatic exchanges may obtain access to exchanges which are barred to U.A.X. No. **14** subscribers. In the incoming parent exchange equipment, the discriminating signal

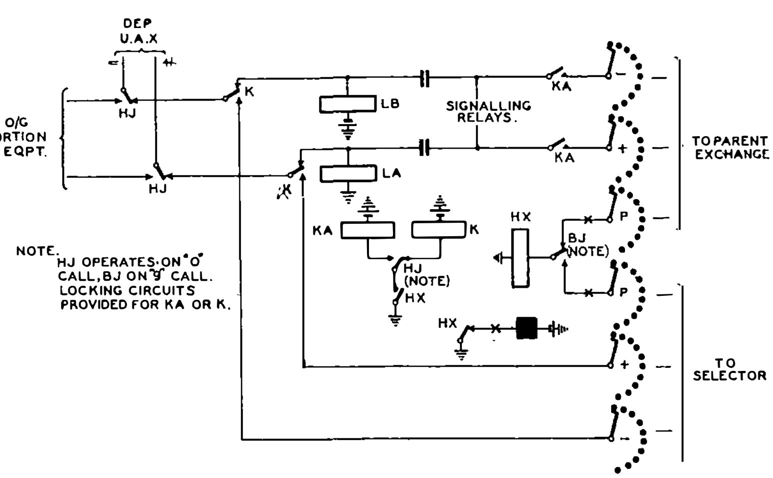


FIG. **14**.—INCOMING JUNCTION CIRCUIT FROM DEPENDENT U.A.X.

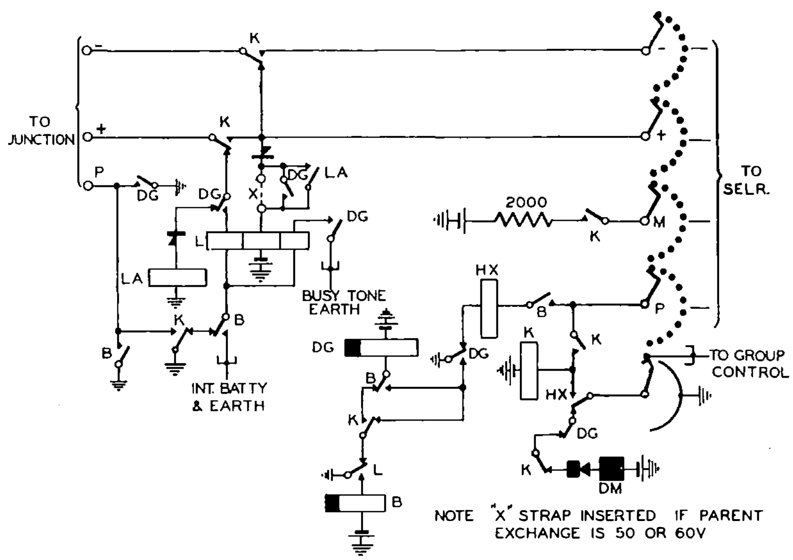


Fig. 15.—Incoming Junction Circuit from Non-Parent Exchange.

selector. A brief outline of the controls is shown in Fig. **15**.

Miscellaneous Services.

A novel feature is the provision of a P.G. alarm scheme (Fig. **16**) whereby the P.G. lamps associated with the 1st selectors are fed via a contact ammeter, an urgent alarm being given when a pre-determined number of P.G.'s is reached. During maintenance attendance at the U.A.X., the P.G. alarm is connected to the delayed alarm equipment. Called subscriber held (C.S.H.) and other alarms follow non-director auto exchange practice during the period of exchange attendance. Urgent alarms only are extended when the exchange is unattended—arrangements being made to disconnect the alarm lamps at the U.A.X.

Conclusion.

Several U.A.X.'s No. 14 are now being installed by Messrs. Siemens Bros., Ltd.,

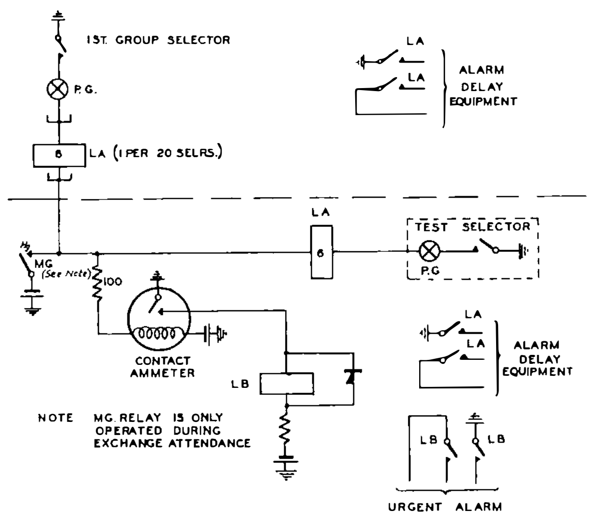


Fig. 16.—P.G. Ammeter Control.

who co-operated with the P.O. Engineering Department in the development of this type of U.A.X.

also prepares outgoing equipments to the dependent U.A.X.'s for the reception of trunk offering signals.

Parent Exchange.—This is a simple equipment for receiving the line signals and giving connection to a group selector. The controls are similar to those shown in Fig. **15** excepting that hunting for a selector is not employed; individual selectors terminate parent exchange junctions.

Dependent U.A.X.—The equipment is designed to accept similar signals to those for a parent exchange, i.e. negative battery on the + ve line for an ordinary subscriber "0" call (LA relay operating), earth on the — ve line for a C.C.B. "0" call (operating LB relay), or a loop when access to the auto equipment is desired. A selector and junction hunter is associated and, dependent upon the incoming signals, access is given either to a junction direct to the parent (repeating the signal) or to a 1st selector at the U.A.X. No. 14. Fig. **14** gives an outline of the circuit arrangements providing the necessary switching. Arrangements are made for the homing of the selector and junction hunter on a call to the manual board, in order to test and connect the junctions in numerical order. Overflow metering is provided should the whole of the junction outlets be engaged.

Incoming calls from other types of exchanges employ an equipment for receiving the line signals and causing the selector hunter to give access to a group

Thanks are due to Messrs. Siemens Bros., Ltd. for the photographs, and the authors also desire to thank various members of the Engineer-in-Chief's Office staff who supplied information useful in the compilation of this article.

The London—Birmingham Coaxial Cable System

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Part III.—Layout of Equipment and Test Results

Details of the layout of the equipment are given, followed by a brief outline of the experimental results obtained to date. Further test results will be given in the July issue.

THE terminal stations are located in Faraday Building, London, and Telephone House, Birmingham. Where no building existed that could suitably be converted into a repeater station, sufficient ground was purchased to enable small brick built buildings of the U.A.X. type, 14 ft. by 10 ft. by 8 ft. 6 ins. high, to be erected. Twelve such buildings have been provided along the route. Accommodation for the other five stations has been provided in telephone exchanges or normal repeater stations.

The rack layout plan adopted in London and Birmingham is shown in Figs. **38** and **39** respectively.

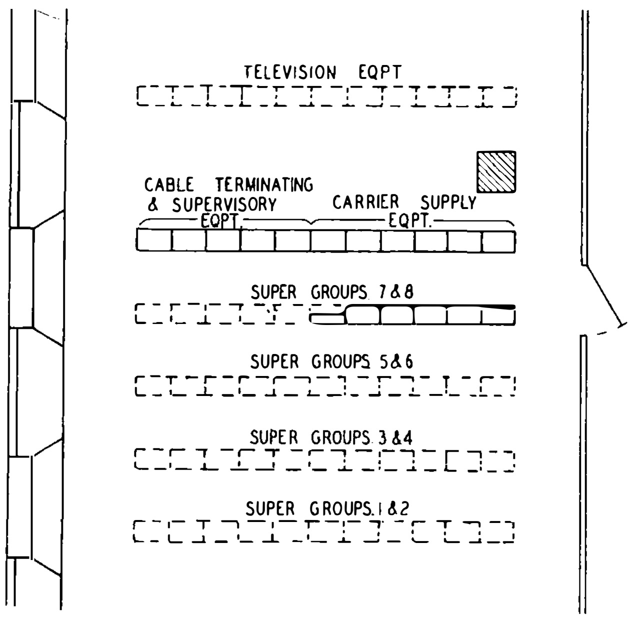


FIG. **38**.—RACK LAYOUT, LONDON TERMINAL STATION.

In view of the extension of the cable through to Manchester and the definite allocation of certain super-groups to the London-Manchester traffic it will probably be unnecessary to bring the through circuits down to audio frequency at Birmingham and the corresponding super-groups will have to be deleted from the floor plan; the absence of a break-in facility at Birmingham on these particular super-groups will obviously very materially reduce the cost of the London-Manchester circuits.

Modulating Equipment.

In associating various units the policy has been to make groups and super-groups self contained as far as possible, and to associate corresponding transmitting and receiving equipment closely.

Each of the five groups occupies both sides of a 10 ft. 6 in. bay, one side being devoted to transmitting equipment and the other to receiving equipment. The super-group modulators and various subsidiary units involved in the combination of the five groups to form a super-group are mounted on one side of a sixth bay. The other side of the latter bay is occupied by similar equipment for a second super-group while the seventh to eleventh bays are used for the groups constituting this second super-group. A plan view showing the way in which the bays are associated is given in Fig. **38** and elevations of the group and super-group bays are given in Fig. **40**. This arrangement of apparatus possesses several advantages from the point of view of circuit requirements in addition to the following facilities which make the equipment flexible:—

(*a*) The groups are entirely self contained and can therefore be used for certain other purposes without alteration, e.g. extension of the range of existing 12-channel equipment; multiplexing an ultra short wave transmitter.

(*b*) The layout of all super-groups is exactly the same.

(*c*) The bays carrying the super-group modulators etc. are independent of the group bays and may therefore be used with certain modifications for translating super-groups from one frequency band to another for the purpose of diverting blocks of circuits.

It will be seen from Fig. **40** that blank panels have been fitted where the additional modulator and demodulator units will be required when the channel spacing is reduced from 5 to 4 kc.p.s. corresponding to an increase in channels per group from 8 to 10.

In the course of maintenance it will occasionally be necessary to isolate various major units for test purposes, or it may be desired to insert special equipment for experimental work. Facilities have, therefore, been provided for breaking into the circuit at various points. The terminals of the various units of audio frequency equipment are connected to sockets mounted on one of several test tablets, the normal circuits being completed by U links. In view of the possibility of cross-talk this practice has not been extended to radio frequency equipment but sockets and U links are mounted on the various units underneath the dust covers.

The equipment is designed to work directly from the normal repeater power supplies of 24 and 130 volts.

Carrier Generating Equipment.

The working and standby sets are mounted on opposite sides of six standard 10-ft. 6-in. bays, the

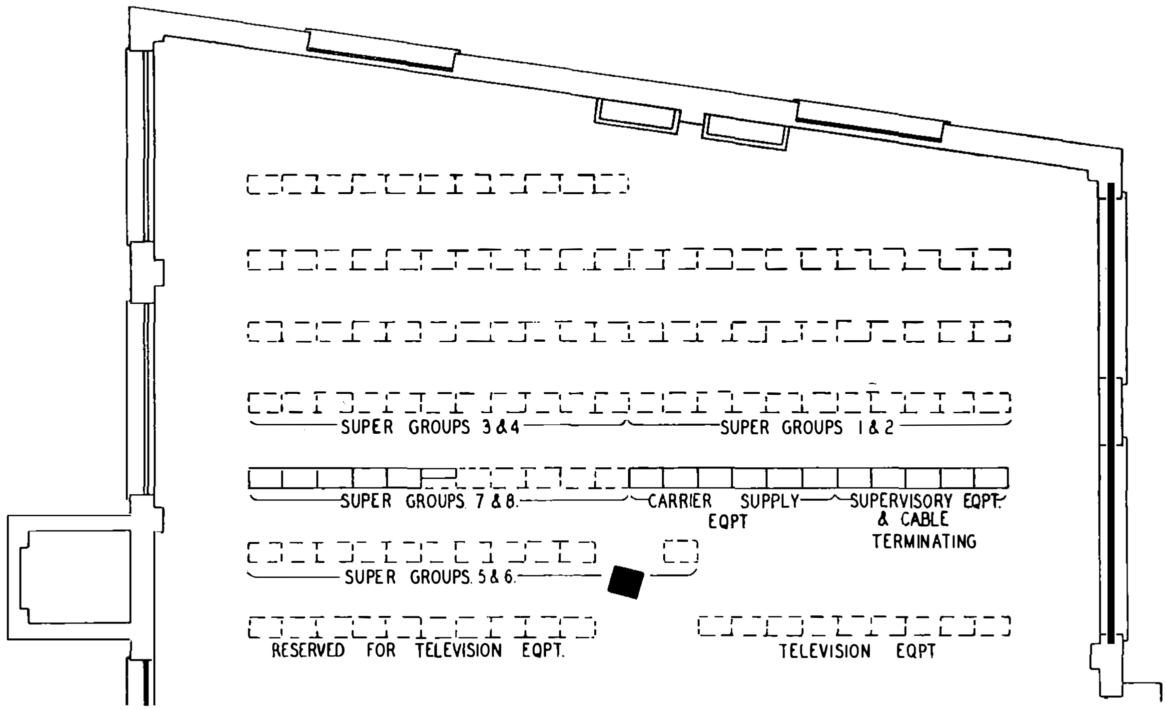


FIG. 39.—RACK LAYOUT, BIRMINGHAM TERMINAL STATION.

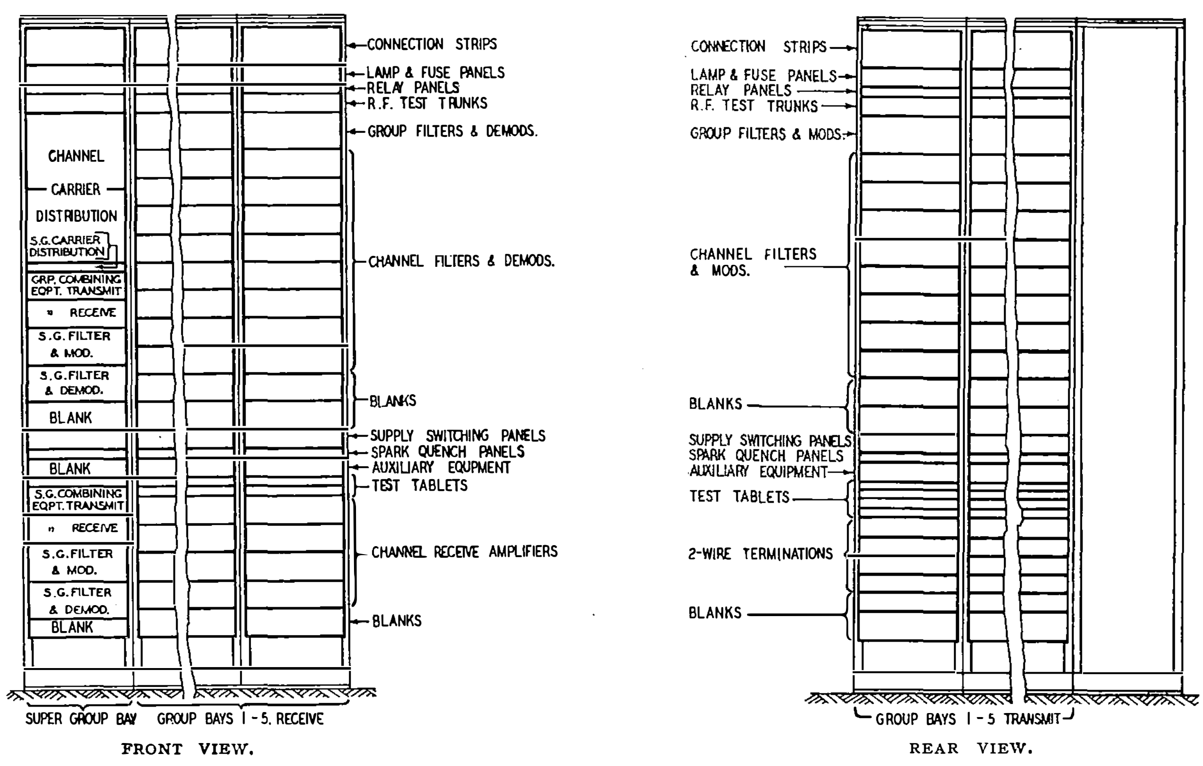


FIG. 40.—TERMINAL EQUIPMENT.

one set being an approximate mirror image of the other. Standard unit construction is employed, each unit being protected by a 6-in. dust cover. The arrangement is given in detail in Fig. **41**, the blank

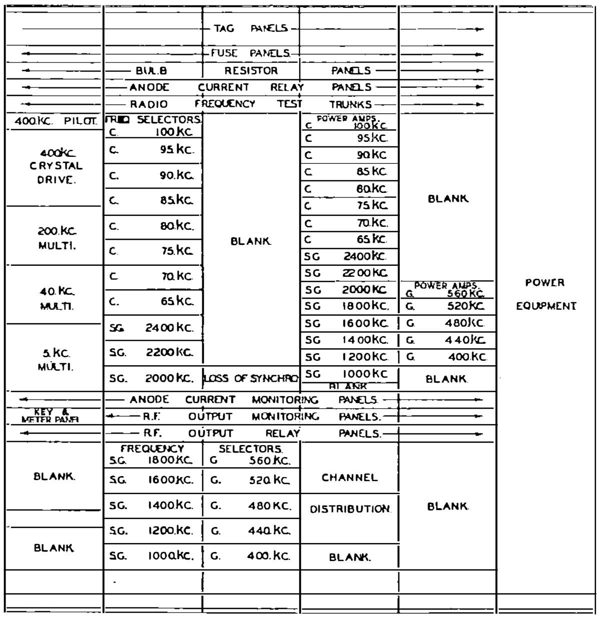


FIG. **41**.—CARRIER GENERATION EQUIPMENT.

panels occupying space reserved for additional equipment when the channel spacing is modified.

Three standard types of valve are used and each valve anode circuit is fed through a jack shunted by a fixed resistor and through a relay coil. The valve anode current is measured in terms of the volts drop across the resistor and the relay contacts are connected to a lamp and bell to give warning of a valve failure. The input voltage to each amplifier stage may be measured across a screened socket connected across the grid input circuit and the outputs of the selectors and power amplifiers are monitored in the rectifier circuit associated with each of these units.

In addition to the normal repeater power station supplies, 4 and 240 volt A.C. supplies are obtained from a power bay similar in design to the repeater station power equipment.

Repeater Station Equipment.

Each repeater station is fitted with four 7-ft. 6-in. double-sided bays arranged for single-sided panel mounting. All panels are provided with 6-in. deep dust covers and a standard grey paint finish has been adopted throughout. Particular attention has been devoted to earthing arrangements since the presence of very small mutual impedances in the earth leads can cause serious interference. All panels are directly earthed to a $\frac{1}{4}$-in. diameter copper rod which is fixed inside the channel verticals.

The "up" and "down" coaxial cables are, in general, brought through a floor chase or duct to one end bay of the rack where the coaxial pairs and the interstice pairs are separated out at a sleeve. The coaxial pairs are brought up to two termination filter boxes mounted near the top of the bay and the telephone pairs looped in to trunk test tablets mounted near the bottom of the bay. The second bay carries the power equipment on the back and miscellaneous test, speaker and supervisory equipment on the front. The third bay carries all the H.F. equipment required for repeatering the two coaxial pairs carrying the multi-channel telephone circuits. The fourth is to be used for the apparatus required for television transmission.

The front and rear views of the bays in a typical station are given in Figs. **42** and **43**.

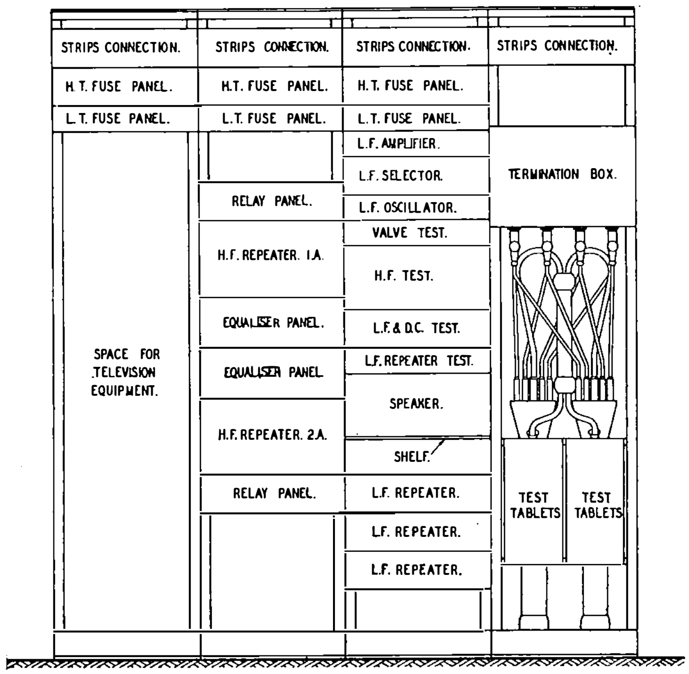


FIG. **42**.—LAYOUT OF RACKS IN MAIN REPEATER STATION. FRONT VIEW.

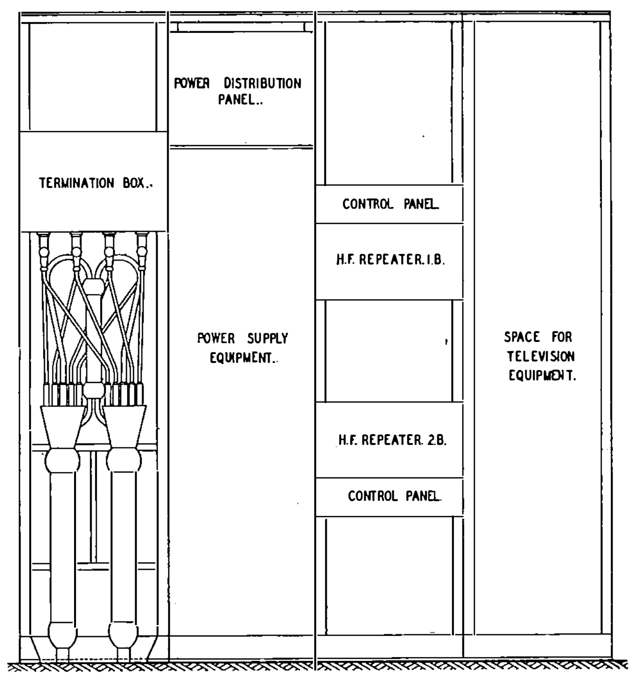


FIG. **43**.—LAYOUT OF RACKS IN MAIN REPEATER STATION. REAR VIEW.

MEASURED CHARACTERISTICS OF THE CABLE

The major problems encountered in the development of the coaxial cable system for the provision of circuits between London and Birmingham have been discussed and many details of the equipment given. Obviously there are many points of interest to which no reference has been made ; for instance the provision of through circuits to more distant points than Birmingham, for the cable is already well beyond Birmingham, without reducing the through signals to audio frequency at Birmingham. As the experiment is not completed, detailed results are not yet available. A brief outline of the results, obtained to date follows:

Propagation Constant and Velocity.

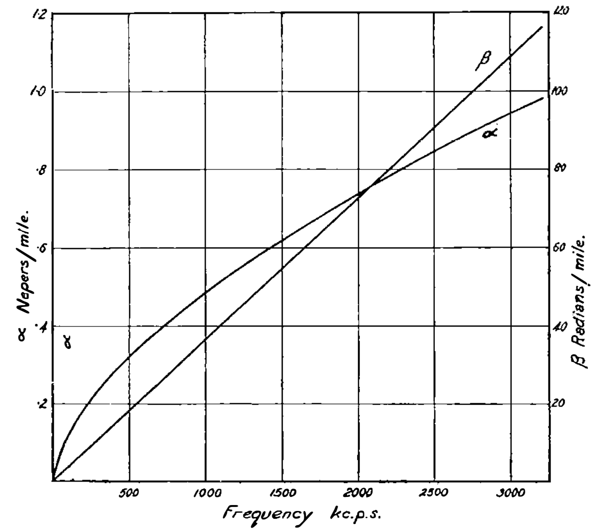


FIG. 44.—ATTENUATION (α) AND WAVELENGTH (β) CONSTANTS PER MILE.

Fig. **44** shows the attenuation and phase constants per mile. The phase constant is nearly proportional to frequency, the phase velocity increasing slightly with increasing frequency and approximating to about 93 per cent. of the velocity of electro-magnetic radiation in free space.

Characteristic Impedance.

Between 500 and 2,100 kc.p.s. the value is approximately 74.0 ohms, increasing slightly as the frequency decreases. At 2,100 kc.p.s. the small negative reactance component is 0.4 ohm increasing with decrease of frequency until at 500 kc.p.s. it amounts to 1.0 ohm.

Capacitance and Inductance.

The capacitance is constant apart from an apparent gradual decrease from 0.0789 microfarads per mile at 100 kc.p.s. to 0.0783 at 400 kc.p.s.

At 2,100 kc.p.s. the inductance is 0.425 millihenries per mile, increasing with a decrease in frequency and following closely the value derived from theoretical considerations.

Resistance and Leakance.

The resistance of the cable is 86 ohms/mile at 2,100 kc.p.s. and varies directly as the square root of the frequency over the band covered by the transmissions. This measured resistance is some 8 per cent. higher than the theoretical value—assuming the interleaved copper tapes to be replaced by a solid copper tube and neglecting the lead sheath—and it would appear that this difference is due to the manner in which the copper sheath is made up.

The measurements on leakance indicate a dielectric power factor, practically independent of frequency, equal to 0.0044.

TABLE 2.

ATTENUATION MEASUREMENTS ON THE VARIOUS REPEATER SECTIONS

Repeater Section	*Average attenuation of the four coaxial pairs for each repeater section expressed in db. per mile.*						
	Frequency kc.p.s.						
	200	400	800	1,200	1,600	2,000	2,400
1. Faraday Bldg., London–Gladstone Exch.	$1{\cdot}70_9$	$2{\cdot}47_1$	$3{\cdot}65_6$	$4{\cdot}61_4$	$5{\cdot}40_7$	$6{\cdot}17_9$	$6{\cdot}88_2$
2. Gladstone–Elstree	$1{\cdot}72_1$	$2{\cdot}49_6$	$3{\cdot}69_6$	$4{\cdot}61_8$	$5{\cdot}44_3$	$6{\cdot}25_0$	$6{\cdot}91_2$
3. Elstree–St. Albans	$1{\cdot}70_7$	$2{\cdot}49_0$	$3{\cdot}68_1$	$4{\cdot}59_6$	$5{\cdot}38_5$	$6{\cdot}20_0$	$6{\cdot}85_5$
4. St. Albans–The Kennels	$1{\cdot}70_6$	$2{\cdot}47_1$	$3{\cdot}58_8$	$4{\cdot}57_6$	$5{\cdot}34_3$	$6{\cdot}13_5$	$6{\cdot}80_6$
5. The Kennels–Streatley	$1{\cdot}70_2$	$2{\cdot}45_5$	$3{\cdot}62_4$	$4{\cdot}55_9$	$5{\cdot}36_0$	$6{\cdot}13_9$	$6{\cdot}80_9$
6. Streatley–Haynes West End	$1{\cdot}72_1$	$2{\cdot}47_7$	$3{\cdot}62_9$	$4{\cdot}58_0$	$5{\cdot}38_4$	$6{\cdot}17_9$	$6{\cdot}83_9$
7. Haynes West End–Bedford	$1{\cdot}71_1$	$2{\cdot}45_5$	$3{\cdot}60_4$	$4{\cdot}56_3$	$5{\cdot}37_0$	$6{\cdot}15_2$	$6{\cdot}80_4$
8. Bedford–Turvey	$1{\cdot}69_4$	$2{\cdot}45_2$	$3{\cdot}62_6$	$4{\cdot}53_3$	$5{\cdot}33_1$	$6{\cdot}13_2$	$6{\cdot}79_3$
9. Turvey–Yardley Hastings	$1{\cdot}69_8$	$2{\cdot}44_1$	$3{\cdot}60_0$	$4{\cdot}55_4$	$5{\cdot}32_5$	$6{\cdot}10_2$	$6{\cdot}80_1$
10. Yardley Hastings–Northampton ..	$1{\cdot}68_5$	$2{\cdot}43_2$	$3{\cdot}70_5$	$4{\cdot}54_8$	$5{\cdot}33_2$	$6{\cdot}13_2$	$6{\cdot}82_9$
11. Northampton–Upper Heyford	$1{\cdot}69_8$	$2{\cdot}48_7$	$3{\cdot}67_3$	$4{\cdot}62_5$	$5{\cdot}42_3$	$6{\cdot}12_3$	$6{\cdot}88_6$
12. Upper Heyford–Daventry	$1{\cdot}75_0$	$2{\cdot}52_7$	$3{\cdot}66_4$	$4{\cdot}74_3$	$5{\cdot}50_2$	$6{\cdot}20_0$	$6{\cdot}95_0$
13. Daventry–Willoughby	$1{\cdot}75_0$	$2{\cdot}53_5$	$3{\cdot}67_3$	$4{\cdot}69_4$	$5{\cdot}51_3$	$6{\cdot}23_9$	$7{\cdot}00_3$
14. Willoughby–Stretton-on-Dunsmore ..	$1{\cdot}76_9$	$2{\cdot}54_8$	$3{\cdot}77_1$	$4{\cdot}77_1$	$5{\cdot}58_9$	$6{\cdot}30_3$	$7{\cdot}05_6$
15. Stretton-on-Dunsmore-Coventry ..	$1{\cdot}78_5$	$2{\cdot}54_1$	$3{\cdot}79_8$	$4{\cdot}78_3$	$5{\cdot}61_3$	$6{\cdot}37_5$	$7{\cdot}11_2$
16. Coventry–Meriden	$1{\cdot}76_1$	$2{\cdot}54_4$	$3{\cdot}75_3$	$4{\cdot}72_1$	$5{\cdot}58_0$	$6{\cdot}36_0$	$7{\cdot}08_8$
17. Meriden-Sheldon	$1{\cdot}77_5$	$2{\cdot}58_3$	$3{\cdot}77_4$	$4{\cdot}75_1$	$5{\cdot}59_5$	$6{\cdot}31_1$	$7{\cdot}09_8$
18. Sheldon-Birmingham	$1{\cdot}76_4$	$2{\cdot}57_6$	$3{\cdot}80_8$	$4{\cdot}82_0$	$5{\cdot}64_8$	$6{\cdot}36_2$	$7{\cdot}18_7$
Average attenuation db/mile for all sections	$1{\cdot}72_9$	$2{\cdot}49_9$	$3{\cdot}68_4$	$4{\cdot}64_7$	$5{\cdot}45_2$	$6{\cdot}21_9$	$6{\cdot}92_9$
Extreme variations from the average values in db.	$+0{\cdot}05_6$ $-0{\cdot}04_4$	$+0{\cdot}08_4$ $-0{\cdot}06_7$	$+0{\cdot}12_4$ $-0{\cdot}09_6$	$+0{\cdot}17_3$ $-0{\cdot}09_4$	$+0{\cdot}19_6$ $-0{\cdot}12_7$	$+0{\cdot}15_6$ $-0{\cdot}11_7$	$+0{\cdot}25_8$ $-0{\cdot}12_8$

Attenuation.

An attenuation-frequency characteristic for a typical repeater section has been given in Fig. **2**. Table 2 summarises in some detail the attenuation characteristics of the various repeater section lengths. The variation in attenuation among the four coaxial pairs in any one section was found to be within the limits of experimental error in making the measurements but the variation between various sections was definitely outside these limits. A general tendency should be noted for the attenuation per mile to be lower in the sections nearer London. Between Upper Heyford and Birmingham the attenuation per mile at 400 kc.p.s. was about 3.5 per cent. higher than between Upper Heyford and London, while at 2,000 kc.p.s. it was about 2.2 per cent. higher. This difference can only be accounted for to the extent of about 1 per cent. by temperature changes during the progress of the tests and the remaining difference must be due to non-uniformity in manufacture. D.C. resistance measurements on the central conductors indicate that the difference is not due to the central conductor being thicker in the sections nearer London.

Crosstalk.

The near-end crosstalk frequency characteristic of a repeater section fluctuates considerably. At frequencies above 400 kc.p.s. the near-end crosstalk was always greater than 140 db. The far-end crosstalk frequency characteristics were smooth curves showing increasing crosstalk ratios with increasing frequency. The average values at 400 kc.p.s. were about 128db between adjacent cores and 119 db. between opposite cores.

Voltage Test.

All the coaxial pairs of the several repeater sections successfully withstood an alternating (50 c.p.s.) test voltage of 2,000 V R.M.S. for 2 minutes.

Since the original type of cable was designed development work by the manufacturer has been continuous. The Birmingham-Manchester coaxial cable has "super-cotopa" in place of cotopa cords for positioning the inner conductor in the tube. The result of this modification is that, although the inner and outer conductor diameters remain unaltered, the attenuation has been decreased appreciably due to a reduction in dielectric loss. In fact, this cable has the same attenuation at 2.5 Mc.p.s. as the London-Birmingham coaxial cable at 2.1 Mc.p.s. Another modification has been the substitution of mild steel tapes for the lead sheath surrounding each coaxial pair, thereby reducing crosstalk in the cable by some 10 db.

A more noticeable modification has occurred in the Manchester-Newcastle coaxial cable, the make-up of a sample of this cable being illustrated in Fig. **45**. It will be seen that the inner conductor is now positioned in the centre of the tube by means of rubber discs, spaced at intervals of about 1.25 in. This modification has reduced the dielectric loss to such a low figure that it has been found possible to reduce the dimensions of the pair to approximately 80 per cent. of their original values, at the same time retaining the same loss at 2.5 Mc.p.s. as the Birmingham-Manchester type of cable or 2.1 Mc.p.s. for the London-Birmingham design; this reduction in size has necessarily been reflected in the cost of the cable.

Present Position.

Early in the development of the system it was decided that its possibilities could only be fully explored by transmitting a complete super group, i.e. 40 circuits, over the cable and arrangements were made for the construction of the required terminal and repeater station equipment; the super group to occupy the frequency band 1,100-1,200 kc.p.s. In

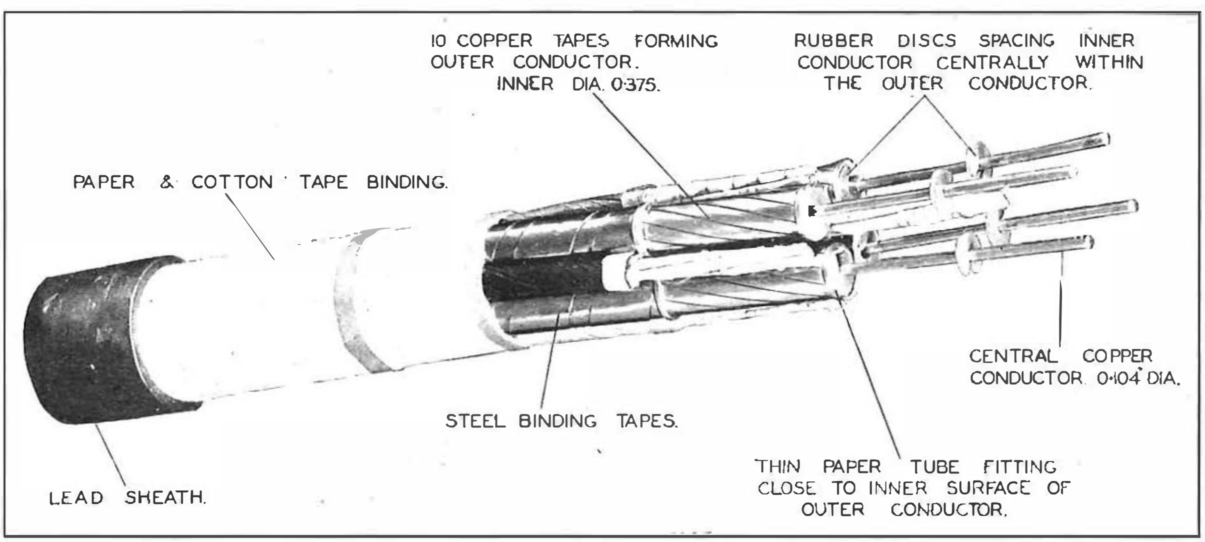


FIG. **45**.—MANCHESTER-NEWCASTLE COAXIAL CABLE.

view of the complexity of the system, it is essential that standby equipment, as outlined earlier in this paper, should always be available during commercial operation and arrangements have been made for the provision of this standby equipment so that the circuits may be handed over to and tested on traffic as early as possible. Certain preliminary overall tests of limited scope were made in mid-January of this year pending the completion of the equipment.

In these tests one coaxial pair, complete with repeaters and associated equalisers, was set up in the direction London to Birmingham. For convenience, arrangements were made to transmit the signals arriving at Birmingham from London back to London at audio frequency over order wires, formed from the interstice pairs available in the complete cable ; the interstice pairs are unloaded. The " looping back " of the circuit is not, of course, a normal arrangement and no attempt was made to preserve the balance of the pairs and so avoid mutual interference between the pairs and/or the coaxial pairs. Actually during the demonstration a slight amount of hum was present due to pick-up on these interstice pairs from the power supplies which are transmitted over the coaxial pairs.

The first test consisted in making a two-way conversation, both talkers being located in London, over a 4-wire circuit, the go and return channels each consisting of a coaxial channel up to Birmingham, thereby including 19 high frequency feedback repeaters, and an audio channel to bring the signals back to London, the audio frequency channel including 6 audio frequency (feedback) repeaters. Thus the talkers were separated by 250 miles of circuit. Sufficient time was not available to enable the circuit to be adjusted to have zero loss, the actual transmission equivalent being some 3 db. The demonstration was successful in every respect, the good quality and complete absence of echo being particularly noticeable.

The next test was for crosstalk between the two channels. For this test tone was applied to one channel at a level 6 db. above the level that is equivalent to the volume of the loudest speech that is ever likely to be transmitted, and this will only happen, according to present evidence, in one case out of a hundred.

The level of crosstalk under these conditions was only just discernible to an experienced observer. It is probable that the crosstalk that was audible arose on the audio frequency portions of the circuit, i.e. the interstice pairs, since these are not balanced for crosstalk.

The final test consisted in connecting in tandem the go and return channels used in the two way test, so as to provide a single channel 500 miles long, having a loss of some 6 db. This set-up included approximately 250 miles of coaxial cable and corresponding repeater equipment and is equivalent to transmitting signals from London to Leeds. During this test 38 high frequency repeaters and 12 audio frequency repeaters were operating in series. A slight degradation of quality was observed due no doubt to the extra audio frequency pairs and terminal equipment, which would not normally be used. For instance, signals from London to Leeds over the coaxial cable will not normally be reduced to audio frequency at any intermediate point on the system.

Since these early tests both coaxial pairs, complete with repeaters and associated equalisers, have been set up and all the carrier generating and frequency translating equipment for 40 circuits installed and adjusted. Details of the further test results obtained will be given in a subsequent article.

TELEGRAPH AND TELEPHONE PLANT IN THE UNITED KINGDOM
TELEPHONES AND WIRE MILEAGES. THE PROPERTY OF AND MAINTAINED BY THE POST OFFICE IN EACH ENGINEERING DISTRICT AS AT 31st DECEMBER, 1937.

Number of Telephones	Overhead Wire Mileages				Engineering District	Underground Wire Mileages			
	Telegraph	Trunk	Exchange*	Spare		Telegraph	Trunk	Exchange†	Spare
1,105,788	368	1,305	58,072	5,008	London	32,124	279,692	4,289,668	85,760
135,531	1,690	1,775	64,590	12,597	S. Eastern	6,337	118,808	421,356	54,790
159,907	2,215	12,803	127,231	9,841	S. Western	19,297	129,188	354,884	71,284
115,603	2,819	12,344	111,929	17,480	Eastern	8,327	132,180	252,722	64,058
132,834	3,399	13,060	84,062	25,703	N. Midland	9,098	203,786	300,105	103,490
149,410	1,864	8,100	97,155	17,292	S. Midland	10,078	172,968	443,663	62,462
78,066	1,173	6,715	72,162	11,683	S. Wales	5,662	75,322	175,859	42,274
196,160	1,610	9,618	107,233	23,352	N. Wales	11,791	206,064	555,306	117,110
234,058	971	1,477	39,040	8,884	S. Lancs.	9,292	118,074	821,683	58,588
98,243	739	2,170	40,478	17,447	N. Western	6,287	113,380	299,879	60,750
38,438	2,873	8,112	22,825	1,185	N. Ireland	1,439	9,784	98,222	23,584
278,044	4,763	15,852	115,043	29,238	N.E. Region	16,784	231,126	790,618	137,834
261,011	6,335	25,819	126,969	24,627	Scot. Reg.	8,560	200,598	552,456	101,992
2,983,093	30,819	119,150	1,066,789	204,337	Totals	145,076	1,990,970	9,356,421	983,976
2,910,011	32,064	124,076	1,054,071	198,209	Totals as at 30 Sept., 1937	146,297	1,925,606	9,240,459	905,030

* Includes low gauge spare wires, i.e. 40 lb.
† Includes all spare wires in local underground cables.

Noise and Treatments for its Reduction in Telephone Exchange Manual Switchrooms

E. C. C. STEVENS and JACK CULLUM (Horace W. Cullum & Co. Ltd.)

The authors discuss the nature of noise and the amount which may be tolerated in Telephone Exchange manual switchrooms and give a number of different treatments by which the noise level may be reduced.

Introduction.

NOISE has been broadly defined as all unwanted sound. This definition includes not only incidental sounds such as from mechanical machines, movement of persons, etc., but also speech, which, although regarded as sound by the interested recipient, is noise to uninterested persons within audible range.

With the advancement of civilisation the noises from these sources have steadily increased until they are of such proportions that the public are rapidly becoming noise conscious. This is noticed in the formation of a "Noise Abatement League," articles in the national press on noise reduction and the proposal to limit the maximum noise emitted by motor vehicles, etc. Sound in buildings is being controlled, forming a new industry which has grown to importance during the last decade. A new laboratory has been built at the National Physical Laboratory to enable acoustic measurements to be made of sound-absorbing materials, and at the Building Research Station at Watford, floors are tested for insulation against sound. The British Post Office has an acoustic group at Dollis Hill. In addition to the normal work of this group on electro-acoustical telephone apparatus (microphones, receivers, etc.), noise problems affecting the Engineering Department are investigated. Here, rooms have been treated with various experimental sound-absorbing materials, and in other rooms sources of artificial noise have been set up for testing apparatus under service conditions.

Sound.

When a sound is produced in a room it will continue to be heard in the room until it is either absorbed by absorbing surfaces in the room or transmitted through to adjoining rooms or out into the open air.

In an ordinary room or office the surfaces do not normally absorb sound to any great extent, and in consequence the beam of sound is reflected from them a large number of times before its energy is reduced below the audible limit. These reflections cause the listener to be subjected not only to sounds just produced but also to those from some considerable antecedent period; the level of sound or noise in the room is thus greatly increased. A room of this nature is termed "reverberant."

Sound Absorption.

If the surfaces of a room are lined with materials which readily absorb sound or if sound-absorbing materials in some form or other are present in the room the level of the sound is lowered. This is due to the energy of the individual sound waves being reduced (by rapid absorption) to below an audible value in a lesser number of reflections from the absorbing surfaces. If a large quantity of sound-absorbing material is provided the room will sound "dead." The amount of absorption which should be provided depends upon the use to which the room is to be put. Sound-absorbing materials are used for two main general purposes:

(*a*) To provide good acoustic conditions in theatres, churches and auditoriums.

(*b*) To reduce the loudness level of the room noise where direct reduction of the noise at its source is impracticable.

It is with purpose (*b*) that the Post Office Engineering Department is mainly concerned.

SOME CONSIDERATIONS OF NOISE, ITS EFFECT AND REDUCTION IN EXCHANGE MANUAL SWITCHROOMS.

With the noise and transmission levels usual in manual switchrooms a reduction of x db. in room noise is practically equivalent to a gain of a similar amount in the reception efficiency. Clearly, therefore, the masking effects of room noise should be judged in relation to the reception efficiency.

The ideal way of reducing noise is by stopping or reducing it at its source, either by mechanical changes or surrounding the source with absorbents (a typical example of this is the cover of a teleprinter). If this is not possible, then absorption material in the room can be used. If sound enters from outside (traffic noises, etc.) the room should be "sound-proofed." Double windows should be employed (or one window with heavy glazing) and artificial ventilation installed. Such treatment is best provided when the building is being erected.

Noise encountered in telephone exchange manual switchrooms falls under one or both of the following headings:

(a) *Traffic and Machinery.*

Noise due to these causes may be considered as entering the room at a fixed level and from no particular source. For such noise, if there is little absorption in the room initially, the addition of an absorbent treatment gives appreciable relief, but this method of dealing with the problem has only a limited effectiveness. For example, if the room contains x absorbent units initially, then the addition of another x units reduces the noise by 3 db., a further 2 x units would be required for a further reduction of 3 db. and so on. The correct treatment for noises of this kind is to prevent their entering the room by means of sound-proofing or sound-insulating construction.

(b) *Speech.*

Since noise due to this cause cannot be eliminated at the source, an absorbing treatment (if the room is reverberant) provides the most effective method of reducing the noise level. This can give additional benefit by influencing speakers to lower their voices, i.e. by reducing the power level at which noise is generated. This psychological effect has been observed in certain treated rooms in which measurements have been made.

The Best Position for an Absorbent Treatment in Switchrooms.

It is generally required to reduce the noise level in the whole room, and for this purpose the exact position of the absorbent material is unimportant. The ceiling is very often used as offering a large surface where the treatment can be applied with minimum obtrusiveness of fitting. Although this treatment is effective for lowering the general level of room noise it will not appreciably reduce the noise heard from a nearby source of sound. Thus the treatment of a switchroom will reduce the particular noise at one operator's position due to speech at an adjacent position only in so far as it helps to control the speech of the operators at a reasonable level.

When it is desired to quieten the room in the vicinity of a listener in a particular position, the effect of an absorbing treatment will be greater the nearer it is placed to the listener and/or to the sources of sound.

An absorbent treatment in the form of a complete partition sub-dividing a room gives more protection from noise than would the same amount applied directly on the ceilings or walls.

Amount of Absorption Required.

The question whether the reverberation of a given room, used for a stated purpose, is excessive or not, can be answered by experience only, that is to say by the collective opinion of a number of persons accustomed to use rooms for a similar purpose. The information has been collected only for the use of a room as an auditorium. In an auditorium there is an optimum reverberation time. A time longer than the optimum results in a loss of definition or intelligibility, and too short a time creates a " deadness " and a loss in quality of tone. For the Post Office purposes there would not, as a rule, be too short a reverberation time from the acoustic point of view, but the expense involved in carrying an absorbent treatment beyond a certain stage would be excessive.

An approximate rule, based on the optimum reverberation time of a room used as an auditorium, may be applied as a guide to an upper limit of what is reasonably tolerable in the way of reverberation in an exchange switchroom. Thus, if T is the optimum reverberation time of the room used as an auditorium then for most other usages (switchrooms, etc., in which absorption by the furniture is slight) a reverberation time not greater than 2T for the unfurnished room would not be considered excessive.

Based on this rule, Table I shows the minimum number of absorption units required in rooms of various cubic capacities.

This minimum should provide sufficient absorption in the majority of rooms, but in certain locations (such as in phonogram rooms and at enquiry positions) where acoustical considerations are especially important or where the work entails the hearing of difficult messages, the higher cost of more absorption would be justified.

TABLE I.

Volume of Room (cubic feet)	Minimum number of absorption units
5,000	125
10,000	250
20,000	400
40,000	750
80,000	1,300

(Absorption units = surface area of absorbing treatment in square feet × absorption coefficient of material used.)

Selection of an Absorbent Treatment.

In selecting a treatment for a manual switchroom several considerations have to be taken into account—cost, acoustical efficiency, decorative appearance, fire risk and hygiene.

The acoustical efficiency can be assessed on a cost basis when the absorption coefficient of the material is known. There are two methods of finding this coefficient, and these may be classified broadly as the stationary wave or small sample method (this is based essentially on measurements of the stationary wave obtained in a tube closed at one end with a sample of the material under test) and the reverberation or large sample method (in this test the material is assembled in a room and the absorbent coefficient calculated from measurements of reverberation time made before and after introducing the absorbent material). The National Physical Laboratory has facilities for making the latter test which is the one generally used because it has the advantage that it applies to sound coming from all directions and takes into account, not only the material itself but also the manner of its application and this can influence the coefficient to a marked extent. The test is made at several frequencies and Fig. **1** shows typical curves of

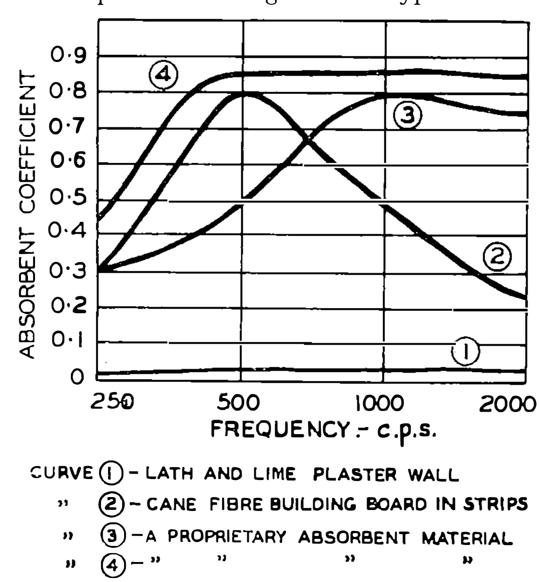


FIG. 1.—TYPICAL CURVES OF ABSORBENT COEFFICIENTS.

absorbent coefficients plotted against frequency. As an interesting comparison a curve is also shown for a lath and lime plaster wall.

A single figure is generally required for the coefficient of a material in order to calculate the absorption units. For Post Office rooms, wherein the noise is mainly due to speech, preference should be given to the middle frequencies. At the lower frequencies the hearing is less acute and at the higher frequencies sound is produced at a lower level of intensity.

Post Office practice is to mean the coefficients obtained at frequencies of 250 and 2,000 cycles per second and average this figure in with those obtained at the intermediate frequencies of 500 and 1,000 cycles per second.

Decoration of Sound Absorbent Treatment.

An important consideration in the design of a treatment is the question of decoration. A material which is a satisfactory absorbent of sound may have this property spoiled or considerably reduced by the application of decorative materials to its surface. The paint or distemper covers up either wholly or partially the pores via which sound is absorbed.

Some methods of treatment used by the Post Office which aim at combining acoustic efficiency with artistic merit are described in the following paragraphs.

If the material is of the rigid type and the surface can be given a decorative finish that is aesthetically pleasing, the surface facing the room is dealt with in this manner. The sound is then allowed access into the material via porous surfaces obtained by arranging a honeycomb of holes on the surface (see Fig. 2), or alternatively by fixing the material in strip form with

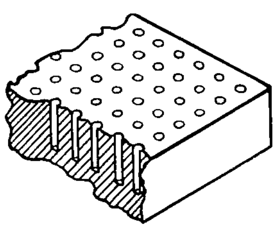


FIG. 2.—PORTION OF RIGID ABSORBENT MATERIAL, SHOWING HONEYCOMB OF HOLES IN FACE.

spaces between the strips so that sound has access via the interstices to the unpainted side surfaces.

Other methods adaptable to any absorbent material but especially suitable for those surfaces that do not present a pleasing appearance when decorated, consist of covering the treatment with a painted surface of paper or muslin perforated with small holes close together. Instead of paper and muslin, perforated oil-cloth (cribble cloth) can be used and re-decoration carried out by sponge-washing the surface.

The juxtaposition of the facing cloth (painted muslin, cribble cloth, etc.) with the sound absorbent does not adversely affect its acoustic efficiency. In fact, on reference to curves 1 and 3 of Fig. 3 it will be seen to increase the coefficient at the middle frequencies. Curve 2 of the same figure was obtained prior to perforating the painted muslin surface, and this indicates how necessary are the perforations to nullify the harmful effect of paint on the absorbent property of the material. With cribble cloth, a similar gain in absorbent coefficient is obtained at the middle frequencies, the actual amount of gain and shape of the curve depending upon the diameter of

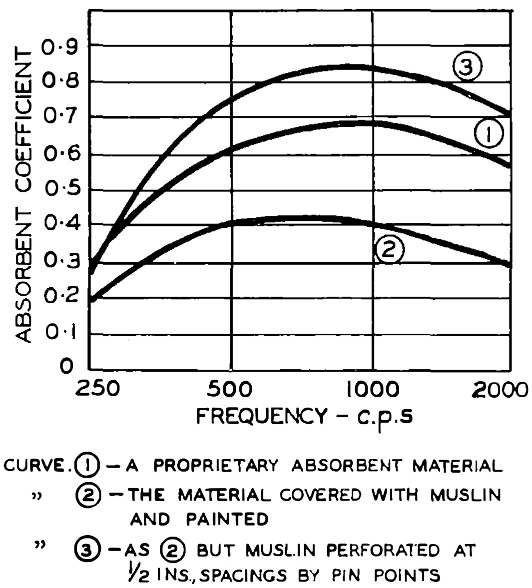


FIG. 3.—EFFECT OF PAINTED MUSLIN FACING SHEET UPON ABSORBENT COEFFICIENT

the holes in the cloth. Fig. 4 shows curves of an absorbent material alone and when faced with cribble cloths of 0·1 and 0·09 inch diameter holes respectively.

In the treatment of the International telephone exchange, London, which will be described later, perforated sheet-metal takes the place of cribble

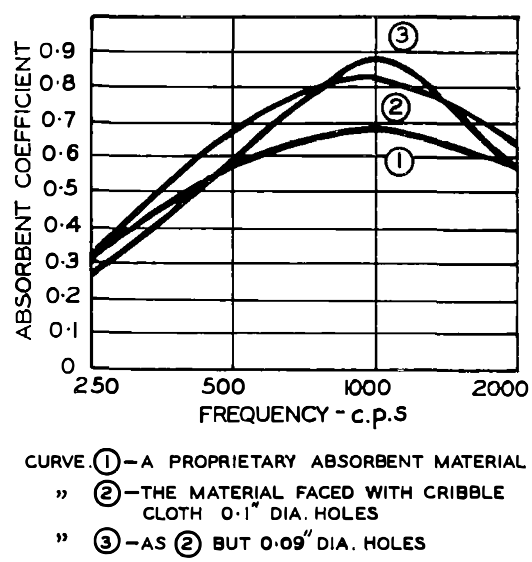


FIG. 4.—EFFECT OF CRIBBLE CLOTH FACING SHEET UPON ABSORBENT COEFFICIENT.

cloth. Although metal is a very good reflector of sound, when perforated with holes covering about 10 per cent. of the total surface area, it is reasonably transparent to sound which passes through and is absorbed by the material behind. A rigid perforated facing sheet may even increase the efficiency of the treatment over certain frequencies depending upon the pitch and diameter of the holes. This treatment can be washed or repainted with a minimum of difficulty if care is taken not to obstruct the perforations.

Treatments that have been Applied to Manual Switchrooms.

In the following paragraphs, some of the treatments that have been used in exchange switchrooms in this country are described.

Switchrooms in Faraday Building.

The International telephone exchange was treated in 1932 with an acoustic ceiling consisting of a perforated metal facing sheet with a 2-inch thickness of rock wool independently suspended above.

Rock wool, which is largely used in the acoustic lining of sound film studios, is a good sound absorbent. It possesses a frequency absorption characteristic which is sensibly flat over a wide frequency range.

The application of this material to the particular requirements of the Post Office presented a number of difficulties. The design was also complicated by the necessity for avoiding all combustible materials. Even hard wood such as teak or oak was not permitted in the construction. The installation finally adopted was designed by the Office of Works in collaboration with Messrs. H. W. Cullum & Co., Ltd., the acoustic specialists who carried out the work.

At the company's works at King's Cross the rock wool was made up into blankets 6 feet long by 2 feet wide. It was then laid on small mesh wire netting stretched across the switchroom ceiling; this supported it clear of the perforated metal facing sheet which is independently fixed to the ceiling. In this way bellying of the facing sheet is avoided. Owing to the necessity for a ceiling to possess high light reflecting qualities this point is very important.

The facing sheet is in the form of perforated enamelled metal trays, each 16 inches square. The method of construction is shown in Fig. 5. Strip-iron

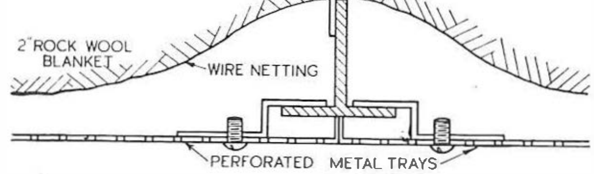


Fig. 5.—Rock Wool with Perforated Metal Facing Sheet.

brackets hold the trays between parallel inverted "T" pieces which run across the room 16 inches apart. The "T" pieces are suspended from the ceiling with iron strips of sufficient length to locate the perforated trays about 2 feet below the ceiling proper. The treatment was constructed this distance below the ceiling to obtain a surface in one plane. At this level the various obstructions (pipework and beams in the ceiling construction) are avoided. The appearance of this treatment is shown in Fig. 6.

Other treatments of lower price were tried in other exchanges in the same building. One of the treatments most extensively used employs the same absorbent material but has a perforated asbestos cement facing sheet instead of metal. This was fixed in panels 2 feet square with bevelled edges and painted after fixing. The holes are $\frac{1}{8}$ inch diameter on $\frac{1}{2}$-inch centres.

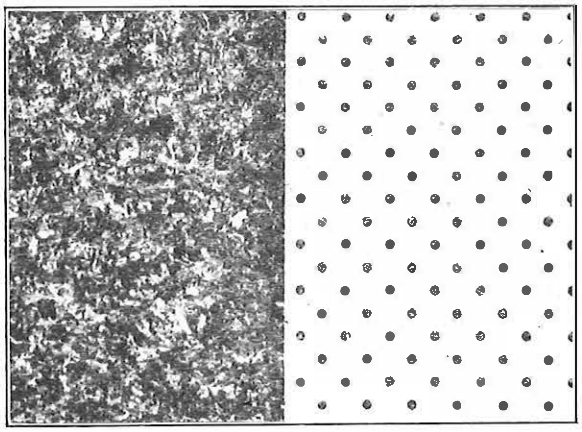
Fig. 6.—Ceiling Treatment in International Exchange.

Cullum Acoustic Felt Treatment.

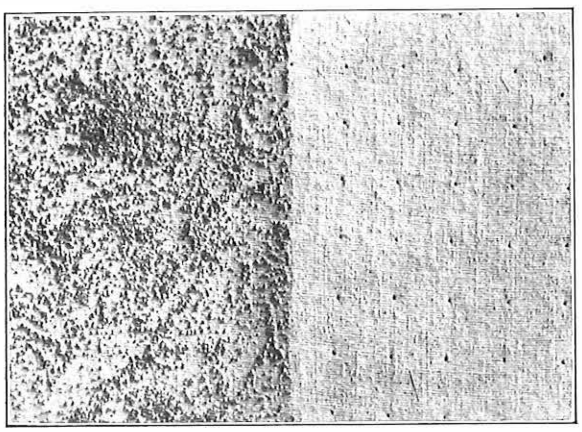
The sound absorbent used in this treatment is a proprietary brand of hair and asbestos felt which is manufactured in several thicknesses and a variety of finishes. It has high acoustic efficiency and when faced with cribble cloth (the usual finish) can be washed and presents an appearance which is not unpleasing to the eye. The treatment has been installed with satisfactory results in a number of exchanges in Great Britain.

The usual method of fixing is to glue the felt to the ceiling with a waterproof cement, all joints being carefully butted. The cribble cloth is thereafter applied with non-filming size. The latter product has been specially developed for the purposes of gluing together porous materials without clogging the pores.

As an alternative to the cribble cloth finish, muslin is used. This material is fixed in the same way and after painting (and pricking with pinholes after the paint is dry) has an appearance which is almost indistinguishable from painted plaster. Fig. 7 shows the appearance of this treatment, with three alternative finishes.



Felt Cribble Cloth Finish



Sanded Muslin Finish Pricked Muslin Finish

FIG. 7.—CULLUM ACOUSTIC FELT TREATMENTS.

Strip Building Board Treatment.

This is one of several treatments tried out in rooms in the Research Building at Dollis Hill. It was developed by the acoustic group of that Branch in 1931 as an efficient, cheap alternative to the rather expensive commercial treatments at that time. As in other treatments, a surface of a porous nature is used, but in addition a non-porous membrane surface is incorporated in the construction. This is held loosely and there is an appreciable dissipation of sound energy by its mechanical vibration.

Tests made in the Research Branch showed that paper was a material specially suitable for dissipating sound mechanically, and this in conjunction with a fibre building board (which supplies the porous portion) was used in the treatment.

Fig. 8 shows the method of construction used in the room at Dollis Hill. Wood battens were screwed to the ceiling about 20 inches apart and with their lower surfaces about 1 inch below the ceiling. A good quality ceiling lining paper, 20 inches wide was pinned to the battens to cover the ceiling area. Finally the building board, cut in strips 2 inches wide was fastened transversely to the battens, a space of $\frac{3}{8}$ inch being left between the strips. This treatment may be decorated without appreciable effect on the sound-absorbing properties if care is taken in painting to prevent access of the paint to the interstices.

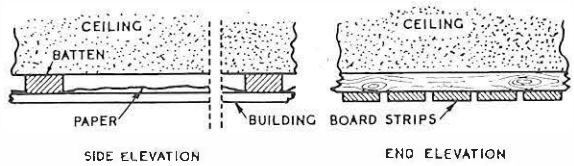


FIG. 8.—CONSTRUCTION OF STRIP BUILDING BOARD TREATMENT.

A treatment on these lines was installed at Dudley exchange and tests made when half the ceiling had been covered showed a reduction in reverberation time for the room of from 4·1 to 2·2 seconds. In this exchange, to improve the appearance and present a flat surface to the eye, the treatment was covered with cloth and painted, with the result that the efficiency was somewhat reduced.

The treatment has also been made up in the form of wall panels and folding screens for local application.

Absorbent Slabs.

Absorbent material of a fibrous nature is made up in the form of a rectangular slab. It is a rigid unit which can be fixed in position with an adhesive or screwed to battens previously attached to the ceiling.

A treatment carried out with this type of material presents a surface which can be distempered with the aid of a high pressure spray gun (in this application care must be taken not to clog the pores of the material unduly), or alternately covered with muslin, distempered and then finely pricked all over to allow the sound access to the absorbent material.

Absorbent Tiles.

These are of a similar nature to the slabs mentioned above, but they are usually smaller and provided with bevelled edges. Each tile has a number of holes spaced regularly over the surface. The more porous surface that the walls of the holes offer to the sound acts as a better absorbent than the tile face, especially if the latter is painted or distempered. The method of fixing is the same as for an absorbent slab.

Conclusion.

In conclusion the authors would state that they have not attempted to describe all the sound-absorption treatments that have been installed, but in their opinion those mentioned are fairly representative of the ones in use by the Post Office.

Australian Commonwealth Communications

H. P. BROWN,
Director-General
Australian Posts and Telegraphs

This article, which is reprinted from " The Times Australia 150th Anniversary Number " by kind permission of the Editor, gives a complete summary of the recent growth of the communication services throughout the Commonwealth of Australia.

IN the expansion and development of a nation, transportation and communications must play a vital part. In fact, it would be true to say that a country's progress is dependent on the creation of these two services and their subsequent control and operation in an efficient manner.

Australia has an unusual problem to solve during the period of its growth because of the great distances between its existing centres of population, the wide expanse of its territories, and the small number of its inhabitants. The area of the country is roughly 3,000,000 square miles—26 times as large as the United Kingdom—and its people number fewer than 7,000,000, about two-thirds of the population of Greater London.

The establishment of communications for the transmission of intelligence by electrical means no longer presents a serious technical problem, for science has shown the way to overcome almost limitless distances in conveying signals or even the spoken word. The problem is economic. In a densely populated country heavy traffic is carried over short distances and the return on investment is proportionately high, but under conditions of long distances and small volumes of traffic expense is likely to get out of proportion to possible income, and the large sums needed for a far-flung intercommunication system may retard an expansion very desirable and quite profitable in an indirect way from the national standpoint.

Multi-Channel Systems.

The Commonwealth Post Office has taken advantage of the results of all technical research pursued in other countries and within Australia itself, and has incorporated in its telephone, telegraph and radio services the most modern equipment available. Its telegraph and telephone lines, mostly composed of copper wires erected on poles (except in the cities, where extensive underground cable networks exist), have been reconstructed in recent years to give the greatest possible freedom from interruption, and to afford such a standard of design that the modern multi-channel telephone or telegraph systems may be superimposed on them to the utmost extent permissible by electrical considerations.

These multi-channel or carrier systems, as they are known, allow for several conversations to be transmitted simultaneously on one pair of wires or, alternatively, many telegrams may be signalled over the one pair of wires at the same time as telephone conversations are taking place. The Post Office has in service 225 channels of this character, which give a service equivalent to that which, under earlier methods, would have required the erection of over 167,000 miles of copper wire.

Complete Telephone Network.

Australia has now a complete telephone network giving full inter-communication to all its populated area, the last important link in the system being the ocean cable connecting the mainland of Victoria with Tasmania, nearly 200 miles across the Bass Strait. This cable contains only one conductor, yet it carries simultaneously six telephone conversations, ten telegrams, and a musical programme which can thus be broadcast from Tasmanian stations at the same time as it is being transmitted by stations on the mainland.

In the cities numerous large, modern automatic telephone exchanges have been provided, and in the rural areas a rapid introduction of automatic or dial telephones is taking place. The telephone habit has been highly cultivated and every encouragement has been offered by maintaining the charges at the lowest possible level short of making the system a burden on the general taxpayer.

Australia takes seventh place in the order of greatest telephone density among the countries of the world, Great Britain occupying ninth place. There are 607,000 telephones in use, obtaining service through 6,250 exchanges. The revenue from the telephone branch of the Post Office was £7,061,200 for the year ended June 30, 1937.

Automatic machine printing systems have largely superseded the older form of telegraph apparatus. Great distances are covered by direct transmission, as, for instance, the 2,708 miles from Perth to Sydney. Instantaneously with the operation of a typewriter keyboard at the transmitting station in Perth the telegram is printed automatically letter by letter in Sydney.

Telegraph density is high, Australia occupying second place among the greatest telegraph users of the nations of the world. There are 9,252 telegraph offices, and the year's revenue to June, 1937, was £1,370,517.

Australia is remarkably well served by oversea communications. Submarine cables diverge from three main points. These are Perth, leading to Africa, with access to Europe and America by the Atlantic and also connecting by the Indian Ocean with the East, with India and through the Mediterranean with the United Kingdom, Europe, etc.; Darwin, the landing point for cables extending to the Malay States and Singapore, also giving an outlet through the extensive main Indian Ocean system; and Sydney, the important centre for the cables extending to New Zealand, the Pacific Islands, and Canada, which give access to the whole American continent and across the Atlantic to Europe.

Radio high-speed telegraph stations also carry heavy volumes of traffic direct to the United Kingdom and to Canada, from both of which places more distant distribution and collection of traffic takes place.

A radio telephone service operates to New Zealand and another to the United Kingdom, by means of which it is possible to communicate via London with 95 per cent. of the world's telephone subscribers.

Road, Rail and Air Mails.

On the postal side the development has not been neglected. There is scarcely a resident, even in the most remote and isolated parts, who is not served. Although the railway system has been built to an almost lavish extent, providing a wonderful service, it does not reach many of the thinly populated areas and, in consequence, more than 5,000 road mail services have been established. These are undertaken by motor, horse-drawn vehicles, and pack horse, and the distance traversed exceeds 35,000,000 miles per annum. The length of route of some of these services reaches the great distance of 650 miles.

The Sydney General Post Office contains one of the most extensive and comprehensive mechanical mail-handling plants to be found in any postal administration in the world. It embodies most ingenious electrically controlled machines for the internal conveyance and distribution of the great volume and diversity of mail matter to be dealt with.

The Post Office disposes of approximately 1,000,000,000 items of mail annually. Air mail services extend over the whole continent and cover a route distance of 17,185 miles. The distance flown by these services reached a total of 4,505,000 miles during the year ended June, 1937. Further rapid expansion is taking place, and it is the intention to carry all first-class mail by air between the six State capital cities in the near future. This plan, which is in process of development, will revolutionise the long-distance postal service as it will reduce the time of transit to a fraction of that now occupied.

An air mail service exists between Australia and the United Kingdom and reduces the normal sea transit time from 31 days to 13. Within 12 months a further speeding up is expected which will enable the journey to be covered in 10 days, with subsequent improvements in the near future, bringing Australia within seven days of the United Kingdom.

The revenue from the Postal Branch reached £6,170,233 during the year ended June 30, 1937.

Broadcasting Stations.

Broadcasting in Australia has grown at a phenomenally rapid rate. The Post Office now possesses 22 national stations distributed from Townsville (Qld.) in the north to Perth (W.A.) in the west, and a complete system of high quality programme lines interconnects all these, making it possible to transmit simultaneously any programme from the whole or any portion of this group of stations.

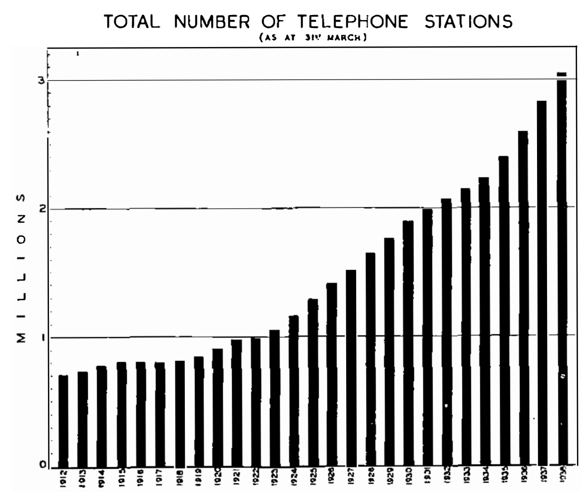
There are now over 986,000 licensed broadcast listeners and within a few weeks the number will reach the million mark. There are also 89 licensed broadcasting stations spread throughout the Commonwealth. These are operated by private enterprise and form a most valuable adjunct to the national service, by giving the listener a varied choice of programmes of high quality.

The Commonwealth Post Office employs 45,000 people and operates approximately 10,000 post offices. Its assets are represented by £58,067,000 of capital. Its income for the year ended June 30, 1937, was approximately £16,000,000, and its expenditure, including depreciation and interest, was approximately £12,315,000. It is fortunate in its staff, who have a great pride in their service and who insist that the Post Office shall be a live and progressive organisation contributing to the full towards the development and prosperity of their country.

The Three-Millionth Telephone

In the Post Office Electrical Engineers' Journal for 1922/23, page 357, the following appeared :—

" After an extraordinarily checkered career the telephone system of this country in September last reached a million stations, exclusive of the telephone stations in Ireland. An eminent millionaire is said to have made the statement that in the amassing of a fortune the first £100 is the most difficult part of the task. In a similar way, it is perhaps not inappropriate to say that in the setting up of a telephone system the acquiring of a million stations is the most difficult part. This is perhaps more apt in the case of the telephone system than in the amassing of a fortune, as heritage may play a very important part in acquiring a fortune. There is a very important financial aspect of a million stations that is not to be overlooked. When a telephone system is small, establishment charges, supervision costs and many other overhead expenses must of necessity be comparatively high per station, but the magic number 1,000,000 is symbolical of greatness, and one expects from that achievement onwards overhead charges per station will be reduced, that practices which previously might be regarded as uneconomical may in future be placed within the realm of practical needs. The Board of Editors feel that this moment should not pass without comment in the Journal, and it is hoped that in spite of all the hindrances and difficulties following the European upheaval, trade in this country will gradually recover and that an era of coming prosperity will bring the inevitable concurrent progress of the Government telephone system and that the second million stations will be acquired in record time."



Now that the telephone system of the country has topped 3,000,000 stations, it may be interesting to our readers to see how the hopes of 1922 have been realised.

Pneumatic Dispatch Tubes—their Economics and Uses

J. E. McGREGOR, A.C.G.I., A.M.I.E.E.

The use of street, house and ticket tubes is compared with other methods of dealing with messages and some cost figures are given.

Introduction.

PNEUMATIC tubes used for the dispatch of messages fall naturally into three classes:—street tubes connecting buildings, house tubes and ticket tubes connecting parts of the same building. House tubes use carriers in which the telegraph forms, telephone fault dockets, etc. are conveyed and ticket tubes convey trunk call record tickets or similar items without the use of a carrier.

When it is necessary to transmit messages such as telegrams from office to office or from one part of a building to another, it is necessary to compare the costs and relative advantages of the various methods available, i.e., messengers, telephone or teleprinter circuits, or pneumatic tubes. The first may generally be neglected owing to considerations of cost and delay, and of the others pneumatic tubes have the great advantage of handling without delay messages arriving in bulk which would have to wait their turn for transmission by wire, while with telegrams, since the actual forms are transmitted to and from the central telegraph office, errors in retransmitting by telephone or telegraph are obviated. When the costs are compared, though wired circuits are cheaper to provide they are relatively costly to operate, whereas pneumatic street tubes, though the capital cost of laying is comparatively high, have a long economic life (40 years), are cheap to operate and their overall annual costs are consequently not excessive.

The advantages of pneumatic tube transmission are recognised by many newspaper offices and cable companies which rent tubes from the Department.

Street Tubes.

Street tubes may be laid radially from the central telegraph office direct to the various branch offices with occasionally one intermediate station if an office is close to the route, or a number of offices may be grouped in series on one tube. The latter method gives direct intercommunication between the various offices and has its uses in connection with express letters, etc., but involves working to a timetable or employing complicated and expensive switching arrangements (sometimes controlled by the carriers themselves) unless every carrier is stopped and examined at every office on the tube. Furthermore it introduces undesirable delays as far as telegraph traffic is concerned. The radial system is normally employed by the Department.

The cost of laying a street tube is of course proportional to the length and will depend on the nature of the roadway or pathway under which it is laid. Where subways exist tubes can be run very cheaply, brass tubing being used instead of the lead tube in C.I. pipe used for buried work. Iron or steel tubing is not normally used by the Department as the frictional drag on the carrier is greater, there is constant liability to rust, and with the large number of joints there is always liability to trouble which offsets any economy in capital expenditure resulting from the use of cheaper material. For tubes larger than 3 ins. diameter, however, lead would have to be abandoned in favour of iron or steel for mechanical reasons as the lead tubing would tend to deform.

Although $1\frac{1}{2}$ ins. diameter tubes can be used for short distances and light traffic they do not present much economy over larger tubes apart from the cost of material. The standard $2\frac{1}{4}$ ins. diameter tube is generally used in such circumstances as there is very little saving in the power required by the use of the small tube if the same transit time obtains, whereas the reserve capacity of the larger tube at rush times is a valuable asset.

For first estimates a figure of £2 10s. per yard may be taken as the cost of a tube but this is liable to wide ± variations when the actual route is surveyed. For very long distances, i.e., above 2,000-3,000 yards, 3 ins. diameter tubes have to be considered to maintain a reasonable transit time. Terminal apparatus is not costly, except where automatic plant is installed, and where there is a fairly long internal run should be covered by the above figure.

In recent years there has been a radical change in the method of operating the tubes resulting in a considerable saving in power. In the past, generally the same pressure was applied whatever the length of the tube, so that the shorter the tube the higher was the velocity obtained. Instead of standardising the pressure a standard velocity of 30 ft./sec. is now aimed at and obtained on all but the longest tubes, the power taken being proportional to the length of the tube (Fig **1**). Street tubes are, of course, operated by vacuum as well as pressure but as more power is required under pressure working, this is taken as the basis in these

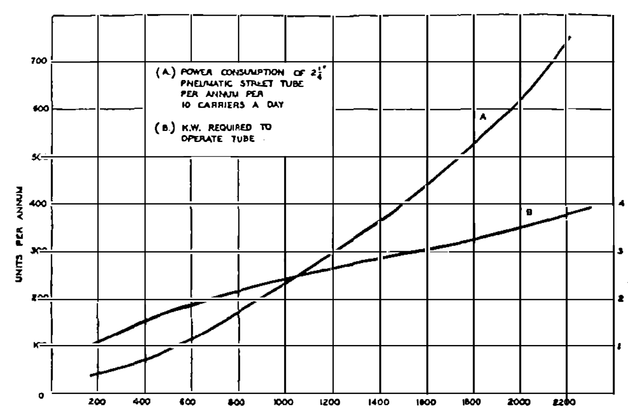


FIG. 1.—CURVES OF ANNUAL POWER CONSUMPTION AND OF POWER REQUIRED TO OPERATE $2\frac{1}{4}$-IN. TUBE.

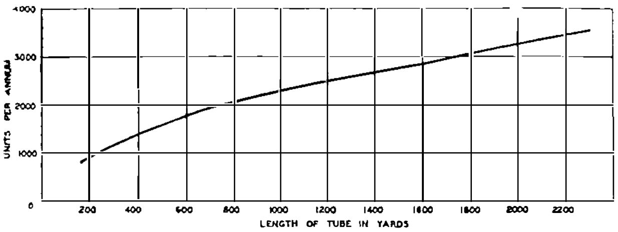


FIG. 2.—EXTRA POWER CONSUMPTION PER 2¼-IN. TUBE IF COMPRESSOR IS RUN CONTINUOUSLY ON LIGHT LOAD BETWEEN CARRIERS.

notes. Estimates of the power consumption must include the consideration of many variables. On long busy tubes more than one carrier may be travelling at the same time and the power used per carrier will then be reduced. On large systems there will be a diversity of use of the tubes and it is not necessary to consider standby running losses of the compressors, but where only one or two tubes are connected and the compressor is kept running between the transits of carriers there will be the standby power consumption shown in Fig. **2**. On small systems where traffic is small it will generally be practicable to run the compressor when required and only the current taken when carriers are in transit need then be considered.

Where there are existing systems the addition of an extra tube will not generally involve alterations or additions to the air compressing plant but the cost of this and the provision of space for the installation has to be considered for new systems. This cost, however, does not amount to a big charge and should be covered by a 5-10 per cent. addition to the capital cost of the tube.

Except in London where, owing to the complexity of the service, tube attendants are employed at the C.T.O., no special operating staff is required. In London, however, the tubes have now been converted to automatic working, which simplifies and makes the operation similar to that on house tubes, and there have been both a considerable reduction in operating staff and large economies in power owing to the automatic cutting off of the air supply at the moment of arrival of a carrier. At branch offices up-traffic is inserted in the tube by the counter staff, and down-traffic for local delivery is taken directly to the messengers' room so that there are savings both as regards staff and accommodation as compared with the transmission of the telegrams by wire.

House Tubes.

With house tubes the capital cost per yard run is small, compared with street tubes, as light brass tubing with cemented sleeve joints is used instead of the lead tube in C.I. pipes used for street tube working. As the runs are generally short the cost of terminal apparatus becomes of greater importance and cheapness in design is necessary.

These tubes are of great utility in connecting one part of an office or building with another, they are inconspicuous, the runs are fairly flexible, and since the system is operated by means of a low vacuum of only about ½ lb. per sq. inch below atmosphere, the cost of power is low while the convenience is high. Generally the blower operating the tube or tubes is left running continuously although, when only one tube is connected, it may be shut down between messages except at very busy times. As a ½ h.p. motor only is installed to drive the blower or fan on systems up to three 1½-inch loops the power used per tube is small.

Although, of course, the cost of the tube will vary with its length, an average figure of £40 to £50 per tube will generally cover all installation costs including the blower. 2¼ ins. tubes are used occasionally where the length of the run is over 300 feet and the cost of the tube and blower will then be higher. Generally the 1½ in. tube meets all requirements and as carriers may be fed in, one after the other if necessary, the carrying capacity is high notwithstanding the smallness of the carrier used.

Ticket Tubes.

The ticket tubes used in trunk telephone exchanges, to collect and distribute the call record tickets, although also of brass, are rather more expensive to install than house tubes as, owing to the rectangular section used, the tubing, bends and twists are more costly to produce than are tubes and bends of circular section. Again owing to the difficulty of inserting tickets in pressure operated tubes and especially of obtaining automatic ejection of tickets from vacuum operated tubes, the cost of terminal apparatus is greater and in earlier days was the principal item to consider on a short tube. This has been altered by the adoption of the author's design of discharge terminal, and the cost is now not much greater than that of the apparatus used on carrier operated house tubes, so that the cost of installing the tube itself is now the predominent factor, this being about double that of a comparable house tube.

The power taken to operate these tubes (about 1/10 H.P. per tube on a large installation) is very small and almost negligible on collecting tubes when it is considered that only one tube is necessary to collect the tickets from up to 9 or 10 operators.

Blowers are installed in duplicate owing to the importance of keeping the tubes in operation. The cost per H.P. for installing the blowers (in duplicate) and ductwork for the air supply varies with the size of installation and has fallen considerably during the past few years to about £3 10s. to £4 per tube on a fairly large installation. These blowers are installed. to meet the ultimate requirements as far as possible.

Owing to their simplicity of operation and the rapidity with which the tickets may be transferred to a second operator or to the filing position, these ticket tubes have no serious competition. Conveyors are much slower and although practicable on straight runs they become too complicated when the layout of the usual trunk exchange is considered. Hand collection is slow, uncertain and causes congestion in the exchange, so that cost, though important, is not the all important factor which decides the adoption of ticket tubes. Speed and reliability are all important and without this facility the general speeding up of trunk working which has been carried out in the last few years would to a certain extent have been unrealisable.

Notes and Comments

New Year Honours

We were pleased to learn of the recognition accorded to Mr. T. H. Boyd, the Assistant Director-General, in the New Year Honours List, in which the Companionship of the Most Honourable Order of the Bath was conferred upon him.

It was also a great pleasure to see in the List the name of Mr. B. O. Anson, Assistant Engineer-in-Chief, who was awarded the O.B.E., and those of Mr. T. H. Edgerton, Assistant Superintending Engineer, London Telecommunications Region, and Mr. A. Dunlop, Chief Engineer of the "Monarch," who were awarded the M.B.E.

Post Office Accounts

The Post Office Accounts for 1937 show that new records have been achieved in almost all directions.

The growth of telephone business has still further accelerated, partly through the continuance of trade improvement and partly through reductions in charges. Local calls were of the order of 1,882,000,000, an increase of about 150,000,000 over the comparable figure for 1935-36. Trunk calls (roughly, calls over a distance of more than 15 miles) totalled 99,000,000, against a comparable figure for 1935-36 of 88,250,000.

The number of telephone instruments in service at March 31, 1937, was 2,827,000, an addition of 248,000 during the year. That is by far the greatest increase ever recorded in any year in the history of the Post Office system. Public call offices increased by 2,000 to a total of 46,000. More than half the total now consists of street kiosks, which increased in number by 3,000. Part of this increase is due to the replacement of call offices in shops, where service can only be given during business hours, by kiosks that are always open. There were at March 31, 1937, 5,600 exchanges and 13,250,000 miles of wire, of which nearly 12,000,000 miles are underground.

Inland telegrams, at 49,250,000, showed an increase of 4,750,000 over 1935-36 and oversea telegrams, at 9,250,000 showed an increase of 500,000.

Ten-Year Index

A few copies of the Index of Volumes 19 to 28 are still available and may be obtained at a price of 6d. per copy from the Managing Editor or through local agents. The indexes to Volumes 29 and 30 are given in the fourth part (January issue) of each volume.

Binding

This issue is the first of Volume 31, and readers are reminded of the binding facilities which are available for past volumes. Full details will be found on page 84.

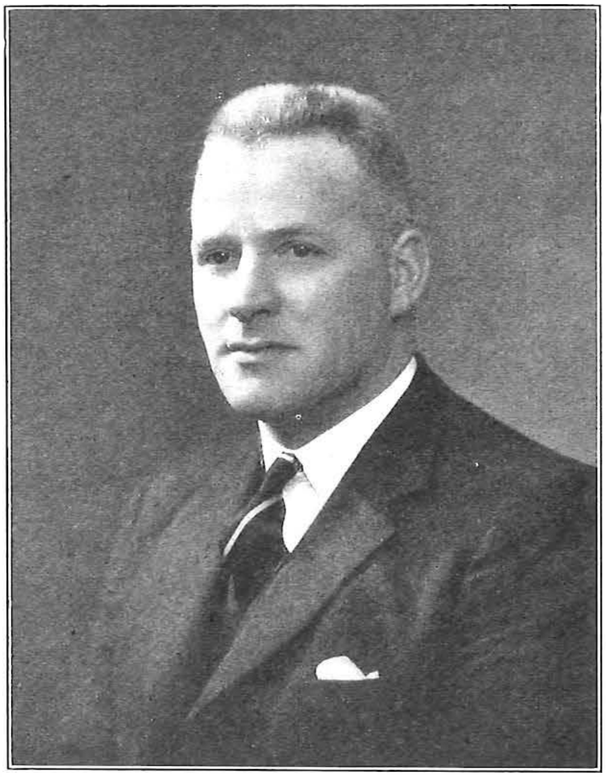
Circulation

In the April issue a year ago we announced that 14,000 copies of that issue had been printed. Throughout the year there was a steady increase in the sales, and to meet anticipated demands 16,500 copies of this issue have been printed. With a journal that is growing in circulation so rapidly as ours it is difficult to gauge correctly the number which should be printed to meet demands, and old and new readers would help considerably, and also avoid the possibility of being unable to obtain a copy because the issue is sold out, if they would place an order with their local agent for the four parts of this new volume.

Junior Section Activities

The attention of our readers is drawn to the record of the activities of the local centres of the Junior Section shown in each issue of the Journal under the heading of Junior Section Notes. The wide range of the papers read, the works visited and the social gatherings held show that the Junior Section is in a very healthy state. These Junior Section Notes, it is hoped, are of interest to all members of Junior Centres and especially to those at Centres recently formed or about to be set up. It is noticed that the Fenny Stratford Junior Centre has held discussion nights to discuss points of difficulty encountered in the lessons of the Department's Correspondence Courses for Workmen. It is not known if this is a practice unique to this Centre, but it would appear to be a very useful and helpful one.

L. H. Harris, M.Sc., A.C.G.I., M.I.E.E.



Mr. L. H. Harris, who has been appointed Superintending Engineer, North Midland District, left London for Australia as a boy of 16 to learn wheat farming. He returned five years later, having spent one year at the remote settlement of Wynarka in South Australia, and four years with the Australian Imperial Forces during the Great War.

Afterwards he entered the City & Guilds Engineering College and obtained their diploma and an electrical engineering degree in 1921. The following year he entered the Engineering Department of the Post Office as an Assistant Engineer, and spent the following ten years in the Research Branch. During this period he obtained a Master of Science degree and twice the senior medal of the Institution of Post Office Electrical Engineers, while the results of his work and ideas on V.F. and D.C. relays and contacts have now spread throughout the telephone and telegraph plant of the Department.

In 1932 he was promoted to Executive Engineer in the Telegraph Branch and became Assistant Staff Engineer in 1936, being transferred to the Eastern District in 1937. In the Telegraph Branch he was concerned with the installation of the present V.F. telegraph network and with the development of the teleprinter switching scheme. He was a delegate to the C.C.I.T. conferences at Prague 1934 and Warsaw 1936.

Mr. Harris has represented the Post Office Engineering Department on a number of occasions in Civil Service swimming championships. He joined the Territorial Army after the War, and now commands a company of the 44th (H.C.) Divisional Signals.

J. R.

L. G. Semple, B.Sc. (Eng.), A.M.I.E.E.

On May 1st, L. G. Semple will leave the Engineer-in-Chief's Organisation and Efficiency Branch, to become Superintending Engineer, South Midland District. His alert and analytical mind, his powers of constructive criticism, and his fund of original and valuable ideas will be much missed on reorganisation questions and on many Headquarters Committees.

In his "teens" Mr. Semple was an air force pilot in France, and after the war he graduated in Engineering at London University, and was successful in 1925 in the open competition for Assistant Engineerships.

Mr. Semple commenced his Post Office duties with the Research Branch cable testing force, and then moved to Cambridge, where he spent seven years, first on the general work of a busy Section, and later as first Efficiency Engineer of the Eastern District. He was very successful in devising many improved methods of construction work and maintenance, and had full scope for his initiative and ingenuity.

In 1933 Mr. Semple was promoted to Executive Engineer-in-charge of the Bristol Section, and in 1935 to Assistant Staff Engineer, "O" Branch. His work in all these spheres will not quickly be forgotten, particularly his imaginative conception of the "Executive Control Unit."

In 1937 Mr. Semple shared in a two months' tour of the Bell Telephone system in America. He was universally popular (not least on the boats) and his shrewd and searching questions and his insatiable thirst for knowledge were extremely valuable.

Everyone will wish the best of luck to him and to his wife and family in their new sphere at Reading—and afterwards.

N. F. C.

Retirement of Mr. A. Wright, M.I.E.E.

Mr. A. Wright, M.I.E.E., Superintending Engineer, North Midland District, retired from the service on March 31st, 1938. He entered the National Telephone Company in January, 1896, after having served three years as a student at Finsbury Technical College and as an engineering apprentice to the London, Brighton and South Coast Railway.

In 1898 he was appointed manager of the Kensington telephone exchange and, in 1905, Divisional Maintenance Electrician, Met. W. District. He was appointed Metropolitan Maintenance Electrician in 1907.

Shortly after the transfer of the Company's undertaking to the Post Office, Mr. Wright took charge of the South Internal Section in London as Sectional Engineer, which position he held until 1926 when he was promoted to Assistant Superintending Engineer, London. On March 1st, 1934, he took up duty as Superintending Engineer, North Midland District.

In all these appointments he secured the respect and affection of his staffs and colleagues and his retirement is regretted by a wide circle of friends who wish him many years of health and happiness.

Mr. Wright has played a prominent part in the practical application of many technical developments, including the conversion of approximately a third of a million telephones to automatic working. In the North Midland District he devoted special attention to the introduction and development of "Control" working for Advice Notes, Minor and Major works, the improvement of construction and maintenance methods, and the reduction of faults.

Mr. Wright served for six years on the Council of the I.P.O.E.E. He was Vice-Chairman of the London Centre in 1933/4. As Chairman of the North Midland District Centre he encouraged the setting up of several additional Junior Centres in the North Midland District.

Mr. Wright was a recipient of the King George VI Coronation Medal in 1937.

P. J. R.

Book Review

"The Collected Papers of George Ashley Campbell," published by the American Telephone and Telegraph Company, New York, 1937.

In the minds of telephone engineers the name of G. A. Campbell is firmly linked with the early history of the coil loaded line and of electric wave filters. The publication of "The Collected Papers of George Ashley Campbell," by the American Telephone and Telegraph Company is a reminder of pioneer work continuing till his retirement at the end of 1935. The bringing together in a single volume of his published work is a happily conceived tribute to Dr. Campbell's long and distinguished service with the Company and of his fundamental contributions to the development of electrical communications.

Dr. Campbell joined the Company in 1897 and an early memorandum gives some indication that before the end of 1899 he had developed his well-known formulæ for the coil loaded line, though it was not until 1903 that they were published. Many methods of simplifying the calculations involved and also approximate formulae have since been evolved but the completeness of the information implicit in the curves of the article is striking.

It is not possible here to do more than name a few of the other directions in which his genius has led the way, e.g. capacity balancing of lines, articulation testing, anti-side-tone transformers. His work in connection with electrical transient conditions in networks can be fully appreciated only by mathematicians.

The later papers are concerned with Dr. Campbell's advocacy of a rationalised system of fundamental units. One has no hesitation in saying that few engineers are aware that 63 systems of fundamental units have been suggested or employed—references in technical literature to each of them are given as well as the names of their advocates. Dr. Campbell enlivens with a quiet humour his case for Giorgi's system when he refers to units outside this system as "Orphan Units" and to advocates of the c.g.s. absolute system as the "4π adherents."

One wishes that the valuable and interesting introduction by E. H. Colpitts, who early collaborated with Campbell, could have recorded more of the man himself, who in his specially honoured position as Research Engineer was an inspiration to his colleagues.

G. J. S. L.

The Institution of Post Office Electrical Engineers

TELEPHONE HISTORY

The Institution of Post Office Electrical Engineers has always recognised the importance of maintaining a record of the technical milestones in the Engineering Department's history. The Post Office Electrical Engineers' Journal in many respects covers the happenings of recent years, but history prior to the existence of the Journal has been mainly in the memories of the older servants of the Department, many of whom are now absent from the Service. Some steps have been taken to collect data of a special character on the retirement of the older officers, and much information is thus placed in the archives of the Institution. It will, however, be recollected that some time ago the Chief Engineer in charge of the North Eastern Region, Mr. F. G. C. Baldwin, Chairman of the Institution's Regional Centre, produced a very complete history of the telephone which was published by Messrs. Chapman & Hall. This book, entitled "The History of the Telephone in the United Kingdom," was published at the price of 42s. but we now hear from the publishers that it is proposed to issue a cheap edition of this work for 15s.

It is desired to bring prominently before the notice of the younger generation this important contribution to the literature of the subject, and it is suggested that the reduction in price provides an excellent opportunity for all the younger members of the Department to obtain for their book-shelves this record of the important events in the history of the telephone.

RECENT ADDITIONS TO THE INSTITUTION LIBRARY

New Books.

1320 British Experiments in Public Ownership and Control: A study of the Central Electricity Board, British Broadcasting Corporation and London Passenger Transport Board.—T. H. O'Brien. (1937, Brit.)
1323 Elementary Applied Mechanics.—A. Morley and W. Inchley. (1936, Brit.)
1325 Control of Overheads.—Management Research Groups. (1937, Brit.)
1326 Conduction of Electricity in Solids: Report of Conference on.—Physical Society. (1937, Brit.)
1327 Fundamentals of Vacuum Tubes.—A. V. Eastman. (1937, Amer.)
1328 Machine Drawing: For Students of Electrical Engineering.—A. Bridge. (1937, Brit.)
1329 Television Up-to-Date.—R. W. Hutchinson. (1937, Brit.)
1330 Book of Practical Television.—G. V. Dowding. (1935, Brit.)
1331 Elements of Co-ordinate Geometry: Cartesian Co-ordinates, Trilinear Co-ordinates, etc.—S. L. Loney. (1933, Brit.)
1332 Boiler Management: Maintenance and Inspection.—H. G. Armstrong and C. V. Lewis. (1937, Brit.)
1333 Business Statistics and Statistical Method.—H. J. Wheldon. (1936, Brit.)
1334 Graphic Methods for Presenting Business Statistics.—J. R. Riggleman. (1936, Amer.)
1335 Elements of Statistics with Applications to Economic Data.—H. T. Davis and W. F. C. Nelson. (1935, Amer.)
1336 Graphs: How to Make and Use Them.—H. Arkin and R. R. Colton. (1936, Amer.)
1337 Principles of Road Engineering.—H. J. Collins and C. A. Hart. (1936, Brit.)
1338 Writing of Clear English: for Students of Science and Technology.—F. W. Westaway. (1936, Brit.)
1339 Symbols for Thermodynamical and Physico-Chemical Quantities and Conventions Relating to their Use: Report of Joint Committee on.—Chemical, Faraday and Physical Societies. (1937, Brit.)
1340 Generation, Transmission and Utilization of Electric Power.—A. T. Starr. (1937, Brit.)
1341 Modern Foremanship.—T. H. Burnham. (1937, Brit.)
1342 Noise.—A. H. Davis. (1937, Brit.)
1343 Elementary Engineering Science.—A. Morley and E. Hughes. (1937, Brit.)
1344 Electricity and Magnetism for Degree Students.—S. G. Starling. (1937, Brit.)
1345 Electric Light, Starting and Ignition for Motor Vehicles.—A. M. Codd. (1937, Brit.)
1346 Working Principles of Motor Vehicle Lighting and Starting.—W. C. Stoddart. (1932, Brit.)
1347 Modern Physics.—H. A. Wilson. (1937, Amer.)
1348 Sound.—E. Nightingale. (1933, Brit.)
1349 Physics: An Introductory Text-book.—H. J Taylor. (1937, Brit.)
1350 Sound.—A. T. Jones. (1937, Amer.)
1351 Science and Music.—Sir Jas. Jeans. (1937, Brit.)
1352 Text-book of the Differential Calculas.—S. Mitra and G. K. Dutt. (1937, Brit.)
1353 Introduction of Office Machinery into Government Departments.—F. W. Fox. (1936, Brit.)
1354 Heat, Light and Sound.—R. G. Shackel. (1933, Brit.)
1355 Intermediate Algebra.—S. E. Urner and W. B. Orange. (1937, Amer.)
1356 Elementary Theory of Operational Mathematics. E. Stephens. (1937, Amer.)
1357 Light: Principles and Experiments.—G. S. Monk. (1937, Amer.)
1358 Bessel Functions: Functions of Orders Zero and Unity.—Committee for Calculation of Mathematical Tables. (1937, Brit.)
1359 Copper in Cast Steel and Iron.—Copper Development Association. (1937, Brit.)
1360 German Copper and Brass Welding Practice.—Copper Development Association. (1937, Brit.)
1361 Television Reception Technique.—P. D. Tyers. (1937, Brit.)

New Editions.

458 Mathematical Theory of Electricity and Magnetism.—J. H. Jeans. (1925, Brit.)
855 Alternating Current Electrical Engineering.—P. Kemp. (1937, Brit.)
961 Strength of Materials: a Text-book covering the Syllabuses of the B.Sc.(Eng.), A.M.I.C.E. and A.M.I.Mech.E. Examinations on the subject.—F. V. Warnock. (1937, Brit.)
975 Radio Engineering.—F. E. Terman. (1937, Amer.)
1021 Wireless: Its Principles and Practice.—R. W. Hutchinson. (1937, Brit.)
1122 Television: Theory and Practice.—J. H. Reyner. (1937, Brit.)

Local Centre Notes

North Wales Centre

The third meeting of the 1937-1938 Session was held at 2.30 p.m. in the Assembly Room, Chamber of Commerce, New Street, Birmingham, on Thursday, 9th December, 1937. In the absence of the Chairman, the Vice-Chairman of the Centre, Mr. J. H. Watkins, presided over a record attendance of approximately 220 members and visitors, the latter including Mr. J. L. Parry, Telephone Manager of the new Birmingham Area, Mr. J. Grindley, Asst. Postmaster-Surveyor of Birmingham, representatives of the Chester and Gloucester District Managers' staffs, representatives of the Telephone Manager's Traffic and Sales staffs, and representatives of the Postmaster-Surveyor's staff, etc. A warm welcome was extended by the Chairman to nine new members, bringing up the strength of the Centre to 302, and also to the large number of visitors.

The large gathering had met together to hear a paper of common interest, Mr. W. R. Tyson, B.Sc. (Eng.), A.M.I.E.E., Telephone Manager of the Lincoln Telephone Area, reading his paper " An Introduction to Telephone Area Working." The paper was of especial interest as the Birmingham Area had been inaugurated on the Monday of the same week as the lecture.

Mr. Peck, Asst. Suptg. Engineer of the North Wales Centre, opened the discussion and congratulated Mr. Tyson upon the way in which he had explained the setting up and working of a Telephone Area, following with questions upon certain aspects of the work. Many speakers took the opportunity to discuss the paper, the meeting terminating with a hearty vote of thanks to Mr. Tyson at 5.30 p.m.

The fourth meeting of the session took place at Morris's Ballroom, Pride Hill, Shrewsbury, at 2.30 p.m. on Thursday, 27th January, 1938. The Chairman, Mr. H. Faulkner, presided over an attendance of 120 members and visitors and announced that the membership of the Centre stood at 315 as a result of the addition of 13 new members. After welcoming visitors and new members, Mr. Faulkner called upon Mr. L. G. Semple, B.Sc. (Eng.) of the Engineer-in-Chief's Office to read his paper entitled " The Control Centre as the Basic Executive Unit."

Mr. Semple first apologised to the Centre for the fact that no copies of the paper were available owing to his recent return from America, and pressure of work since. He explained that the paper proper had not yet been fully written and he proposed to speak extempore from "a few scrappy notes that he had pushed together." The " few scrappy notes " resolved themselves into a brilliant lecture and Mr. Semple gave many interesting comparisons between the telephone administrations in America and this country.

Mr. Peck opened the discussion, congratulating the Speaker on the excellent way in which he had woven a fine paper around a few notes. He passed on to point out that this District had had the privilege to take part in the initial experiments with Control Centres, but not to the extent illustrated by Mr. Semple as being in operation in the Scottish Region at Edinburgh. Many members took the opportunity to discuss the paper and the meeting finally terminated at 5.35 p.m. with a hearty vote of thanks to Mr. Semple, which was passed by the assembly in the customary manner.

The fifth meeting of the session took the form of a joint meeting with the South Midland Centre of the Institution of Electrical Engineers, taking place at the usual Birmingham meeting place at the Chamber of Commerce, on Tuesday, 8th February, 1938. The meeting was timed to start at 7.0 p.m. but members of both Institutions renewed acquaintance at the buffet tea which was served in the smaller portion of the Assembly Room at 6.15 p.m.

The Chairman, Mr. H. Faulkner, who is also Vice-Chairman of the South Midland Centre of the I.E.E., presided over an attendance of approximately 120 of whom 50 were members of the I.E.E. A warm welcome was extended by the Chairman to all the members of the I.E.E. and the visitors, among whom were Col. Reid of Headquarters, Mr. J. Entwistle of the Simplex Electric Co., Mr. Turner of Walsall Conduits, Ltd., Mr. J. Coxon, M.I.E.E., late of the Engineering Department, etc. A welcome was also extended to five new members including Mr. J. L. Parry, Telephone Manager of the Birmingham Area who becomes our first Associate Honorary Member. The Centre membership now stands at 320, an increase of 50 since the start of the Session.

The Chairman then called upon Mr. C. G. A. McDonald and Mr. F. C. Carter to read their joint Paper " Electrical Services to Large Buildings," the paper dealing in general with the system of underfloor ducts for electric light and power and communication services, which the Department is sponsoring. A fine display of the ductwork and accessories was on view in the hall, being kindly loaned and arranged by Messrs. Walsall Conduits, Ltd., one of the makers. The reading of the paper was undertaken by Mr. F. C. Carter, and Mr. McDonald replied to the discussion.

At the conclusion of the reading the Chairman asked Mr. Hooper, Chairman of the I.E.E., to open the discussion. Mr. Hooper thanked Messrs. McDonald and Carter for a very interesting paper, also the I.P.O.E.E. for their invitation to the evening's meeting. He thought that the underfloor duct system was long overdue and suggested that a précis of the lecture should be circulated to electrical contractors, etc. Col. Reid next spoke congratulating the Centre on the idea of a joint meeting between the I.E.E., and I.P.O.E.E., and thought that the idea should be extended over the whole country. He stressed the extending use of electric power in telephone practice bringing many common problems to the two sections.

The meeting was then thrown open to general discussion which rapidly defined itself into two camps, for and against the system, with many interesting arguments.

Mr. McDonald effectively dealt in a few choice words with many of the arguments against the scheme and pointed out that the idea was a step in the right direction. The general meeting terminated at 9.15 p.m. with a hearty vote of thanks to the Authors.

In honour of the occasion the Chairman and Committee of the I.P.O.E.E. entertained the principal visitors and the Committee of the I.E.E. to supper at the White Horse Hotel, Birmingham, at the conclusion of the meeting.

S. T. S.

Scottish Centres

The Co-ordinating Committee of the Scottish Region have decided to award a prize of the value of £1 to the student taking first place in each grade of Telephony, Telegraphy and Transmission at each of the Post Office Workmen's Classes held within the Scottish Region.

Prizes will be awarded during the current Evening Class Session to the following classes :—

Glasgow	*Edinburgh*	*Aberdeen*
Telephony I.	Telephony I & Telegraphy I. combined	Telephony I.
Telephony II.		Telegraphy I.
Transmission I.	Telephony II.	

The prizes will be known as the Scottish I.P.O.E.E. Prizes and funds for their provision are being raised by subscription from members of the Institution in Scotland of the grade of Assistant Engineer and above.

South Midland Centre

RETIREMENT OF MR. T. CORNFOOT

On March 2nd at the close of the final meeting of the South Midland Centre's 1937-38 session, Mr. E. S. Francis, Assistant Superintending Engineer, reminded those present that it was the last meeting which would be presided over by their genial chairman, Mr. T. Cornfoot, before his retirement. Members of all grades took the opportunity to pay tribute to Mr. Cornfoot's admirable chairmanship and to the corresponding remarkable progress of the Centre in every way during his period of office.

A motion recording the deep appreciation felt by all members of the efficient yet kindly way in which Mr. Cornfoot had filled the office of chairman was carried unanimously and with prolonged applause.

In his reply Mr. Cornfoot said that if his services to the Institution had resulted in its advancement and had met with the approval of the members he felt amply repaid.

Junior Section Notes

Bristol Centre

The meetings of the Centre have been well attended during the present session. The following programme indicates the diversity of interests which are covered by the papers submitted to the Centre :—

1937—

December 6th.—" Railway Signalling." C. E. A. Iles.

1938—

January 10th.—" Mining." E. Moore.

February 7th.—" Carrier Telephony." D. B. H. Elms.

March 7th.—" Summary of U/G Construction." H. Howe.

April 4th.—Competition Night (10 min. papers and prizes of £1 1s. and 10s. 6d. awarded).

Chichester Centre

We are pleased to note that a Local Centre has been formed at Chichester under the chairmanship of Mr. G. P. Sait, with Messrs. F. W. Greenaway and H. J. Robinson as Treasurer and Secretary respectively.

Dundee Centre

Meetings of the Centre were not held during the 1936/37 session. The assimilation of Regional conditions and the rapid growth of work involved a good deal of overtime and late work and it was not found possible to hold meetings. The Centre was kept in being by a few enthusiasts however, and they have been rewarded by a very large increase in membership this session. The membership now stands at 70.

Meetings have been held on 6th December, 6th January and 8th February.

At the first meeting Mr. W. S. Procter, Area Engineer, gave an interesting lecture on " Transmission," in the course of which he explained the terms Sound, Sound Waves, Speech Attenuation, Distortion and Transmission Units. The lecture was illustrated by lantern slides and Mr. Frew, of the Engineer-in-Chief's Research Station, demonstrated the oscillograph. At the meeting Mr. R. B. Rae, Telephone Manager, presented the Imperial Service Medal to Messrs. A. Taylor and G. D. Milne who recently retired from the service. There was an attendance of nearly 100.

A paper on the " 200 Point Line Finder " was read by Mr. W. S. Grant, Unestablished Workman, at the second meeting when there was also an attendance of over 100. Mr. Grant held the interest of the meeting as he traced the history of the present switch from its inception and described the economic aspect of present day plant provision.

The third meeting was attended by 60 members, when Mr. S. J. Smith the recently appointed Area Engineer read an interesting paper on " Trunking and Grading." The paper was full and instructive and was illustrated by lantern slides.

Discussion was well maintained at each of the meetings. Our members are showing a keen appreciation of the technical education to be obtained through the medium of the Junior Centre.

Edinburgh Centre

The members were privileged to visit the Edinburgh Fire Station on the evening of December 17th, 1937, when much that was of interest was explained by the Firemaster, and the Chancelot Flour Mills on the 20th January, 1938, when an efficient set of guides explained the process of Flour Milling and the sub-products extracted at the different stages.

Mr. J. McIntosh, Area Engineer, was unable to read his paper on Unit Construction Costs before the Centre on January 24th, but we were fortunate in securing a paper on Country Satellite Exchanges by Mr. D. Justice from the Regional Training School.

Arrangements were made to hold the February meeting on a Friday to enable the Evening Class students to attend the meeting. It is hoped this will result in a larger attendance for Mr. W. P. Davidson's paper on Units Auto No. 13.

Exeter Centre

The membership of this Centre has suffered some considerable reduction by reason of promotions, but the interest has been well maintained and it is hoped that the forthcoming session will show an increase over the previous membership. The programme for the session was as follows :—

1937—

October.—" Promotion." W. E. Walton, A.M.I.E.E.

November.—" U.A.X. 13." T. Foster.

December, 1937.—" Maintenance Control." F. Squires.

1938—

January.—" Wireless in the R.A.F." F. Chave.

February.—" Underground Cable." Coles.

March.—To be announced later.

Fenny Stratford Centre

The following papers have been given to the Centre this session.

1937—

September 30th.—" Gas in Underground Plant." E. T. Goodwin (Luton).

October 14th.—" Sound and Hearing." F. Palin.

November 11th.—" Sound and Hearing applied to The Department's Apparatus." G. H. Wash.

December 9th.—" Air Raid Precautions applied to the Department's Plant." W. E. Everson.

1938—

January 13th.—" The Transmission of Electrical Energy." R. S. Gosling (Resident Electrical Engineer, Bletchley).

All meetings have been well attended and the members have much appreciated the papers.

Discussion nights have also been held to discuss points of difficulty encountered in the lessons of the Correspondence Courses for Workmen.

The papers still to be given are :—

March 10th.—" Underground Construction." C. H. R. Almond.

April 7th.—" Motor Transport." E. W. Hancox (Mechanic-in-Charge, Bletchley).

The Officers of the Centre are :

Chairman : W. E. Everson.

Vice-chairman : E. E. Griggs.

Secretary and Treasurer : F. Palin.

King's Lynn Centre

The second half of the session was opened on Thursday, 13th January by a lecture on " First Aid " by Mr. E. J. Easter. The lecture was immensely interesting—full scale diagrams illustrating the lecturer's points.

At this meeting the presentation to Mr. W. J. Coe (retiring Inspector) of a silver and oak barometer, and a 40 years' long service medal, was carried out by Mr. J. E. Pidgeon (Executive Engineer, Cambridge Section). Mr. H. Duffield supported Mr. Pidgeon's remarks of appreciation towards Mr. Coe's service to the Department.

Mr. Pidgeon and Mr. Duffield congratulated the Centre upon its activities and stressed the importance of that night's subject.

Also present from the Cambridge Senior Section at this meeting were Mr. H. D. Sursham, Mr. W. D. Coe, Mr. S. F. Brown, Mr. W. H. Brown and Mr. P. W. Banyard.

On Tuesday, January 25th, Mr. A. H. Triscott gave a knowledgeable lecture on " Maintenance Control " —an interesting discussion followed.

A lecture on " Overhead Construction and Maintenance " was given by Mr. P. C. Carter on Wednesday, 9th February; a large number of lantern slides terminated a really complete lecture.

Peterborough Centre

The 1937/38 session opened on October 6th, 1937, under the Chairmanship of Mr. J. Mc A. Owen, M.I.E.E. (Sectional Engineer).

The following papers have been read during the session.

1937—

November.—" Amplifiers." E. H. Overall.

December.—" Fault Abatement." J. Mc A. Owen, M.I.E.E.

1938—

January.—" Fitting—Accounting Side." C. Welch.

February.—" Heating." H. W. Sharman.

March.—" Underground Contract Works." A. H. Brown.

April.—" Carrier Equipment." R. M. Flaxman.

The membership of the Centre is now 47, a slight gain on last session, but we are hopeful that further enrolments will take place before the next session commences.

Portsmouth Centre

Contributions to the programme have, with one exception, been made by members of the Centre and a selection of subjects on the most up-to-date telephone and motor transport methods has proved very beneficial to the members. At the opening meeting of the session held on October 21st, 1937, the Sectional Engineer, Mr. T. Bagley, Chairman of the Centre, gave a very interesting address on the subject " Costing Systems."

A paper entitled " Modern Automatic Developments," was read at the next meeting on November 18th, 1937, by Mr. C. H. Hishon. This lecture was much appreciated and provided opportunity for a good constructive discussion.

At a meeting held on December 16th, 1937, Mr. J. Munday read his paper on " Advice Note Control." The subject being a new one created considerable interest and revealed some excellent qualities in its production. This was followed at the January meeting by a paper read by Mr. E. T. Smith, Mechanic in Charge, entitled "Motor Transport." Mr. Smith in his paper gave a complete description of the types of vehicle in use by the Department including engines, gear boxes and transmission systems. The exhibits with which the speaker gave demonstrations of the working of various components had all suffered from some form of abuse and many members left the meeting more careful drivers.

For the February meeting, Mr. D. R. Hishon selected the subject " Maintenance and Construction." This subject covered a very wide field and reflected admirably upon the speaker in his ability to produce a paper from his limited experience.

Arrangements for visits of technical interest to various works and undertakings are in hand and will be published for members who wish to avail themselves of the opportunity to attend. L. L. F.

Reading Centre

The Annual General Meeting was held in September, 1937, under the Chairmanship of Mr. H. Mortimer, A.M.I.E.E., Assistant Engineer, when the following programme for the 1937-38 session was arranged :—

October.—" Wireless Interference." E. Pring.

November.—" Maintenance Control." C. A. Pratt.

December.—" Development." A. F. Court.

January.—" Primary Vouchers." E. J. S. Roberts.

February.—" Transmission Over Long-distance Circuits." H. Buy.

March.—" Faults and Maintenance Costs." H. Mortimer.

In compiling the above syllabus the Committee endeavoured to cover a wide range of subjects, and judging by the attendance and discussion that took place it would appear that the session has been an unqualified success.

The membership is now 41, which is a considerable increase over the 1936-1937 session, and it is hoped, in view of the number of visitors who attended the monthly meetings, that there will be a further increase in the membership during the forthcoming session.

Thanks are due to the various speakers for their kindness in preparing and reading the papers and also to our Chairman (Mr. H. Mortimer) and Secretary (Mr. H. F. Butler) for their zeal and energy in helping to make a success of the session. The Committee feel that the opportunities offered through the membership of the Junior Section by the use of the library, etc., are such that warrant the very close interest of the staff, particularly the very junior members.

The programme for the forthcoming session will shortly be under consideration and the Committee will welcome any suggestions or offers of papers from members.

Shrewsbury Centre

On 16th December last, a meeting of the above Centre was held, and Mr. G. Hughes, Radio Investigation Officer, gave a paper on "Wireless and Wireless Interference." During the reading he introduced some interesting letters and photographs, the latter depicting electrical apparatus, and the original wireless set invented by Professor David Hughes, a pioneer in wireless research. He was uncle of the late J. D. Hughes of Corwen, a well-known composer of Welsh music (the father of our member), and he himself was also Professor of Music. In the letters which were written in 1896 to Mr. J. D. Hughes, the Professor states that he had just completed an improvement to his telephone apparatus, and goes on to say that scientific research did not pay, although when he died in 1900, he left £400,000 to London Hospitals. Incidentally he was living then on the spot on which now stands Broadcasting House.

Taunton Centre

The interest in this Centre has been maintained at a high standard during the session and the following programme indicates the wide field which is covered by the papers presented to members :—

1937—
- October 14th.—"Local Line Development." A. W. Brett.
- November 18th.—"Underground Cabling." W. S. Lock.
- December 2nd.—"'The Grid,' S.W. England and S. Wales." C. Morley New.

1938—
- January 13th.—Open Date.
- February 10th.—"Twelve Channel Carrier Cables." C. Riley, E.-in-C. Office.
- March 3rd.—"Auto. Exchange Construction." R. Delafield.
- April 7th.—"Drawing Office Procedure." J. E. Tibbitts.

Torquay Centre

The programme for this Centre during the past session was as follows :—

1937—
- October 10th.—"Promotion." W. E. Walton, A.M.I.E.E.
- November 10th.—"Electrical Interference With Broadcast Reception." P. W. Crouch.
- December 15th.—"Overseas Radio Services." H. Trussler.

1938—
- January 12th.—"U.G. Schemes Including Contract Work." P. Swann.
- February 16th.—"Totnes Unit Auto. No. 7." E. J. Travers and J. Davidson.
- March 16th.—Ten-Minute Competitive Papers.

The interest in the Centre has been well maintained and it is anticipated that the session will close with a membership of fifty.

District Notes

London

HOUSE OF COMMONS CALL OFFICES

The suites of telephone call office cabinets in the House of Commons, situated as they are in very quiet lobbies and passages, have to be as acoustically perfect as practicable combined with reasonable ventilation. Although the cabinets installed are for this reason necessarily better in this respect than those at railway stations and post offices where the external noise level is much higher, overhearing has been possible between the inside and outside of the boxes. Experiment showed that considerable improvement could be effected by raising the height of the cabinets by 12 inches and providing an inner surface lining of cellular Paxfelt over the ceiling and half-way down the sides. To ensure that there should be no sound leakage at the door jambs a seal of ½-in. sponge rubber has been fitted round the door joints. Further, the glazing of the doors has been replaced by double ¼-in. panes. The combined effect of increased sound absorption within the cabinets and the provision of effective resistance to sound through and round the doors has resulted in attenuation between the inside and outside of the cabinets being raised to 35 db. and that between the cabinets to 40 db. In addition, improved lighting and ventilation has been installed in the form of a combined ceiling fitting.

FAREWELL GATHERING AT DENMAN STREET

The London Engineering District staff at Denman Street, who are being transferred to Waterloo Bridge House, Cornwall House, etc., in consequence of the approaching Regionalisation scheme, commemorated the break-up by a Farewell Gathering at Denman Street on Thursday, December 16th, 1937. The function, which was attended by over 500 proved very successful and enjoyable.

Tea at 5 p.m. was followed by a Concert which included items by Mr. J. W. Kimber, Mr. A. Gamgee and the Kew-ites Concert Party (directed by Mr. Bill Barnes) and concluded with Dancing till 11 p.m.

R. G. de Wardt, Esq., Chief Regional Engineer presided and was supported by E. Gomersall, Esq., O.B.E., Regional Director, London Telecommunications Region, and other members of the Board.

During the Concert, Mr. de Wardt, who addressed the meeting as "Boys and Girls" in preference to the orthodox "Ladies and Gentlemen" referred to the growth of the London Engineering District since 1916 when Denman Street was opened by Sir William Slingo, and to the circumstances which necessitated the impending changes. He was confident that the staff would carry with them into their new homes that same spirit of good-fellowship which has always been so strongly evident. He welcomed the opportunity of thanking the staff for their great assistance and loyalty to him during the past 15 months.

Mr. Gomersall spoke in a reminiscent vein of happy times at Wandsworth Common and at Denman Street. He expressed admiration for the staff and the manner in which they sought happiness, i.e. by " ceaseless activity in congenial surroundings." With regard to Regionalisation he stated that the proposals for the remainder of the Region are now undergoing criticism at Headquarters.

Mr. de Wardt in his closing remarks thanked the Committee, the artistes, the stewards and stewardesses, and the Refreshment Club staff for the successful organisation of the party.

Mr. C. A. Edwards on behalf of all acknowledged with gratitude these appreciative remarks and expressed the hope that the remainder of the evening would be equally enjoyable.

The proceedings terminated with singing " Auld Lang Syne."

GIPSY HILL AUTOMATIC EXCHANGE

This exchange was brought into service at 1.30 p.m. on December 15th, the subscribers being transferred from the Gipsy Hill exchange (old Sydenham), Streatham, and Brixton. The new exchange is housed in a building of pleasing design situated at a cross roads. The ultimate capacity is 10,000 lines, initially the exchange was opened with 4,000 multiple, and 3,740 calling equipments. It is interesting in passing to review the history of Sydenham manual exchange which is now being rapidly recovered in order that the Regional School may be extended. The exchange was opened some 30 years ago, and during the conversion of London to automatic working has formed the nucleus of three automatic exchanges, Forest Hill, Sydenham, and lastly Gipsy Hill.

REIGATE AUTO. EXCHANGE TRANSFER

The above exchange, the first of the 2,000 selector type in the L.E.D., was opened successfully on December 8th, 1937, in the presence of the Mayor and Corporation of Reigate and the Regional Director. The number of subscribers transferred was 1,350.

WOLDINGHAM UAX

The above UAX of No. 7 type was opened on January 12th, 1938, with 260 subscribers. The new scheme of Parallel Battery Float is employed at this exchange.

FUNGUS

It would be interesting to learn how many cases have been found where fungus growths have appeared in manholes. There is only one case within our knowledge and it has certain peculiarities which render the origin of the growth somewhat obscure. The manhole concerned is of a modern type, brick built, with plated roof, and is less than three years old. The appearance of the growth is of a comparatively recent date and its origin might normally have been ascribed to the presence of a large stables belonging to a railway company within 50 yards. This possibility has been over-ruled by the fact that other older manholes closer to these premises have not suffered in the same way.

The fungus growth has a woolly appearance, and when first discovered, only recently, it had crept over the walls at one part to an area which was almost two feet in diameter.

No growth was apparent on the previous inspection of the manhole, which took place only two months before, and on a second inspection two weeks later, the original growth had disappeared and several new growths had shown themselves in other parts of the manhole. The fungus had crept over the cables a foot or two from the mouths of the ducts and had dried up in the form of a dried tobacco leaf. The growth within the duct was of the same type for about two feet inside, but beyond this the fungus showed its previous white woolly characteristics.

On the face of it, there would not appear to be any special significance in this growth, for the form is of the usual type associated with dampness, but since it does not appear in other manholes which cannot be said to be free from damp in any degree, there is some possibility that unusual conditions have arisen to promote the growth. The manhole in question is an exchange manhole and the exchange side of the ducts are sealed in the usual manner. It is possible, therefore, that there is an absence of sufficient ventilation and that the stagnant air gives rise to these exceptional conditions.

North Wales

BIRMINGHAM TELEPHONE AREA

A further step in the re-organisation of the Post Office services took place on the 6th December, 1937, when the functions of the four Birmingham Sectional Engineers, and those of the District Manager, were merged and the Birmingham Telephone Area, under the managership of Mr. J. L. Parry, was created.

The occasion was marked by a gathering at Telephone House of approximately 600 members of the staffs from the Engineering Department, Postmaster Surveyor's and District Manager's Offices. In addition, most of the Head Postmasters in the new area were present.

Mr. T. B. Braund, the Postmaster Surveyor explained the objects of the new organisation, and indicated some of the advantages which would accrue to both the public and the Post Office.

Mr. H. Faulkner, Superintending Engineer, North Wales District, commenting on the change, indicated that the correct method of approach to it was to regard both the Sectional Engineer's and District Manager's organisations as dead and that an entirely new regime had been set up.

Mr. J. L. Parry was then formally introduced as the new Telephone Manager.

Tea followed, which gave opportunities for the renewal of old friendships and the making of new.

South Midland

THE DIAL COMES TO CARISBROOKE

High over the old town of Newport, the Metropolis of the Isle of Wight, the ancient Castle of Carisbrooke rears its frowning battlements. This old pile has seen many stirring events in the Island's history. Renowned as a stronghold in far-off times, it sheltered, as a prisoner, the luckless Charles I, and his infant daughter, Princess Elizabeth, who, being kept in confinement there after his execution, died there in 1650. For many years the modernised portion of the interior has been used as the official residence of the Royal Governor of the Island, and it is in these apartments, redolent of the chivalry of the Cavaliers, and full of grimmer memories of the Roundheads, that the ubiquitous dial has, in 1938, made its appearance.

The automatisation of Newport is but a step in the conversion programme in the Isle of Wight. It may surprise many readers to know that, despite its generally rural and " holiday " atmosphere, the island supports nineteen telephone exchanges serving the needs of nearly 90,000 regular residents. In the peak of the holiday season this figure is nearly doubled by visitors, and the telephone traffic at this time is very aptly described as " seasonal." Certain able statisticians periodically publish a very interesting and unique statement about the Garden Isle. They say that the entire population of the world could find ample standing room therein (or thereon).

It is, however, suggested that from the point of view of the communications engineer, the Isle of Wight is an ideal training centre for the young of that species. A brief resumé of the possible telephone (and telegraph) engineering activities that are available may be convincing. Of the nineteen telephone exchanges previously mentioned, three are of the modern provincial non-director type, one under construction is a U.A.X. No. 14, another is a U.A.X. No. 13, there are four U.A.X.'s of the No. 12 type, and three, due for early conversion, of the No. 5 type. This is fairly representative of modern provincial automatic practice.

Of the remaining seven exchanges, worked at present on a manual basis, but scheduled for eventual conversion, two are of the C.B.10 type, and the others C.B.S. No. 2. Three of the C.B.S. No. 2 exchanges will be converted within the next two years, and the remainder within four years, according to present programmes, when the automatisation of the Isle of Wight will be complete.

The bulk of the long distance traffic is effected via a modern sleeve control manual board at Ryde, where also is situate a telegraph instrument room complete with teleprinters, etc. There is no repeater station located in the Island, and this is possibly the only major telephonic activity that is not represented, although terminal amplifiers, the repeater's poor relation, are installed at two exchanges.

All classes of underground construction in all kinds of geological strata may be encountered, from the impenetrable rock of the southern cliff areas to the blue slipper clay found in profusion in some of the inland centres, Newport in particular. Again, in the southern part of the Island, large sections of duct, have, in past years totally disappeared due to coast and cliff erosion, and this brings its specific problems for the consideration of the telephone engineer.

From a cabling point of view the choice is still more diversified. All the more common classes of cables for subscribers' services can be found, and in addition to these, and the more complex composite junction cables and loaded cables, the engineer in the Isle of Wight has to have a fair working knowledge of submarine cable technique, both in tidal and non-tidal waters. Subaqueous cables are maintained under rivers, and, of course the whole of the ordinary telephonic communication with the mainland is effected via submarine cables. These are present in various types, and the local engineer must be prepared to carry out " shore end " work when required.

Submarine cables of the P.C. Lump-Loaded and P.C. Continuous Loaded types are maintained, and one prehistoric survival in the shape of one of the early types of gutta-percha insulated cables is still in use for teleprinter circuits.

A Post Office " Ship to Shore " Wireless Station at Niton, on the southern coast, is partially maintained by the local Engineering staff, as is also the antenna of a Direction Finding station situated on the top of a cliff near the wireless station. The aerial masts at Niton W. T. S. are of lattice steel-work construction, and they were erected by an ordinary " heavy construction " gang impressed from local sources. They are 160 feet in height, and the periodical inspection and painting is a part of the local maintenance load of the Engineering Inspector at Ryde. Incidentally, it might be mentioned that a wind velocity in excess of 100 miles per hour has been recorded at the Lloyds Signal Station, situated next door to the Post Office Wireless Station at Niton, so that the time-worn explanation, " due to storm damage " is occasionally employed with unimpeachible accuracy in this locality. Up to a few years ago a telephone circuit from a shore exchange to the Lighthouse on the " end one " of the famous " Needles " rocks was maintained by the local staff. The circuit was run via submarine cable, but the conditions were consistently too rough to permit of a service without interruption, and the circuit was abandoned, much to the relief of the local jointers and linemen. It was a nightmare experience to go out to the Lighthouse in any sort of weather, as many conflicting currents made the waters perpetually rough, and only a very small boat could approach the light sufficiently close to permit landing at the base of the tower.

Perhaps sufficient has been said to indicate that the Isle of Wight though insignificant from a telephone engineering viewpoint in point of size, is nevertheless a place where a comprehensive experience of most phases of telecommunication work may be gained.

F. J. G./PT.

South Wales

RETIREMENT OF MR. H. J. HUNTER

In January the South Wales District lost in the person of Mr. H. J. Hunter, M.I.E.E., Assistant Superintending Engineer, a highly esteemed officer. He came to the district from Plymouth in 1924, to occupy the position of sectional engineer of the now defunct Newport section, and was promoted to assistant superintending engineer at Cardiff, in 1930. He was one of the rapidly diminishing band of officers who entered the Department by examination from the telegraph side and became a sub-engineer. Having served in this capacity for some years at Manchester and Leeds he proceeded to Plymouth as a second-class engineer, during which period he was busily engaged upon coast defences and the many-sided activities of an engineer in a naval area. He, therefore, brought to the South Wales district an experience which, in many ways, was unique. His knowledge of Departmental procedure was uncanny, and this knowledge has stood him, and those who sought his advice, in good stead in the Department which he served so faithfully and ungrudgingly for so many years. His example of what a zealous and efficient officer can accomplish is an inspiration to all who have the well-being of the service and of their colleagues at heart.

Tributes to his many good qualities were paid by all sections of the staff at smoking concerts which were held at Cardiff and Newport on January 12th and 16th. At the former he was presented with a handsome pair of binoculars on behalf of his colleagues by Colonel Carter, M.I.E.E., superintending engineer, who, in making the presentation, expressed the hope that Mrs. Hunter's health would improve and that both of them would enjoy many years of happiness in their new home at Worthing.

H. W. G.

South Western

SCILLONIA TELEPHONE EXCHANGE

An event of some importance in the history of the Scilly Isles occurred in January when telephone communication was provided between St. Mary's and the mainland.

The service was inaugurated at a ceremonial opening of Scillonia telephone exchange on the afternoon of January 28th, by a telephone call between Major Dorrien Smith, at St. Mary's, and the Postmaster-General at Salisbury, in which reference was made to the great technical developments which had made the talk possible.

Situated some 28 miles due west of Lands End, the Isles of Scilly consist of five inhabited islands and over 100 islets. They are within easy reach of each other, and enclose an almost land-locked sea. Each island has its own individual character and atmosphere ; Trescoe is famous for its sub-tropical gardens ; Bryher, St. Martins and St. Agnes each has its own special charm, while St. Mary's, the largest of the islands, is noted for its flowers and delightful coast line.

Hitherto, the communication system on the islands has been inadequate, magneto telephones at the Post Offices and Coastguard Stations on the off-islands of Tresco, Bryher and St. Martins being teed on a single-wire circuit by submarine cables to St. Mary's, where the circuit was metallicised and teed to the Coastguard Station at Telegraph Tower and thence to St. Mary's Post Office. Similar teed circuits provided communication between St. Mary's Post Office and St. Agnes, and between the Lifeboat Offices and other Coastguard Stations at St. Mary's.

Communication to the mainland was effected by means of a sounder circuit to Penzance via a submarine cable between St. Mary's and Porthcurno.

The service, as now established, provides at present only for subscribers at St. Mary's, the trunk facilities being provided by means of radio links. It was decided that a magneto exchange at St. Mary's was the most economical way of giving service to the islands, since the establishment of separate exchanges on each island would have meant increased fault liability and difficulty of maintenance, especially in winter when access from St. Mary's is sometimes impracticable.

Operations were commenced in November, 1937, and the work accelerated throughout in order that service might be available some time prior to the opening of the flower season in February. Weather conditions generally proved to be favourable, although on a number of occasions gales of over 80 miles an hour were experienced.

FIG. 1.—TRENCHING OPERATIONS.

The external work involved the laying by direct labour of over 1½ miles of 3-in. S.A. duct, forty casual labourers being employed on this work. Fig. 1 indicates the rock met with and it was necessary to use an Ingersoll Rand Compressor and Warsop Rock Breakers and Drills. In this comparatively short section approximately 80 lbs. of explosives were used for blasting. The external work on the mainland involved extensive reconstruction of the Penzance-St. Just overhead route in order to

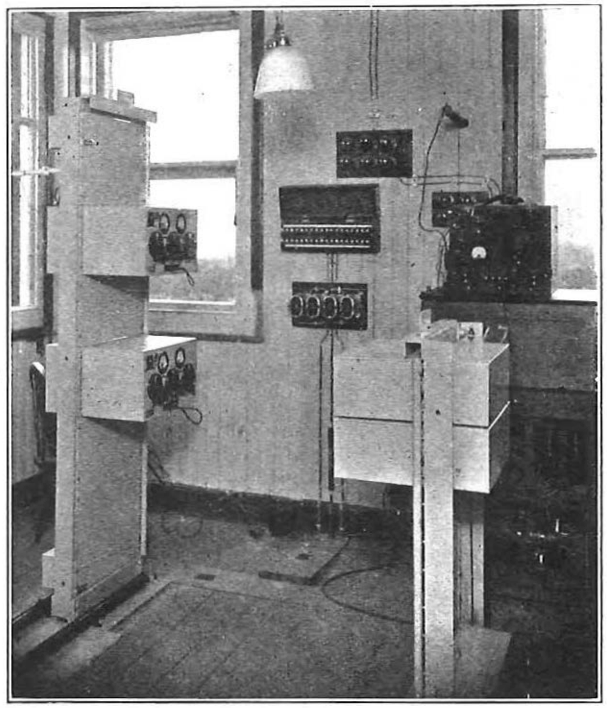


FIG. 2.—RECEIVER, ST. MARY'S RADIO STATION.

accommodate the two 4-wire circuits between Penzance exchange and the Radio Station.

Communication with the mainland is effected by means of ultra short wave radio channels working on wave lengths between 4 and 5 metres. The Radio Station at St. Mary's is located at the Coastguard Station, Telegraph Tower, and that on the mainland, in a new building of modified U.A.X. type, near St. Just. The equipment comprises very low-powered crystal controlled transmitters and super heterodyne receivers with crystal controlled oscillators. The radio equipment (Fig. 2) is entirely mains operated.

The aerial system at each site consists of multi-element arrays supported by 60 ft. poles, each array comprising 16 elements and reflectors. There are two transmitting and two receiving aerials.

Two radio links have been set up initially and a carrier channel together with testing equipment may be added later. During the day one circuit is used for telephone traffic, and the other for teleprinter working, while at night both circuits are used for telephone traffic. The telegraph circuit whereby the teleprinters at St. Mary's and Penzance are operated directly over the radio link, is the first of its kind in the country.

Structural alterations at St. Mary's Post Office preceded the installation of the 100 line magneto switchboard (Fig. 3), signalling terminations, batteries and power equipment. The 4-wire terminations at Penzance and St. Mary's were installed by contract and the Department installed the 500/20 ringers and associated rectifier

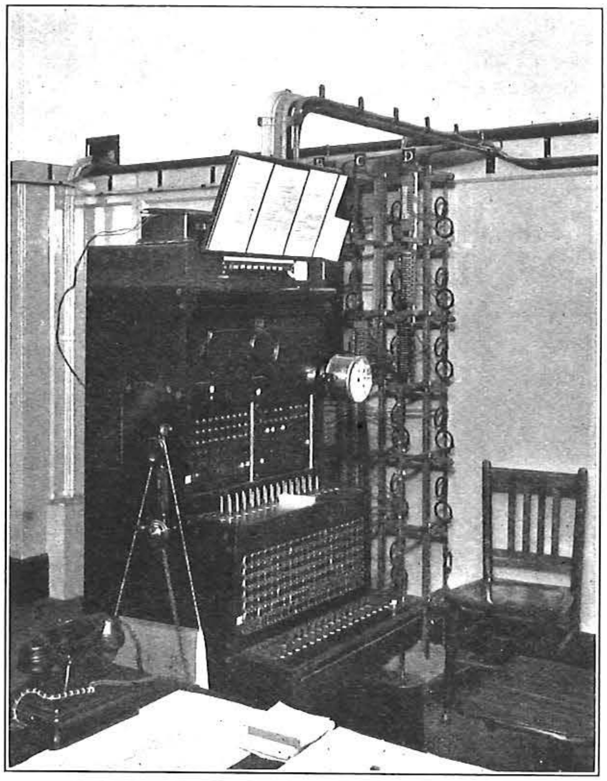


FIG. 3.—100 LINE MAGNETO SWITCHBOARD.

equipment. Two 24-volt and two 130-volt batteries for filament and anode supplies to the terminating equipment have been provided at both exchanges.

At the time of writing 38 subscribers and two kiosks are connected to the new system and there is little doubt that the service now given will considerably stimulate telephone activity on the islands.

CHESIL BANK, DORSET

Construction of a somewhat unusual character was involved at Chesil Bank, which is a pebble beach extending from Portland to Bridport, a distance of some 15 miles. A section of the beach, which is no doubt well known to tourists, is used for a Bombing Range, and is separated from the mainland by tidal water about half mile in width.

The work consisted of laying ·625 miles of subaqueous cable, 8 core, 42 wire/55, from the mainland to the Chesil Bank, and the erection of overhead line along approximately 6 miles of pebble beach along which no form of mechanical transport was possible. Owing to the very exposed position of this route special consideration was given to the design of the pole route to reduce the fault liability to a minimum, and to the most economical method of carrying out the work. It was finally decided to erect 16-ft. light poles, with 40 yards spans, and 150-lb. insulated J. wire. Approximately 290 poles were required and these were conveyed to a point on the beach near Portland, placed in the water and formed into rafts, each raft containing about 80 poles. In this formation they were floated on the tide and unloaded one by one, at the points of erection which had been previously marked along the beach.

All other stores were rowed across in a small flat-bottomed boat from the mainland to the beach by Departmental labour. As it was impossible to hire a suitable boat for less than 30s. per week and the work was estimated to last from six to eight weeks, one was purchased at Weymouth for £5. The use of any form of motor boat on this water is strictly forbidden.

Before poling was commenced the various methods of erecting poles and stays were examined and the times observed, and it was finally decided to use empty road tar drums with the top and bottom portions removed. A moderate quantity of drums was provided free by the Public Road Authority. These drums were gradually forced down in the running beach by "spooning" out the shingle from inside until a depth of from 3 ft. to 3 ft. 6 ins. was reached. Each pole was then stood in a drum and a layer of about 6 ins. of concrete placed at the bottom of the drum around the pole; the drum was then withdrawn from the excavation and lifted over the top of the pole, in readiness for use in a similar manner at the next pole hole. The shingle was then levelled and the operation completed by pouring a liberal quantity of cement wash over the shingle around the pole at surface level. This method of construction should give reasonable stability to the pole line.

Each drum was used on an average for the erection of four poles by which time it became buckled and unfit for further use, when it was left in situ.

Stays were provided on a liberal basis and each stay block was concreted in, timber being used to shore up the sides of the excavation.

Arms were fitted to the poles before erection, and then removed to allow the drum to be passed over the pole and were finally fitted after the pole was erected.

The wiring work was straightforward, but much time was spent in trudging along this loose beach, and in transporting 16 men and stores daily across the half mile of water separating the mainland from the beach. As there were no other means of approach the ineffective time was exceptionally high, and although these conditions produced considerable fatigue, it was carried through by the very willing help of all concerned at a reasonable cost.

Shingle from the beach and sea water was used in making the concrete, the cement and sand being purchased on the mainland and transported across to the beach by the Department's rowing boat.

The laying of the Subaqueous Cable was a still greater problem owing to the extreme shallowness of the water, which, along the track in which the cable had to be placed, was only 12 ins. deep at normal high tide. At low tide the mud was exposed and as this was several feet deep it was essential that, whatever means was adopted, there must be no risk of the craft used running aground.

It was therefore decided to await a "Spring" tide which increased the depth of water to 18 ins. In the meantime enquiries were made to ascertain whether a suitable shallow draught barge was available for hire. One was found, and after calculating the "displacement" under "load" conditions, it was found that at springtide there should be from 1 in. to 2 ins. clearance between the barge keel and the mud. This course was therefore adopted.

Floating the cable across this water supported by empty drums was impracticable owing to the strong tide. The length of cable would also have made this method too unwieldy, the flow of the tide being at right angles to the course of the cable. The load on the barge consisted of the drum of cable weighing approximately 3 tons and 10 men, comprising the crew and Department's staff.

A 1 in. rope was placed across the half mile of water from the mainland to the beach on the previous high tide and secured at each end for use as a tow line to manhaul the barge across later, allowance being made for the deviation which would occur as a result of drift due to the tide. In the meantime the cable drum was loaded on to the barge at Weymouth and " jacked up " ready for paying off. The barge was floated into position at the beach end at Chesil Bank and remained there in readiness for the spring tide. The time of high water was about 10.30 p.m., and at 10 p.m. the word was given to commence cable laying so that advantage would be derived from the relatively " slack " water between 10 and 11 p.m. The whole operation was carried out according to plan, the barge being hauled across in one hour, and a reasonably straight course maintained. When the shore end of the cable was landed a " bight " of cable was made fast on shore, the barge was also made fast for the night and work was suspended until the following day. It only remained to unload the surplus cable the following morning, unload the drum, discharge the barge and terminate the cable in the standard manner, this completing an unusual and very successful operation.

STORM DAMAGE—DECEMBER 7th-8th, 1937

A snowstorm which occurred during the night of December 7th-8th, 1937, caused extensive damage to all the overhead plant in the north-east portion of Bournemouth Section, all main lines and roughly 90 per cent. of the subscribers' circuits in this area being effected, with several exchanges isolated.

Approximately 1,500 circuits were reported out of order, and the repair work consisted of the erection of approximately 80 poles, 506 miles of wire, 400 stays and stay wires and a considerable amount of wire regulating and resetting poles.

Isolated exchanges were given prior attention and service was restored to them within a day or two of the storm. Permanent repairs were carried out from the outset, the whole of the Section resources being drawn upon to ensure that services were restored as promptly as possible, and the final circuit was restored on December 23rd. Four gangs were loaned from the London Engineering District and two gangs from South Wales District to augment the Section staff.

Trunk circuits carried on the pole line between Ringwood and Salisbury were transferred to the main underground cable, and a decision has since been given for them to remain there and to recover the main overhead route. Where local lines were broken down in or near towns the development aspect was investigated and in many cases restoration was effected by means of interruption cable which will remain in situ until the permanent underground cable is provided, the cost of re-erection of the damaged overhead routes thus being avoided.

By adopting these methods the whole of the work was carried out in a very economical manner and the fault liability of the restored circuits has not increased as a result of the storm.

It is estimated that restoration might have been completed earlier and a maximum saving of three days effected, had the circuits been restored temporarily, but in these circumstances the fault liability must undoubtedly have been considerably increased and would have continued so until permanent repairs were completed. The subscribers were therefore saved the annoying interruptions which invariably follow temporary repairs.

Details of the organisation it was intended to introduce in such an emergency were prepared in advance, and the smooth and efficient manner in which the repairs were carried out is attributed largely to this fact.

BRISTOL STATION SORTING OFFICE

Owing to unforeseen difficulty in obtaining building materials this office will not be completed until May next.

The large engineering works in connection with the installation of the conveyor system, and the electric light and power distribution, lifts, etc., are proceeding rapidly but many engineering difficulties were encountered when it was decided to utilise a portion of the building and conveyor installation to carry out the Christmas parcel work at this office.

The conveyor system is the great feature of the building and is connected from the ground floor through a large tunnel with all the main platforms of Temple Meads Station and all sections of the sorting office. An electrically operated system of remote control has been evolved for the various diverters and the control for this has been centralised in one control panel, so that the operator can send bags through the 390 ft. tunnel at a speed of 180 ft. per minute. He can similarly deal with incoming bags from the railway platforms and deliver them to any section of the sorting office.

Owing to the close co-operation of the supply authority a H.T. substation with three alternative supplies of 450 kW. capacity was built and completed by November but the L.T. substation equipment and conveyor control panel was not received from the contractors until two weeks prior to the date required for Christmas working. Some idea of the work involved may be gained by the fact that approximately 5 miles of wiring alone had to be installed in connection with the conveyor controls. However, by the intensive work of contractors and all concerned the work was completed and the required portion of the installation brought into use on December 20th. This ran practically continuously without any serious trouble until December 28th, and was of tremendous service to the postal staff in the handling of the Christmas traffic.

Book Reviews

"Measurements in Radio Engineering." By F. E. Terman, Sc.D. 813 pp. 475 ill. McGraw-Hill. 30s.

This volume is of American origin and is intended by the author to provide a comprehensive engineering discussion of the measuring problems encountered by radio engineers. It is designed for use both as a work of reference and as a text-book to provide the engineer with a collection of information on measuring technique and measuring equipment and to present the student in an organised and systematic form a complete picture of the laboratory methods and laboratory measuring equipment ordinarily used in radio and allied fields.

The book is divided into fourteen chapters, the first four dealing with voltage current and power circuit constants at low radio frequencies and resistance, inductance and capacitance devices. These sections contain a large amount of useful information on valve voltmeters, thermo-couples, shunts, low frequency bridges and attenuators. Only one and a half pages are devoted to radio frequency bridges and only one type of bridge is described. This seems rather inadequate treatment of one of the most important branches of radio frequency measurements on which a good deal of work has been done in recent years and on which there is a reasonable amount of published information. It is true the author gives several references to published articles, but the function of a book of this kind is to give information rather than references. Chapter 5 is on measurement of frequency and covers the subject fairly well. The description of precise primary frequency standards and their calibration justifies rather wider treatment than is given, but exigencies of space no doubt prevented this. The succeeding chapter discusses wave form and phase measurements; this also receives rather scrappy treatment and one would like to see more about phase-measuring methods at high frequencies. Following chapters deal with vacuum tube characteristics, audio-frequency amplification, receiver measurement and oscillator power amplifier and modulation measurements. The treatment calls for little comment and seems to cover requirements fairly well.

The four final chapters are on measurements on radio wave antennæ and transmission lines, laboratory oscillators, cathode-ray tubes and miscellaneous items. The subject of field strength measurement is not fully covered and nothing is said about short-wave measurements, while the subject transmission line measurements is also dealt with rather too briefly. Two appendices are included, the first giving particulars and instructions for thirty-two laboratory experiments and the second on laboratory organisation.

It is, of course, impossible in a book of this size to give complete information, and the subject of many of the chapters could be expanded into complete volumes. Bearing this in mind the author has been remarkably successful in covering such a wide ground and providing at the same time so much useful information, and the book will be a valuable adjunct to all radio laboratories. Little reference is made, however, to European work, and the volume could be usefully expanded in places to take account of this.

A. J. G.

"Elements of Symmetrical Component Theory." G. W. Stubbings, B.Sc., F.Inst.P., A.M.I.E.E. 104 pp. 60 ill. Pitman, 5s.

The problems associated with three-phase distribution systems are essentially the concern of the power engineer, but nevertheless it behoves all engineers to take full cognisance of the aids and artifices adopted by others in the solution of their problems. The dodge of resolving an unbalanced three-phase load into two symmetrical systems, one of positive and the other of negative phase sequence, plus possibly a zero sequence component, is not widely known, largely because the textbooks dealing with the subject are usually highly mathematical in character.

The author of the book under review sets out to remedy this and endeavours to explain as non-mathematically as possible the elementary conception and applications of Symmetrical Component theory.

In the first two chapters the author shows by means of vectors and standard geometrical constructions how an unbalanced load may be considered as the sum of two or three balanced systems. Then follows an introduction to vector algebra in which the reader is introduced to the operator "a," a close relation of the more familiar "j".

Chapter 4 deals with methods by which the positive, negative and zero sequence components may be measured, and applications of these methods to automatic protection are discussed in the following chapter. The author concludes with a chapter on current distribution under normal and fault conditions and some notes on the calculation of earth fault currents.

This little volume is an excellent introduction to the subject of symmetrical components. It will be primarily of interest to the student of power engineering but will serve also to give all electrical engineers an insight into this valuable method of solving intricate three-phase load problems.

H. L.

"Radio Engineering," by F. E. Terman. 812 pp. 2nd Edition. McGraw-Hill. 30s.

A review of the first edition of this book appeared in the April, 1933, issue of this JOURNAL. At the time it received very favourable mention and was probably in advance of any other book on the subject. In the second edition the book has been thoroughly revised, and with the exception of the first few chapters, dealing with fundamentals, has been rewritten. This has involved an increase in size by over a hundred pages and the addition of a large number of new illustrations and diagrams.

In order to include much of the more recent developments in the subject it has become necessary to omit the chapter on measurements. This is not a serious loss, as the subject has been dealt with more extensively in a separate work by the same author. The arrangement of subject matter has not been altered appreciably, but a new chapter has been added on Television. This is relatively short, consisting of 16 pages, and deals principally with systems and devices which have been produced in America. No reference appears of the British television service, which is the only public service in existence and differs in a number of important respects from proposed systems which have been developed in the United States.

New matter is included on valves, amplifiers and modulators. The subject of wave propagation now includes sufficient material to permit calculation of ground wave coverage, determination of optimum frequency for sky wave transmission from ionospheric data, and the calculation of received field strength at ultra high frequencies.

A useful innovation is the inclusion at the end of each chapter of problems dealing with the more important topics of that chapter. This feature enhances the value of the work as a test book for class work or for private study. The general form of the work has not been changed, and although mathematical analysis is not entirely avoided, material of this character is included only where it is essential, and where at present it is very much to the point.

The earlier edition was widely appreciated by engineers and students and the present edition will give this valuable work a new lease of life. It certainly contains more general, useful, up-to-date information on Radio Engineering than any other work.

A. J. G.

" Tables of Bessel Functions." Part I : Functions of Orders Zero and Unity. Published for the British Association by the Cambridge University Press. 288 pp. 40s.

An important class of functions met with in the applications of mathematics to electrical problems is Bessel functions. Like exponential functions, to which they are closely related, these functions are defined by series. Unlike exponential functions, however, tables of the values of Bessel functions are rare. Consequently the present valuable tables are welcome.

Table I gives the values of the Bessel functions $J_0(x)$ and $J_1(x)$ to ten places of decimals for a range of values of x from $x=0$ to $x=25$ with interval of only 0·001. This table occupies the first 170 pages of the book and is without doubt the most comprehensive table of its kind ever published. The first table was published by Bessel himself in a memoir on Planetary Perturbations (Berliner Abhandlungen, 1824). Bessel's table gives the values of $J_0(x)$ and $J_1(x)$ to ten places of decimals from $x=0$ to $x=3{\cdot}20$ with interval 0·01, and was superseded by Meissel's table (Berliner Abhandlungen, 1888) which has a range from $x=0$ to $x=15{\cdot}5$ with an interval of 0·01. Meissel's table was reprinted in full by Gray and Matthews in their " Treatise on Bessel Functions " (London, 1895), and this has so far been the reference table in English. It can now be seen what a remarkable advance Table I makes ; the interval has been greatly reduced and the range of x increased from 15·5 to 25. Table II gives the first 150 roots of $J_0(x)$ and $J_1(x)$ together with the value of one function at the root of the other. These functions $J_0(x)$ and $J_1(x)$ (the numerical value of which occupy more than half of the book) are of considerable importance in A.C. theory because they represent functions oscillating with increasing frequency and diminishing amplitude.

Table III gives the values of the Hankel functions (second solution of Bessel's equation) $Y_0(x)$ and $Y_1(x)$ from $x=0$ to $x=25$. The figures in the table are given to eight places of decimals with an interval of 0·01. Table IV gives the first 50 roots of $Y_0(x)$ and $Y_1(x)$ together with the value of one function at the root of the other. The $Y_0(x)$ and $Y_1(x)$ functions are oscillatory but unlike $J_0(x)$ and $J_1(x)$ they have a discontinuity at the origin $x=0$. Table V provides a convenient means of obtaining $J_0(x)$, $J_1(x)$, $Y_0(x)$ or $Y_1(x)$ to eight places of decimals at any point in the range $x=25$ to $x=6000$.

The Bessel functions with imaginary argument $I_0(x)$ and $I_1(x)$ are given in Table VI to eight significant figures from $x=0$ to $x=5$ with an interval of 0·001. The corresponding functions $K_0(x)$ and $K_1(x)$ are given over the same range in Table VII. Table VIII gives the values of $\exp(-x)\, I_0(x)$, $\exp(-x)\, I_1(x)$, $\exp(x)\, K_0(x)$ and $\exp(x)\, K_1(x)$ to eight decimal places for the range $x=5$ to $x=20$.

The book is very well produced and contains in addition to the tables all the necessary definitions, auxiliary functions, asymptotic formulæ, etc., as well as a description of the method of preparing the tables. The proofs were read against the printers' copy and also against the original calculations and not a single error was found in the 280 pages of tables (of about a million figures). The British Association and the Cambridge University Press are to be congratulated on producing so fine a work.

H. J. J.

" Transformer Principles and Practice," by J. B. Gibbs, B.Sc., M.A.I.E.E. 210 pp. 191 ill. McGraw-Hill. 15s.

Although a number of good books have been published dealing with the theory of the transformer, a need has been felt by the practical man for a non-mathematical description of the various types of transformers and their uses, together with an outline of the principles governing their operation. The aim of the author has been to supply this need and he has largely succeeded.

The main substance of the book is drawn from articles which have appeared in the technical press ; these have been rewritten and brought up to date. As may be expected therefore, the chapters follow no particular sequence. A number of photographs of transformers representing present-day American practice is incorporated in the text.

As a textbook for the student interested in the practical aspect of transformer operation it can be strongly recommended, while the young designer will find particularly helpful the chapters dealing with the principles underlying the construction of the transformer in its various forms. The book should also be of interest to those concerned with the operation and maintenance of transformers, a number of chapters being devoted chiefly to the treatment of this subject.

K. O. B.

" Machine Drawing for Students of Electrical Engineering." A. Bridge. 75 pp. 38 plates. Blackie & Sons. 4s. 6d.

Machine Drawing can only be learnt by regular practice on the drawing board ; there is no short cut method. Yet the part-time student of Electrical Engineering is often required to take Machine Drawing in a course comprising four other subjects. Mr. Bridge, himself a lecturer on the subject, appreciates the difficulty that confronts this class of student and in this book has attempted a kind of précis of the subject which the student may reasonably be expected to digest in the time at his disposal.

The danger of this approach to the subject is one of scanty treatment in the early stages and the student without some preliminary groundwork may find the transition from the elements to the practical exercises too rapid.

The book consists of a series of exercises beginning with a few geometrical constructions and concluding with the assembly and parts of a small D.C. motor. Where it has been considered necessary, the author has included concise notes on materials and methods of manufacture. There are many useful hints for beginners and a welcome stress has been laid on the value of freehand sketching in preliminary work.

The general lay-out of the book is very clean and the plates are particularly well prepared. With a few exceptions the subjects have been presented in the isometric form with the object of giving the student a clearer impression of the actual shape of the item, and also to provide him with better practice than is gained by copying orthographical views.

The author makes it clear that there has been no attempt to cover a wide range of the subject. There is, for instance, no special reference to apparatus used in telecommunications which would be helpful to Post Office students. It is assumed that the student is obtaining practice in drawing from his own measurements in the classroom, and it is to the student who feels the need of a series of supplementary exercises that this book will appeal.

W. D. B.

"Generation, Transmission and Utilisation of Electrical Power." A. T. Starr, M.A., Ph.D., B.Sc., A.M.I.E.E. 486 pp., 400 ill. Pitman, 18s.

This book covers the syllabus of "Electrical Power" in the B.Sc. and similar examinations. The author deals in one volume with a wide range of subjects which have hitherto only been available in the more specialised works.

In parts the treatment is rather superficial and erroneous impressions are occasionally conveyed due apparently to the author's economy of words. The material is presented in a manner suitable for students with numerous worked examples and at the end of each chapter several typical examination questions are included. The answers to these questions would be appreciated by students and references to other works for more details could usefully be included.

Generation occupies the first chapter and the next nine are devoted to Transmission. After the mechanical and electrical design of overhead lines and underground cable systems the author passes on to Transmission calculation and Voltage Regulation Stability. An introduction to the method of symmetrical components for short-circuit calculation is included but the space allocated to Switchgear is somewhat inadequate compared with that given to Protection. Illumination and Electric Traction are treated in separate chapters from other examples of Industrial Utilisation and the book concludes with a chapter on Economic Considerations.

E. F. H. G.

"Fundamentals of Radio." F. E. Terman. 458 pp. 278 ill. McGraw-Hill. 21s.

Dr. Terman's recently revised textbook entitled "Radio Engineering," and his newly published companion volume "Measurements in Radio Engineering," are well known to radio engineers. This third volume maintains their high standard and presents the fundamentals of radio in an exceedingly clear and logical manner. The book is in effect an abridged edition of "Radio Engineering," with the addition of extra problems of a more simple nature.

The text is mainly of a descriptive nature, and as the title indicates deals solely with the fundamentals of the subject. The use of mathematics is restricted, a knowledge of elementary A.C. theory and of standard trigonometrical identities being sufficient.

The work can be thoroughly recommended to all radio Students.

"Definitions and Formulæ for Students." Pitman. 6d. each volume.

"Electrical." Philip Kemp. 37 pp.

This handy little book of definitions and formulæ now appears in its sixth impression, which testifies its usefulness to students of electrical engineering.

The first 13 pages are devoted to concise definitions of electrical terms and units, while the second half of the book gives the more important formulæ in electrostatics, magnetism, electromagnetism, the magnetic circuit, the electric circuit, electrolysis and cells, illumination, D.C. machines, the A.C. circuit, transformers, A.C. machines, power factor improvement, power transmission, and transients.

The work forms an excellent aide memoire for students and should prove invaluable when revising for examinations. The ground covered is sufficient for the Electrical Technology syllabus in the B.Sc. (Eng) examination.

"Telegraphy and Telephony." E. Mallett. 36 pp.

A recent addition to the series "Definitions and Formulæ" is this booklet dealing with Telegraphy and Telephony. The layout follows the usual practice and 13 pages of definitions are followed by 23 pages of formulæ.

The ground covered by the formulæ is almost entirely confined to the transmission aspect of telegraphy and telephony, sections dealing successively with the leaky telegraph line, telephone lines and filters, transients and the long telegraph line, acoustics, the receiver and transmitter, and valve circuits, with an appendix on units and general theorems.

Trunking and grading are not mentioned either in the definition or formulæ sections—a most surprising omission—and the definition section is generally very incomplete.

Different authorities' definitions of the bel vary and few meet the requirements of the purists. Dr. Mallett's definition as "a unit used in the comparision of the magnitudes of powers, voltages or currents at two different points in a network of lines or apparatus" is not likely to receive their approbation.

In the formulæ section some confusion to Post Office students is likely to be caused by the use of α as the attenuation constant and β as the wavelength constant. Also dB is used in preference to the more usual db as the abbreviation for decibel.

The book will be useful to students studying for university examinations and for the City and Guilds examinations in Transmission and Lines. H. S. L.

Staff Changes

Promotions.

Name	District	Date
From A.S.E. to Tel. Manager.		
Starkey, H. Y.	S. La. to Southend	To be fixed later
From Area Engr. to Regl. Engr.		
Procter, W. S.	Scot. Reg.	15.1.38
From Exec. Engr. to Tel. Manager.		
Farnes, G. H.	E. to Guildford	To be fixed later
Millar, H. T. W.	Scot. to Cambridge	do.
Hill, J. N.	London	do.
From Exec. Engr. to A.S.E.		
Graham, C.	N.E. to E. in C.O.	1.5.38
Harbottle, H. R.	E.-in-C.O.	20.1.38
Chapman, S. B.	E.-in-C.O. to Ldn.	1.1.38
Tolley, L. L.	E.-in-C.O. to E.	1.4.38
From Asst. Engr. to Exec. Engr.		
Towers, R.	Ldn. to N.E.	7.1.38
Cresswell, W. H.	E.-in-C.O.	7.1.38
Sard, P. J.	London	7.1.38
Smith, S. J.	Scot. Reg.	15.1.38
Jones, C. E. P.	Eastern	To be fixed later
Howard, J. L.	S.W. to Scot.	do.
Lewis, N. W. J.	E.-in-C.O.	28.1.38
Carter, R. O.	E.-in-C.O.	28.1.38
Jones, R. E.	E.-in-C.O.	28.1.38
From Chief Insp. with allowance to Asst. Engr.		
Hepplestone, H.	S. Lancs	To be fixed later
From Chief Insp. to Asst. Engr.		
Gay, S. G.	S.W. to N. Mid.	20.1.37
Haliburton, F. C.	E.-in-C.O.	6.12.37
Pyrah, F.	E.-in-C.O.	6.12.37
Smith, G.	London	5.4.38
Linck, H. C. A.	S. Wales	1.6.38
Devereux, R. C.	London	To be fixed later
Waters, H. S.	E.-in-C.O.	13.1.38
Stewart, A. D.	E.-in-C.O.	1.7.38
Pettitt, V. R.	E.-in-C.O.	26.1.38
From Chief Insp. to Chief Insp. with allowance.		
Sceats, F. W.	S. Wales	12.1.38
Chany, F. T.	S. Lancs	28.12.37
McLennan, M.	Scot. Reg.	To be fixed later
Stott, S. A.	Eastern	do.
From Insp. to Chief Insp.		
Griffiths, W. S.	S. Western	20.1.38
Dent, F.	N.E. Reg.	1.4.37
Avery, H. C. T.	S. Western	28.11.37
Barnes, H.	S. Western	19.10.37
Whitburn, G. E.	S. Western	16.12.37
Vear, F.	N.E. Reg.	21.11.37
Gregory, G.	St. Albans to E.-in-C.O.	3.10.37
Middeditch, E. G. H.	E.-in-C.O.	14.10.37
Hunt, A. F. H.	E.-in-C.O.	14.10.37
Wheatley, E. K.	E.-in-C.O.	13.10.37
Banks, W. R.	E.-in-C.O.	13.10.37
Chamberlain, A. E.	E.-in-C.O.	1.1.38
Thwaites, H. J.	E.-in-C.O.	1.1.38
Lloyd, H. H.	Rugby to N. Wa.	30.1.38
Guy, L.	E.-in-C.O. to Scot.	1.1.38
From S.W.1 to Insp.		
Brown, W. H.	Eastern	4.7.37
Payne, F.	Eastern	18.12.37
Street, A. F.	Eastern	17.10.37
Banyard, P. W.	Eastern	16.12.37
Roper, E. K.	Eastern	18.12.37
Cunningham, J. C.	Eastern	5.12.37
South, V. G.	Eastern	3.10.37
Price, E. J.	S. Lancs	5.9.37
From S.W.1 to Insp. (continued).		
Moss, J. W.	S. Lancs.	26.9.37
Willson, J. C.	E.-in-C.O.	1.9.37
Standage, E. F.	E.-in-C.O.	1.9.37
Snook, R. A.	Ldn. to E.-in-C.O.	3.7.37
Barnes, H.	E.-in-C.O.	30.6.37
Forrest, J.	Ldn. to E.-in-C.O.	21.6.37
Shaw, W. H.	E.-in-C.O.	18.7.37
James, E.	Ldn. to E.-in-C.O.	21.6.37
Hopkins, H.	Ldn. to E.-in-C.O.	3.7.37
Hay, M.	Ldn. to E.-in-C.O.	7.8.37
Winterburn, G. E.	E.-in-C.O.	22.9.37
Ash, F. J.	E.-in-C.O.	3.10.37
Ruck, E. F.	E.-in-C.O.	18.7.37
Tite, L. G.	E.-in-C.O.	18.7.37
How, R. C.	E.-in-C.O.	18.7.37
Gibson, R. W.	E.-in-C.O.	8.8.37
Blackie, K. J.	E.-in-C.O.	1.8.37
Cox, J. S.	S. Wa. to E.-in-C.O.	28.8.37
Burgess, R. W.	Ldn. to E.-in-C.O.	25.7.37
Barret, F. W.	Ldn. to E.-in-C.O.	10.7.37
Cooper, R. P.	Ldn. to E.-in-C.O.	9.10.37
Hannah, A.	Ldn. to E.-in-C.O.	24.7.37
Stretton, J. A.	E.-in-C.O.	18.7.37
Beattie, N. W.	E.-in-C.O.	8.8.37
Edgerton, R. L.	E.-in-C.O.	26.10.37
Dibsdall, A. T. D.	Ldn. to E.-in-C.O.	8.8.37
Clarke, T. E.	E.-in-C.O.	6.8.37
Child, H. J.	E.-in-C.O.	7.10.37
Waters, L. A.	E.-in-C.O.	14.12.37
Rook, A. J.	London	24.10.37
Gray, F.	London	13.11.37
Emerson, B. C.	London	5.5.37
Cox, H. W. J.	London	12.9.37
Kranshaar, H. G.	London	24.10.37
Sims, G. H.	London	30.10.37
Rowe, F. A. B.	N. Ireland	1.1.38
Toft, G.	E.-in-C.O.	19.9.37
Morrison, N.	Scot. Reg.	28.10.37
Stewart, J. C.	Scot. Reg.	18.9.37
Maxwell, H.	Scot. Reg.	2.1.38
Harvie, A.	Scot. Reg.	3.10.37
Dewar, J.	Scot. Reg.	13.6.37
Watt, J. P.	Scot. Reg.	18.10.37
Kelly, W. C.	Scot. Reg.	25.12.37
Nimmo, M.	Scot. Reg.	1.1.38
Nelson, J.	Scot. Reg.	21.7.37
MacIntyre, J. M.	Scot. Reg.	8.1.38
Smith, H.	N.E. Reg.	10.11.37
Holdsworth, A.	N.E. Reg.	10.11.37
Stanfield, J. A.	N.E. Reg.	3.11.37
Scrafton, H. D.	N.E. Reg.	19.12.37
Smith, G. H.	N.E. Reg.	13.12.37
Robson, S.	N.E. Reg.	1.12.37
Taylor, E.	N.E. Reg.	27.6.37
Evans, A. W.	N.E. Reg.	20.12.37
Chalder, E. V.	N.E. Reg.	20.11.37
Higgs, H. W.	T.S. Ldn. to E.-in-C.O.	27.11.37
Marsh, B. F.	T.S. Ldn. to E.-in-C.O.	27.11.37
Carpenter, A. E.	S. Western	3.10.37
Harvey, H. A. E.	S. Western	7.1.38
Heath, W. J.	S. Western	15.12.37
Kerslake, R. J.	S. Western	26.11.37
Trickett, A.	S. Western	6.12.37
Davenport, H.	S. Lancs	31.10.37
Potts, A. E.	S. Lancs	1.1.38
Saunders, T.	S. Lancs	31.1.37
Sherwin, H. R.	S. Lancs	13.11.37
Atherton, W.	S. Lancs	14.11.37
Johnson, F. W. B.	S. Lancs	17.10.37
Roberts, J.	S. Lancs	17.10.37
Plenderleith, A.	S. Lancs	28.10.37
Pariser, F. A. A.	Test Secn. B'm	9.6.37
Dulk, R. F.	Test Secn. Ldn.	1.2.38

Promotions—*continued.*

Name	District	Date
From S.W.1 to Insp. (continued).		
Lee, W.	N. Western	29.1.38
Jones, F. V.	N. Western	8.11.37
Greenhalgh, E. R.	N. Western	29.1.38
Campbell, H.	N. Western	29.1.38
Brierley, J. W. C.	N. Western	29.1.38
Harrison, R.	N. Western	29.1.38
Moore, T.	S. Western	30.1.38
Jewers, A.	S. Western	24.10.37
Wadsworth, H. A.	St. Albans	3.10.37
Brady, T. J.	St. Albans	18.12.37
Hurst, S. A.	Eastern	To be fixed later
Nichols, F. J. E.	Eastern	do.
Roxby, H. J.	Eastern	do.
Wilson, L. J.	Eastern	do.
Dyer, R. L.	Eastern	do.
Linsey, C. F.	Eastern	do.
Pearce, F. W.	Eastern	do.
Huke, G. A.	Eastern	do.
Tricker, E. C.	Eastern	do.
Jennings, S. W.	Eastern	do.
Kirvell, F. G.	Eastern	do.
Payne, W. J.	London	21.11.37
Hills, J. A.	London	20.11.37
Maasz, C. F. C.	S. Midland	20.11.37
Brown, M. W. V.	S. Midland	19.2.38
Plank, S. J.	S. Midland	1.10.37
Clear, P.	S. Midland	15.2.38
Fletcher, N. L.	S. Midland	12.2.38
Weait, A. T.	S. Midland	26.2.38
Hester, W. F. T.	S. Midland	20.1.38
Pearce, H. T.	S. Midland	31.10.37
Russell, F. W.	S. Midland	10.5.37
Chuter, A. G.	S. Midland	10.10.37
Seath, W. J.	Scot. Reg.	28.9.37
Gall, P.	Scot. Reg.	29.9.37
Melville, E.	Scot. Reg.	31.1.38
Campbell, R. D.	Scot. Reg.	6.10.37
Birrell, R. C.	Scot. Reg.	4.1.38
Irvine, J.	Scot. Reg.	16.10.37
E. P. O'Neill	Scot. Reg.	2.1.38
H. McBean	Scot. Reg.	21.7.37
R. Henderson	Scot. Reg.	29.1.38
Barr, T.	Scot. Reg.	29.9.37
Dempsey, J.	N. Wales	To be fixed later
Cull, H. L.	N. Wales	do.
Grimmitt, T. W.	N. Wales	do.
Price, A. I.	N. Wales	do.
Hampton, J. H. W.	N. Wales	do.
Llewellyn, W.	N. Wales	do.
Ganderton, W. G.	N. Wales	do.
From S.W.1 to Insp. (continued).		
Brown, L. C.	N. Wales	To be fixed later
Vickers, C. C.	N. Wales	do.
Hewlett, A. V.	N. Wales	do.
Ewart, T. J.	N. Wales	do.
Jones, C. H.	N. Wales	do.
Wright, N. F.	N. Wales	do.
Willitt, A. H.	N. Wales	do.
Sutton, A. J.	N. Wales	do.
Bailey, G. W.	N. Wales	do.
Howes, J. O.	N. Wales	do.
Hall, W. L.	N. Wales	do.
Cooper, J. H.	N. Wales	do.
Lawden, C. A. J.	N. Wales	do.
Beames, A. R.	N. Wales	do.
Fuller, W.	N. Wales	do.
Lewis, W. J.	N. Wales	do.
Mitchell, G. A. R.	N. Wales	do.
Sellwood, S. J.	Rugby to E.-in-C.O.	17.2.38
Myers, T. R.	E.-in-C.O.	1.2.38
Brook, H.	N.E. Reg.	24.1.38
Smith, S. W.	N.E. Reg.	24.1.38
Corbett, G.	N.E. Reg.	24.1.38
Wormald, A. R.	N.E. Reg.	24.1.38
Mullis, H. R.	S. Wales	To be fixed later
Davies, E. S.	S. Wales	do.
Frood, B.	S. Wales	do.
Richards, B. J.	S. Wales	do.
Burton, W.	S. Wales	do.
From S.W.II to Insp.		
Thistlethwaite, W. R.	N.W. to E.-in-C.O.	28.8.37
Farey, W. A.	E.-in-C.O.	18.7.37
Cheesbrough, J. W.	N.E. to E.-in-C.O.	9.10.37
Pikett, F. H. J.	S.E. to E.-in-C.O.	27.11.37
Shelley, G. J.	S.E. to E.-in-C.O.	28.8.37
Haynes, C. T.	S.E. to E.-in-C.O.	9.10.37
Caswell, A. N.	N. Wales	To be fixed later
Llewellyn, A. H.	N. Wales	do.
Farren, J. A. W.	N. Wales	do.
Supper, J. B.	E.-in-C.O.	19.11.37
From U.S.W. to Insp.		
Harris, W. E. G.	N. Wales	To be fixed later
Norgrove, W. G.	N. Wales	do.
Morgan, G. C. A.	N. Wales	do.
Elwell, L.	N. Wales	do.
Morris, W. G.	E.-in-C.O.	26.1.38
From Draughtsman Cl. II to Insp.		
Thomas, H.	N. Wales	19.12.37
Palk, E.	S. Midland	1.9.37

Transfers.

Name	District	Date
A.S.E.		
Beer, C. A.	E.-in-C.O. to S. Wa.	20.1.38
Fulcher, H. W.	Ldn. to E.-in-C.O.	1.1.38
Harris, L. H.	E. to N. Mid.	1.1.38
Exec. Engr.		
McDonald, A. G.	N.E. to Ldn.	21.12.37
Green, H. W.	N. Wa. to N.E.	1.5.38
Asst. Engr.		
Gray, W. D.	E.-in-C.O. to Ldn.	15.1.38
Gardner, A. J.	E.-in-C.O. to Ldn.	15.1.38
Smith, J. G.	E.-in-C.O. to Ldn.	15.1.38
Proby. Asst. Engr.		
Finlason, W. E.	E.-in-C.O. to S. La.	15.12.37
James, M. H.	E.-in-C.O. to S. La.	15.12.37
de Jong, N. C. C.	E.-in-C.O. to S.W.	9.1.38
Beaumont, E. B. M.	E.-in-C.O. to Ldn.	13.2.38
Chief Insp.		
Stacey, P. A.	E.-in-C.O. to Ldn.	15.1.38
Davey, F. R.	E.-in-C.O. to Ldn.	15.1.38
Roberts, E.	E.-in-C.O. to Ldn.	15.1.38
Wheatley, E. K.	E.-in-C.O. to Ldn.	15.1.38
Levens, T. F.	Scot. to N.W.	1.1.38
Abbott, G. A.	E.-in-C.O. to Ldn.	23.1.38
Inspector		
Rudham, J. L.	E.-in-C.O. to Ldn.	15.1.38
Hartwell, C. H.	E.-in-C.O. to Ldn.	15.1.38
Spice, W. H. J.	E.-in-C.O. to Ldn.	15.1.38
Emery, E. A.	E.-in-C.O. to Ldn.	15.1.38
Eagle, R. J. A.	E.-in-C.O. to Ldn.	15.1.38
Cawte, H. M.	E.-in-C.O. to Ldn.	15.1.38
Wells, H. M.	E.-in-C.O. to Ldn.	15.1.38
Mellors, W. J.	E.-in-C.O. to Ldn.	15.1.38
Burgess, R. W.	E.-in-C.O. to Ldn.	15.1.38
Barret, F. W.	E.-in-C.O. to Ldn.	15.1.38
Toft, G.	E.-in-C.O. to Ldn.	15.1.38
Pariser, F. A. A.	T.S. B'm to T.S. Ldn.	1.2.38
Goodchild, C. W.	E. to E.-in-C.O.	13.2.38

Retirements.

Name	District	Date	Name	District	Date
A.S.E.			*Inspector*		
Woollard, F.	E.-in-C.O.	1.1.38	Summarsell, H.	S. Eastern	31.12.37
Gilbert, D. P.	E.-in-C.O.	31.12.37	Beattie, M.	Scot. Reg.	1.1.38
Ryder, W. V.	Scot. Reg.	14.1.38	Hale, G. M.	Scot. Reg.	1.1.38
Hunter, H. J.	S. Wales	19.1.38	Ballett, S.	S. Wales	26.12.37
Exec. Engr.			Bell, B. A.	S. Lancs	31.12.37
Brown, G.	E.-in-C.O.	31.12.37	Horwood, J. T.	London	5.1.38
Asst. Engr.			Pemberton, S. A.	London	3.1.38
Veale, A. H.	E.-in-C.O.	31.12.37	Castle, H. V.	London	4.2.38
Hamilton, W. D.	E.-in-C.O.	30.9.37	Munro, R. M.	London	31.1.38
Wilson, A.	E.-in-C.O.	31.12.37	Wickerson, A. G.	Test Secn. Ldn.	31.1.38
Evans, T.	N. Wales	30.11.37	Beddoes, R. T.	London	28.2.38
Cheetham, W. B.	Eastern	6.2.38	Blofield, J. F.	N. Wales	13.2.38
Gresswell, F. P.	S. Western	28.2.38	Saberton, A.	Eastern	28.2.38
Chief Insp.			Bennett, G. M.	Scot. Reg.	10.2.38
Brough, R.	Scot. Reg.	31.12.37	Seward, W. J.	S. Western	23.2.38
Stockwell, R. R.	London	31.1.38	Stephens, M. B.	London	8.3.38
Martin, P. G.	Scot. Reg.	31.12.37	Robinson, W. B.	N. Midland	17.2.38
Goodman, H. H.	N. Western	31.12.37	Billson, J. W. D.	London	28.2.38

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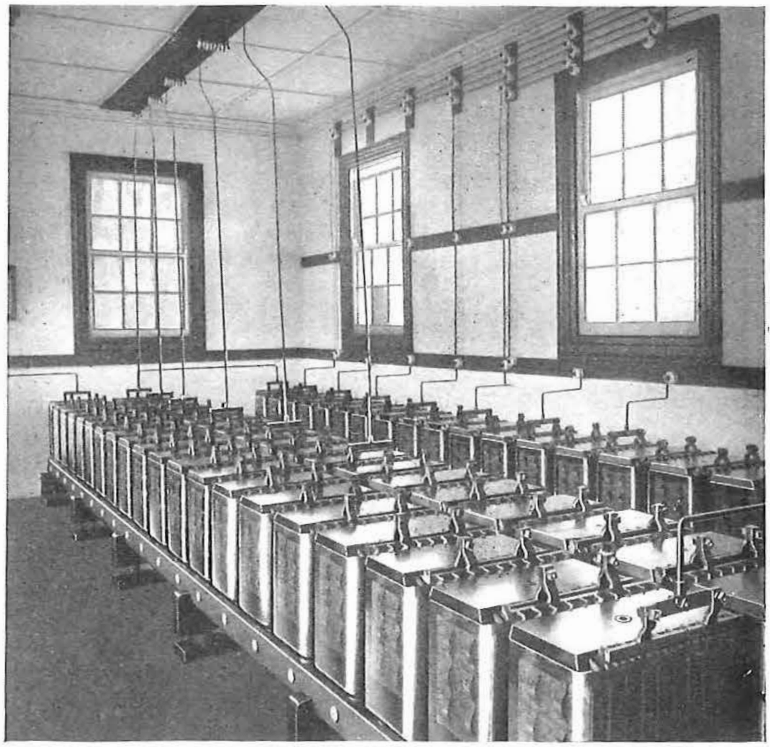

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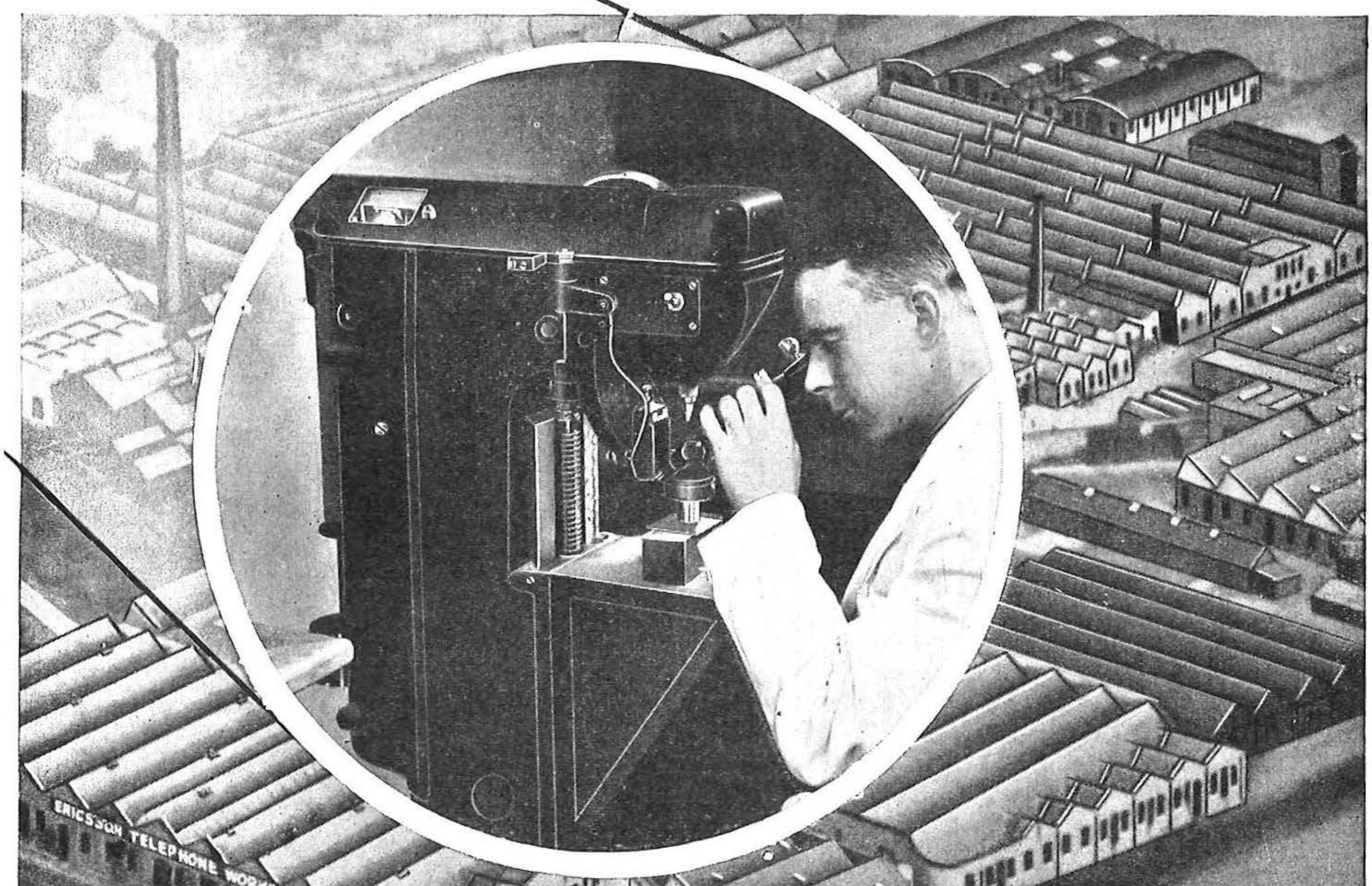

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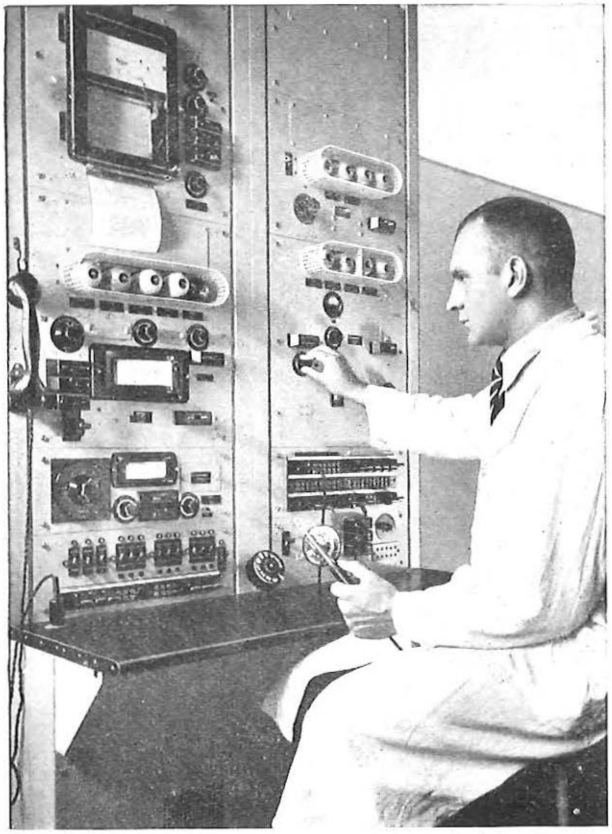

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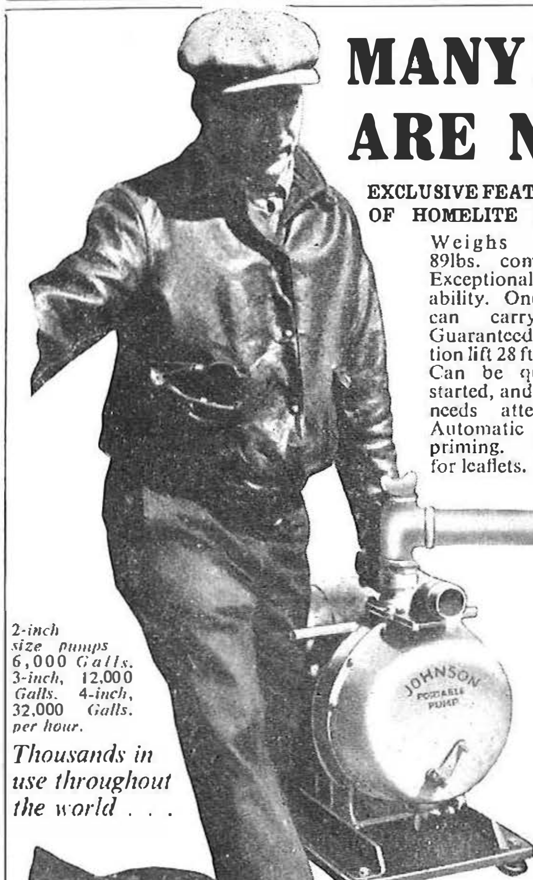

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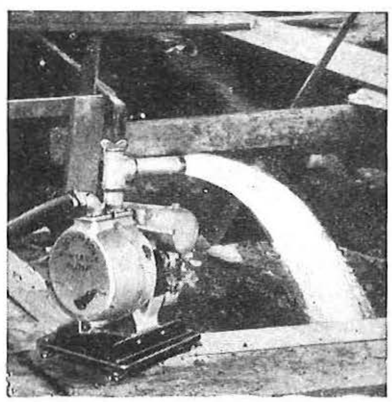

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