THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL

VOL. 29 JULY, 1936 PART 2.

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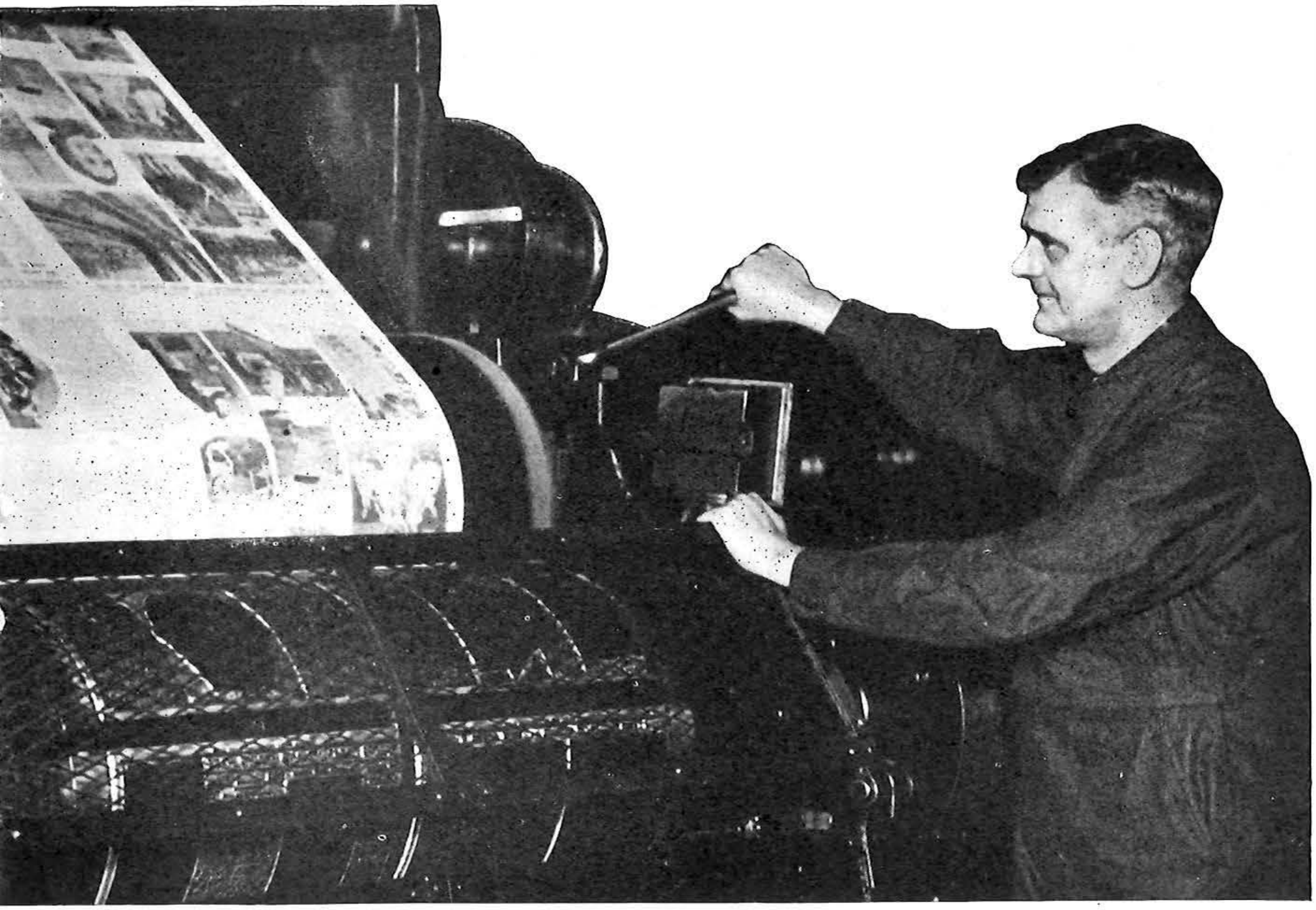

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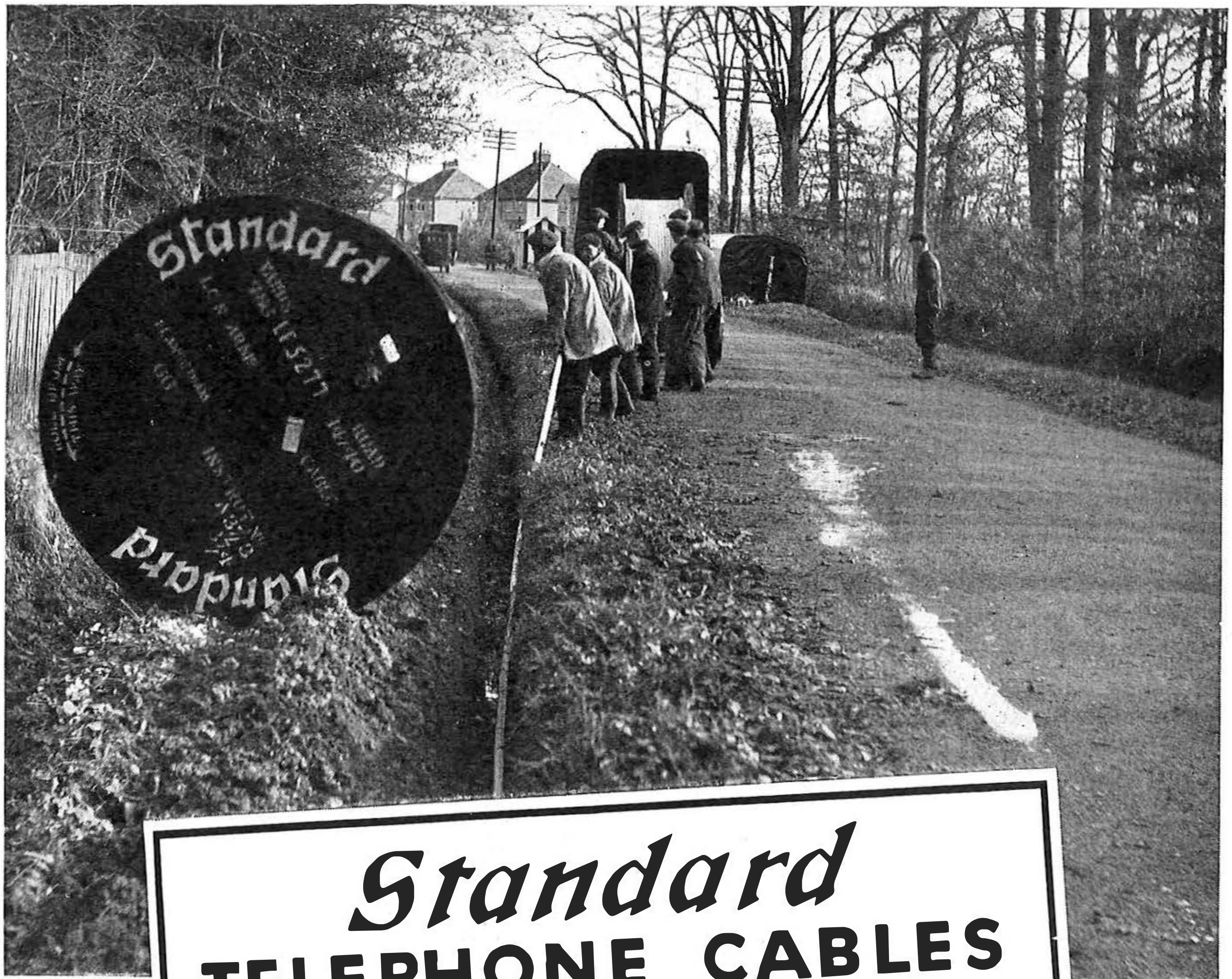

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THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL

Vol. XXIX July, 1936 Part 2

The Development of 2,000 Type Selector Circuits

R. H. CHAPMAN, B.Sc. (Eng.), and J. S. GROOME

A survey of the circuit changes introduced concurrently with the adoption of the new 2,000 type selector is given and the advantages and new facilities afforded thereby are enumerated.

Introduction.

IN recent articles which have appeared in this Journal,[1] the development of the new Post Office standard two-motion selector (2,000 type) has been comprehensively dealt with from the point of view of the mechanical features, racking, mounting arrangements, etc., and it is thought that an account of the circuit aspect may be of interest, particularly in view of the imminent installation of new exchanges employing this selector.

The standardization of the forward rotary release feature (already adequately described) rendered all existing standard two-motion selector circuits obsolete and new circuits had therefore to be developed. Since from the outset it was intended, where possible, to employ the new selector on extensions of existing exchanges, radical departures from previous practice had necessarily to be restricted in considering the development of the new circuits. Nevertheless, opportunity has been taken to effect improvements in facilities and performance where possible. Some of these, such as balanced tones, are purely incidental and could have been introduced independently, whereas others have only been made possible by utilizing the following features which are of advantage to the circuit designer and are peculiar to the new mechanism :—

1. Vertical and rotary stepping by self-interrupted drive can readily be obtained, with consequent saving in hunting time.
2. Owing to the robust mechanical design, the previous limitations in bank capacity no longer apply.
3. Certain restrictions hitherto imposed on the number and types of mechanically operated springs have been removed.

In the ensuing article an attempt has been made to show the influence of the above characteristics on circuit development and to describe in general terms the main innovations incorporated in the new standard circuits. In a few instances some existing principles have been discussed for purposes of comparison and a certain amount of relevant general information has been included which may be of interest. In publishing this article the authors also wish to make an acknowledgment to the Automatic Electric Company, who produced the basic design from which the standard mechanism was evolved, and to whom was assigned the prime responsibility for the circuit development.

Balanced Tones.

Some typical examples of the methods of tone application hitherto employed are shown in Fig. 1, and from inspection of these it will readily be appreciated that the speaking pair to which the tone is connected is unbalanced in respect of tone potential. This condition of unbalance has always given rise to a certain amount of overhearing which has in some instances reached inconvenient dimensions, particularly where star-quad cable has been employed. It

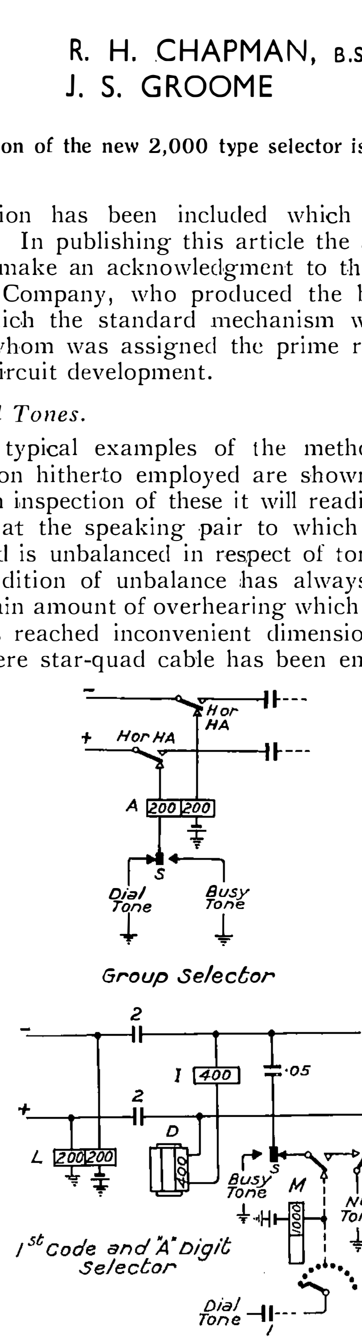

FIG. 1.—EXISTING METHODS OF APPLYING TONE.

[1] Vol. 29, Part 1. April, 1936.

will also be evident that the volume and quality of any particular tone received varied according to the method of application and therefore the non-uniformity of the methods used gave rise to considerable variation.

In the 2,000 type circuits the tone is fed through a 570 ohm third winding, wound over the normal line coils of a bridge relay, usually the A or I relay. The tone winding thus functions as the primary winding of a transformer, of which the line coils of the relay constitute the secondary windings. Some typical illustrations are given in Fig. 2. Bridge relays are normally sandwich-wound and since the tone winding is wound on the outside of the coil, some small unbalance is introduced on account of the difference in

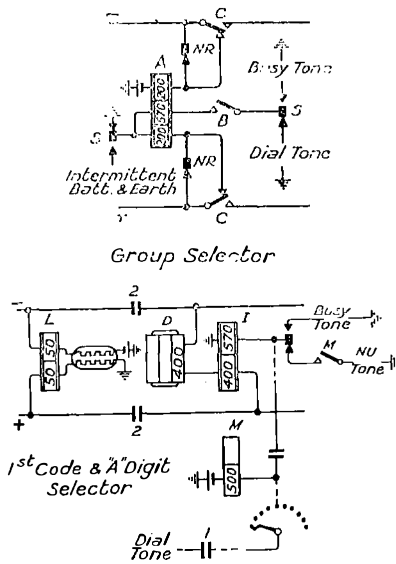

Fig. 2.—New Methods of applying Tone.

coupling between the tone winding and the two coils of the line winding. In spite of this, the arrangement is far superior to the superseded methods, from an overhearing point of view.

The new balanced method of tone application is being introduced concurrently with the new selector on all circuits employing tones.

Hunting Arrangements, Battery Testing and Drive Tripping.

The standard methods of hunting and hunting control are enumerated below, together with some brief notes on their various disadvantages :—

1. *Self-interrupted drive in conjunction with an earth-testing, drive tripping relay.* This is the method employed in the subscribers' uniselector circuit and in common with all earth testing circuits, allows the switch to stop on a disconnected outlet. Further, double connexions are not theoretically precluded, although the unguard period, during which they can occur is sufficiently small to give reasonable immunity, in view of the relative improbability of simultaneous testing.
2. *Relay inter-action drive in conjunction with an earth-testing relay.* This arrangement is normally used in group selector circuits and suffers from both the disadvantages of (1) and, in addition, necessarily limits the hunting speed.
3. *Relay inter-action drive, combined with a battery-testing relay* (used in A. digit hunter, line finder allotter circuits, etc.). This method was designed to obviate double connexions and employs a two-coil testing relay, one winding being of high resistance and the other (the hold winding) of low resistance. The free condition on the outlet is a resistance battery and the testing relay operates to this with its coils in series. The high resistance coil is, on operation, short-circuited by the low resistance winding, which then guards the outlet. Theoretically, the relays should be adjusted so that, if two are applied simultaneously to the same outlet, both will commence to operate, but will not hold with their low resistance windings in parallel. A current adjustment specification, based on this principle, is usually so stringent that the relay is difficult to manufacture and maintain. Generally, however, the holding current required by the relay under circuit conditions, is greater than under conditions of maintenance testing, owing to the short time of application of the operating current, and thus the current adjustment specification limits can be made wider than theoretically necessary and this is normally done. It will, no doubt, be appreciated that the amount of relaxation permissible can only be determined by tests and the construction of a suitable specification based on the practical performance of a large number of samples is a matter of considerable difficulty. Moreover, in spite of the possibility of relaxing the theoretical adjustment limits, the specification is still stringent from a manufacturing and maintenance point of view, particularly where, as is often the case, conditions of triple testing have to be met and the effect of derived networks has also to be considered.

In the case of the 2,000 type group selector, it was desirable that the principle of earth-testing should be continued in order to enable the new selector to be used on extensions of existing equipment, but, in order to take advantage of the high hunting speeds possible with self-interrupted drive, a drive tripping earth-testing relay arrangement was developed. Although the scheme is, of course, not immune from double connexions, the unguard period is less than heretofore. The essentials of the arrangement are shown in Fig. 3, relay H being the drive tripping

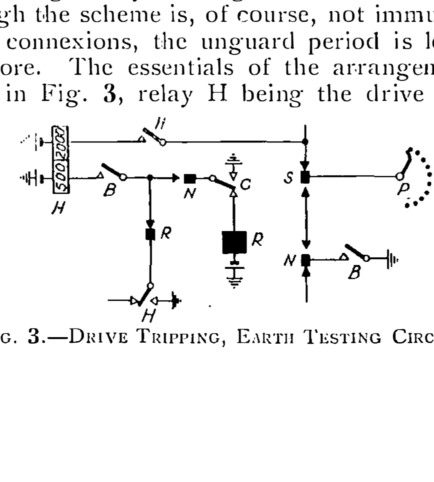

Fig. 3.—Drive Tripping, Earth Testing Circuit.

relay. Incidentally, this relay, although used for holding, is not employed to switch the speaking wires through, this function being performed by the C relay in conjunction with rotary off-normal springs. Relay H is operated over its 500 ohm winding as soon as the switch is stepped off normal. Relay C releases at the end of the vertical impulse train in the normal way and completes the rotary self-interrupted drive circuit. Relay H is held by its 500 ohm winding until the rotary interrupter springs break, while the wipers are on the outlet to be tested. If the outlet is busy, H is maintained by the private earth during this " break " period, but releases and trips the rotary drive if the line is free. The release of relay H causes C to re-operate and switch the positive and negative wires through. The disconnexion period of the rotary interrupter springs is of the order of 10 milliseconds, so that the release time of H must be well within this period. By dispensing with the standard enlarged core end and using a nickel iron core to reduce eddy-currents and thus accelerate flux decay, a design of relay has been produced which will consistently meet the required condition with an adequate margin. It will be appreciated that the preclusion of unwanted disconnexion periods on the private during rotary hunting is essential to the scheme and necessitates rather more stringent mechanical adjustments than would otherwise be required, but this disadvantage is more than off-set by the gain in hunting speed.

For other 2,000 type circuits, employing self-interrupted drive, a standard drive-tripping battery-testing relay has been produced. This relay is extensively used in the new line-finder circuit for the allotter drive, line-finder vertical hunting circuit and secondary control set switching circuit and is normally a single coil 11 ohm relay with one change-over unit. The free outlet condition is a 150 ohm battery and the relay is adjusted not to operate under dual testing conditions, although in these circumstances it will hold, once operated. The scheme, therefore, relies for its success on the fact that two switches hunting over the same multiple, always step at slightly different speeds. Hence if two testing relays arrive at the same outlet simultaneously, both will step on until the switches become sufficiently out of phase for one relay to operate before the other arrives. Since the operate time of the relay to its break contact is of the order of three milliseconds, in practice the switches seldom have to take more than two steps before the necessary phase displacement is achieved. The unguard period is, of course, zero, since the outlet is busied as soon as the relay is applied. The conditions imposed on the relay can be more easily met than in the normal battery-testing case. Moreover, the impedance of the normal battery-testing relay rendered it unsuitable for use in a drive-tripping scheme required by self-interrupted drive. The new scheme offers one of the best solutions so far obtained to the problem of elimination of double connexions and hence has been applied in the majority of the cases where this aspect is of prime importance.

A typical illustration of the principle is shown in Fig. **4**, which represents the circuit element employed in the line-finder secondary control relay set.

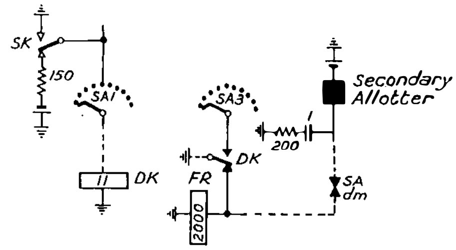

FIG. **4**.—DRIVING TRIPPING, BATTERY TESTING CIRCUIT.

Impulsing.

The maximum junction resistance over which satisfactory impulsing can be obtained is, in the main, dependent upon the performance of the B relay, the limit being reached when the make periods of the A relay contacts are so curtailed that the energization given to the B relay is insufficient to enable it to hold during an impulse train. The standard specification for a 3,000 type B relay requires that it should, after saturation, be capable of remaining operated during an infinite train of impulses of 79.5% break at 12 i.p.s. If this requirement is satisfied, correct impulsing can be obtained over a single 1,500 ohm junction from an auto-to-auto repeater, impulsed in series with a 500 ohm subscriber's line, assuming that all other factors such as voltage, dial speed and ratio, etc., are simultaneously adverse. When tandem junctions are used, the permissible overall junction resistance must be correspondingly reduced on account of the distortion introduced by each repetition.

On pre-2,000 type circuits, the requisite B relay release lag is obtained in the standard manner by means of a copper slug, but even with a slug of maximum dimensions, the fundamental impulsing requirement is, in cases of relays with heavy spring loads, difficult to meet without reducing the residual to such an extent that the relay has a tendency to stick. In some circumstances a more satisfactory method of obtaining the necessary lag, is to arrange for the relay to release with its winding short-circuited, but the efficacy of this method depends upon the winding space available on the relay core. Hitherto, the B relays on group and final selectors have had to be provided with a separate " busy hold " winding to enable the relay to be held operated when the A relay releases during busy flash periods, and the space occupied by this winding is normally such that no advantage can be gained by the use of " release to short-circuit " principle. The use of the three coil A relay for purposes of applying balanced tone, however, has enabled the " busy hold " winding on the B relay to be dispensed with, since the A relay can be held operated *via* the 570 ohm winding during the application of busy flash to line *via* the line windings. It has therefore been possible on 2000 type circuits to employ the short-circuited B relay and the arrangement adopted in the case of the group selector is shown in Fig. **5**. The final selector arrangement is, of course, fundamentally the same.

It will be seen that the operation of the A relay

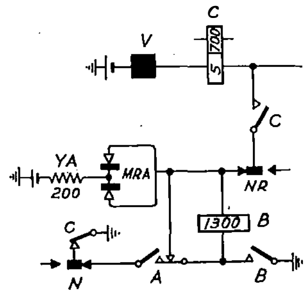

FIG. 5.—GROUP SELECTOR, B RELAY CIRCUIT.

removes the short circuit from the B relay coil and allows this relay to operate in series with the spool YA and rectifiers MRA. Relay C then operates *via* its 700 ohm winding and connects its 5 ohm winding in series with the vertical magnet, and the B relay coil. The small current flowing through the vertical magnet and 5 ohm coil of relay C has at this stage no appreciable effect. Impulsing takes place in the normal way and at each break full earth is applied to the C relay and magnet circuit, the B relay coil being short-circuited. The rectifiers MRA oppose the back EMF from the magnet set up during the make period of each impulse, and thus prevent the consequent surge current in YA from becoming sufficiently great to prolong the magnet release time appreciably. This precaution is necessary to reduce the possibility of failure of the vertical magnet to release after each impulse break under conditions of long line or high dial speeds. Two rectifiers in parallel are used in order to reduce the possibilty of deterioration produced by the overloads carried during the bunching time of the A relay contacts and during the release lag of B on clear down.

Although a full impulsing investigation has not yet been completed, preliminary tests show a considerable improvement in performance under long line conditions. The performance of the switch is peculiar in that under extreme conditions of long line impulsing the target shows two breakdown lines, one representing B relay failure and the other failure of the vertical magnet to release between pulses, brought about by the slugging effect and leakage path offered by the B relay circuit. The B relay failure is the limiting factor at dial speeds below about 12 i.p.s. and since this is the maximum speed allowed for under normal maintenance conditions, the magnet failure, although of interest, imposes no additional limitation on practical impulsing conditions. It may perhaps also be mentioned that although the leak current and magnet surge also pass through the 5 ohm coil of C, the effect on the release lag of the latter is in most circuits, of no account.

While dealing with the subject of impulsing, it may perhaps be opportune to mention the closely allied effect known colloquially as "pick-up." This term is applied to the following two effects which become apparent during impulsing over junctions and are due to the high impedance of the D and I relay loop in the auto-to-auto relay set, combined with the characteristics of the bridge condensers.

(1) When a selector A relay is energized over a junction in series with a D and I relay loop, the operate lag may be such that the bunching time of the make before break contacts is sufficient to produce a false vertical step.

(2) At the reintroduction of the D and I relay loop at the end of an impulse train, an extra impulse may be given to the selector magnet owing to the momentary release of the A relay.

These effects impose additional limitations when fixing allowable impulsing conditions, since in some circumstances either may occur at lower values of junction resistance than would cause actual impulsing failure. The short-circuited B relay arrangement used in the 2000 type selector circuits eliminates the possibility of false impulses on seizure since the magnet circuit is not completed until both B and C relays are operated, *i.e.,* until after the bunching period of the A relay contacts is passed. Although the second effect of pick-up may not permit full advantage to be taken of the improved B relay performance to increase present dialling limits, the new arrangement will at least allow existing limits to be met with wider tolerances on B relay adjustment.

Before concluding the remarks on the impulsing aspect, it may be of interest to draw attention to the method of producing the requisite C relay lag. This is obtained by short-circuiting the 700 ohm winding instead of fitting a slug as formerly. This feature has been included not for impulsing reasons, but in order to enable the relay to be used under either fast or slow releasing conditions according to requirements. In the circuit illustrated in Fig. **5** and also in the case of final selectors, the C relay 700 ohm winding is short-circuited only during impulsing and the relay releases in an unslugged condition on clear down of the selector. This arrangement gives a ready means of providing the private unguard on release, hitherto obtained by the employment of release magnet springs.

The 200-Point Two-Motion Line-Finder.

The pre-2000 type two-motion line-finder has been found by experience to be not entirely satisfactory, particularly under conditions of heavy traffic, and the introduction of the new mechanism presented an opportunity to eliminate undesirable features and improve the routine test facilities. Before dealing with the salient points of the new circuit, it may be of interest to reiterate some of the essentials of the two-motion line finder scheme and consider some of the imperfections of the existing circuit.

A simplified trunking diagram of the scheme is shown in Fig. **6**. The exchange is divided into units of 200 lines, each unit being provided with a primary start relay set, two or three primary control relay sets and a number of primary line-finders. The latter are sub-divided into directly and indirectly connected finders, the former being directly connected to first selectors and the latter having access *via* the banks of secondary finders, to a common group of first selectors serving the indirectly connected primary finders in a number of units. The secondary

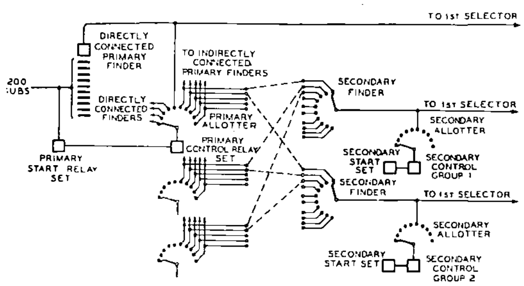

FIG. 6.—LINE-FINDER TRUNKING SCHEME.

finders are controlled by secondary control relay sets and secondary start relay sets reached from the primary allotter banks. Secondary working is brought into use only when the regular finders in the unit are all busy. Normally, each primary control relay set serves a particular section of the group of 200 lines, but during periods of simultaneous calls, team working between the control sets is employed. On account of its importance, each primary control relay set incorporates a time pulse lock-out feature which operates if on any particular call the interval between seizing the control set and releasing after connexion between the subscriber's line and first selector is established, exceeds 6 to 12 seconds. This prolonged control set holding time should normally occur only under fault conditions and hence the time pulse feature locks the control set out of service until released by hand, brings in an urgent alarm, and diverts the traffic into the other control sets. The circuit is so arranged that at least one control set serving the unit is always left in service.

In the past, in several exchanges, the number of lock-outs experienced has been found to be excessive, and in many instances the causes were not readily traceable to specific faults. Some of the defects responsible are given below, together with an indication of the manner in which improvement has been effected in the 2000 type circuit.

(1) *Two control sets seizing the same line-finder.* This was possible on both primary and secondary equipments and resulted from the difficulty in producing a suitable design of battery testing relay. This difficulty has been dealt with in the section on hunting arrangements and as indicated has been alleviated by the development of an 11 ohm battery testing drive cutting relay.

(2) *Faulty stepping of line-finders.* This was in the main due to the necessity for obtaining hunting by an interacting relay common to all line-finders in the unit, it being difficult to devise and maintain a suitable relay adjustment to ensure satisfactory functioning with any line-finder. In the 2000 type circuit this difficulty has been eliminated by employing self-interrupted drive, which incidentally also gives faster hunting, thus reducing dial tone delay.

(3) *Incorrect seizure of primary control relay sets under congestion conditions.* From the previous description of the time pulse feature, it will be evident that under conditions of complete congestion, arrangements must be made to prevent start conditions becoming effective on a unit if all channels from the latter are busy. The existing circuit was designed on the assumption that complete congestion on a unit would always be due to all primary finders (direct and indirect) in the unit being in use, *i.e.*, off normal. Lock-outs could therefore occur during secondary working when (*a*) indirectly connected primary finders were available in the unit, but all secondary finders were busy, (*b*) indirectly connected primary finders were available, but the secondary finder groups associated with them were busy although other secondary groups in the division were free. Condition (*a*) was relatively unimportant owing to the probability of complete secondary congestion being comparatively remote. Condition (*b*), however, is of fairly frequent occurrence during peak load periods in busy exchanges and has given rise to considerable difficulty. The gravity of the effect of a lock-out under congestion conditions was increased by the fact that the circuit arrangement precluded reversion to primary working on the whole 200 line unit until clearance of the lock-out. This feature has been removed in the 2000 type circuit.

The 2000 type circuit makes ingenious use of a valve to meet the various requirements under congestion conditions, the essentials of the arrangement being shown in Fig. 7. The valve is located in the

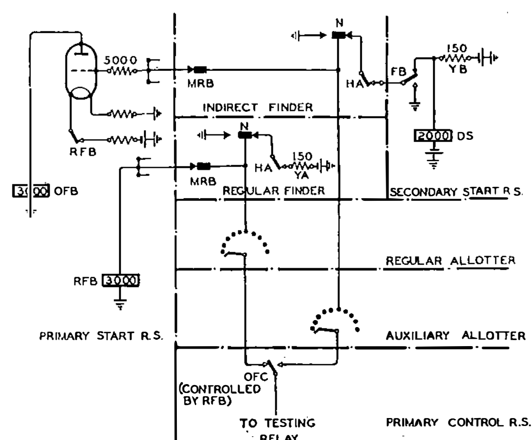

FIG. 7.—LINE-FINDER CIRCUIT EMPLOYING VALVE.

primary control relay set, and indirectly connected line-finders in the unit are commoned to the grid *via* metal rectifiers MRB. Directly connected finders in the unit are commoned to relay RFB which is maintained operated *via* resistance YA as long as any directly connected finders are free. Resistance YA is also the battery testing spool for the control set testing relay, YB being the corresponding spool for indirect finders. Any finder (direct or indirect) taken into service removes the testing battery and busies the relative allotter outlet *via* N springs.

Thus as long as there are directly connected finders free, the filament of the valve is disconnected. When the last available directly connected finder is taken into use, relay RFB releases and the valve filament lights, but as long as there is a secondary channel available the negative potential from resistance YB in the secondary start relay set biases the grid so that the anode current is insufficient to operate relay OFB. The bias potential supplied by any particular indirect finder is removed (i) when the finder is engaged, (ii) when the associated start relay set is busy, or (iii) when the associated secondary start relay set has no free secondary finders available to pick up the indirectly connected primary finder. (In these circumstances relay FB operates and busies the allotter outlet connected to the indirect finder concerned). Thus all congestion conditions are catered for. When the last available secondary channel is taken into service the last bias potential is removed and the anode current allows relay OFB to operate. The latter prevents start signals from operating the control set and thus causing a lock-out, and also connects the congestion meter to a one second time pulse. Rectifier MRB prevents the busying earth from the line-finder N springs or FB contact in the secondary start relay set from short-circuiting the grid bias potential supplied by the free finders. For the circuit functions concerned a valve has the advantage over a relay in that it operates to potential only. Since on secondary working this potential is supplied from spool YB which is also the battery testing spool for the allotter testing relay the use of a relay in place of a valve would, owing to the amount of commoning necessary, cause variation in the battery testing potential and consequently upset the testing conditions.

The congestion metering is carried out *via* a local circuit controlled by a contact of relay OFB and registers the total time during which all channels from the unit to 1st selectors are blocked. The previous circuit registered only the number of calls lost through insufficient primary finders and apart from the fact that all causes of congestion were not catered for, further inaccuracies were introduced owing to the meter circuit being under the control of the subscribers' line relays. Thus over-registration could occur if the subscriber flashed or dialled during congestion, or if tapping earths or loops existed, whereas under-registration could occur if calls overlapped.

In developing the line circuit it was borne in mind that the existing standard circuit presented difficulties in that subsidiary circuits such as night service, centralized service observation, meter routine test, etc., had to be of very special design in order not to upset the operation of the line-finder. With a view to facilitating design of such subsidiary circuits it was decided that the principle of applying a guarding earth to the subscriber's P wire on an outgoing call should be restored.

The desirability of using a two coil L relay to reduce the possibility of line-finder chase was examined, but as this would have restricted the use of the new circuit for extensions on old exchanges, owing to the possibility of incorrect L relay operation to the pre-applied ringing return battery from the final selector on incoming calls, the single coil L relay was retained.

In order to apply the self interrupted drive principle and thus obtain both the advantage of faster hunting and more positive stepping, it was necessary that the principle formerly employed of operating the switching relay in series with relays L and K should be abolished, since the operating time of the switching relay would be adversely affected by the inductance of the series circuit. The expense of providing a non-inductive resistance per line circuit would have been great, and after considerable investigation it was decided to utilize a fourth bank on the line-finder for switching and metering purposes, and to use the third (P) bank entirely for operating K relay and extending earth on the P wire of the final selector multiple. The expense of the additional bank was offset by the transfer of the rectifier previously fitted in the line circuit to the line-finder, and the simplification of the control set made possible by the use of the fourth bank.

Provision has been made in the new circuit for routine testing every level of the line-finder, and as each start relay is shared by the subscribers on two levels, while odd levels are being routine tested, the start circuit for the associated even level is transferred to another start relay. The progress of any call is therefore in no way impeded by routine testing. An allotter " camp on " facility has also been included to enable routine testing of any particular line-finder to be repeated as required. Further, the circuit enables routine testing of indirectly connected finders to be readily carried out.

The series hold circuit for relays HA and HB in the line-finder has been dispensed with in favour of the more usual and more satisfactory arrangement of holding in parallel with other switching relays in the train to earth returned from subsequent selectors.

Group Selector with Discriminating Feature.

As has already been stated in a previous article,[2] the 2,000 type selector can be fitted with two sets of level or normal post springs which can be made to operate on any level by the insertion of screws. Advantage has been taken of this in the proposed design for a 200 outlet group selector with discrimination, which can be used at line-finder main exchanges to discriminate between ordinary and " coin collecting box " subscribers, or at independent exchanges having remote manual boards for the discrimination of calls to dependent unit auto exchanges. The superseded circuit made use of a vertical marking bank for this purpose, and any change to the trunking arrangements necessitated a change to the wiring of the vertical marking bank. Owing to its position and the small gauge of wire used, such changes are not desirable on the 2,000 type switch, and the employment of level springs offered a more satisfactory method for obtaining the necessary discrimination.

[2] Loc. cit.

Other features including the unslugged B relay, balanced tones and the fast releasing switching relays are common to other group and final selectors.

Final Selector. 2/10 P.B.X.

Hitherto the provision of 2/10 P.B.X. facilities on the 100 outlet or 200 outlet final selectors has involved the use of a separate solid arc to control the automatic hunting circuit. Several types were tried but, although serving their purpose, they were subject to a number of disadvantages in that they interfered with adjustment and hid the wipers from view. Moreover one solid arc was sufficient for only 100 outlets and since it was impracticable to fit more than one arc to any one switch, 2/10 facilities could be given on only 100 outlets of a 200 outlet switch. On the introduction of the 2,000 type switch, advantage was taken of its superior bank capacity, and an ordinary bank was employed to provide the necessary conditions for discrimination. This allowed the provision of P.B.X. facilities on both hundreds of the 200 outlet P.B.X. final selector without incurring any appreciable additional cost.

Over 20 P.B.X. Final Selector.

The introduction of the forward rotary release feature on the 2,000 type selector has led to rather more drastic changes to the over 20 P.B.X. final selector than were necessary to other final selectors. In order to obtain the facility for hunting over more than one level, the pre-2,000 type selector made use of a rotary release magnet which restored the wipers to a normal position outside the level to which they had been stepped by the units impulse train. An automatic vertical step was then made to take place and the wipers caused to rotate over the next level. This process was repeated for all the adjacent levels in a P.B.X. group. Only if it were necessary to hunt over levels which were not adjacent were the wipers restored to normal and caused to step to a predetermined level. This level was marked by a permanent marking on the vertical marking bank. The feature was in this way limited to one P.B.X. group.

The rectangular release of the 2,000 type selector makes it necessary for the wipers to restore to normal after hunting over each level. It will be clear that some system for marking the levels belonging to each individual group had to be employed.

As the use of permanent markings on the vertical marking bank for this purpose would limit the flexibility of the scheme, four relays are employed. By operating these relays individually or in combination when the wipers reach the last contact of the level, it is possible to predetermine to which level the wipers must step on the next cycle of operation. By this means the order in which the levels are tested need not be ascending, and assuming the number of lines for a P.B.X. subscriber on level 8 grows beyond 60, it is possible to utilize a lower spare level for extension of the group. The selector would then test levels 8, 9, and 0, followed by the lower level allocated, *e.g.*, level 2.

Although the total number of relays employed in the over 20 P.B.X final selector has been increased from 13 to 15 by the introduction of the 2,000 type selector, the additional flexibility compensates to some extent for the increased cost.

Director Circuits.

The circuit arrangements for the 1st code and A digit selectors and the director are still in the process of development and it is hoped to give details of these in a subsequent article.

Mobile Post Offices

Arrangements are in hand for the provision of a mobile Post Office, which will probably be mounted on a special trailer chassis and towed by a Morris 3-ton tractor unit. It is intended for use at race meetings, etc., where permanent postal facilities do not exist, thus obviating the present practice of erecting and dismantling temporary equipment for such functions. The vehicle will contain two telephone cabinets, teleprinter plant, stamp-selling machines, etc., and will be equipped with its own generating plant to provide power for the transmitting instruments. Business with the public will be conducted through side windows over a counter constructed inside the vehicle. It is hoped to publish a full description of Mobile Post Offices in a subsequent issue.

Recruitment and Training of Post Office Workmen

E. J. C. DIXON, B.Sc. (Eng.), A.C.G.I., A.M.I.E.E.

Part I deals with the recent increase of work in the Engineering Department and the reaction on recruitment and training of workmen. Part II describes the Regional Training School, Shirehampton, Bristol.

Introduction.

REFERENCE has already been made in this Journal[1] to the exceptional necessity experienced during the past year for the recruiting and training of new workmen for the Post Office Engineering Department owing to the great increase in the rate of telephone development since October, 1934. The further reductions of tariff introduced since that date and the increase in the free service radius from 2 miles to 3 miles have greatly increased the work of the Engineering Department and the problem of recruitment and training has become so important and of such general interest in the Districts that it is felt that no apology is needed for a further article on the subject.

Reference is made in Part I of this article to activities in the Bristol Section of the South Western District where the incidence of the increased flow of Advice Notes has been experienced perhaps to a greater degree than in some other Districts. Some notes on methods of recruitment are given followed by a brief account of some special training classes for fitters and wiremen that were set up towards the end of 1935. The second part of the article deals with the Regional School located at Shirehampton, Bristol, which was opened on April 14th, 1936.

PART I.

NOTES ON RECRUITMENT AND TRAINING OF POST OFFICE ENGINEERING WORKMEN.

Recent increase in work of the Engineering Department.

A study of Post Office Telephone Statistics of Total Telephone Stations gives a fair picture of the increase in the work of the Engineering Department, which, although by no means confined to the provision of new subscribers' stations, is governed largely by the number of telephones since increase in telephones means increase in subscribers', junction and trunk circuits, increase in exchange plant and associated services and an increase in the staff required to maintain the plant. The graphs in Fig. 1 show the increase in total stations in the British Isles as a dotted line and the percentage increase per annum as a full line. The latter curve will lead the sanguine statistician to conclude that there is a strong likelihood of a continued increase in telephone business for a number of years at rates from 8 to 10 per cent. per annum. It is interesting to note that the official publication, "The Recruitment and Training of Post Office Engineering Workmen," was published in 1919 and revised in 1920 when the percentage increase curve was also mounting rapidly. In this article reference is made particularly to the Bristol Section and figures for Bristol are therefore included as a fine line from 1925 to 1936, the scale being in tens of thousands exchange lines.

The manner in which total staff is related to new business may be judged from Figs. 2 and 3 which give the Total Advice Notes per month and Total Workmen for Bristol Section between 1932 and 1936. It will be noticed that the storm of 1933[2] caused a temporary inflation of the staff, but the storm of 1935[3] caused no such inflation as it was less severe, more widespread in effect and no staff could be borrowed from other Sections. The latter storm, however, did contribute materially to the necessity for active recruitment at the end of 1935.

From a knowledge of the general trend of Total Stations statistics and with an advance knowledge of such factors as reduction of tariffs and local trade

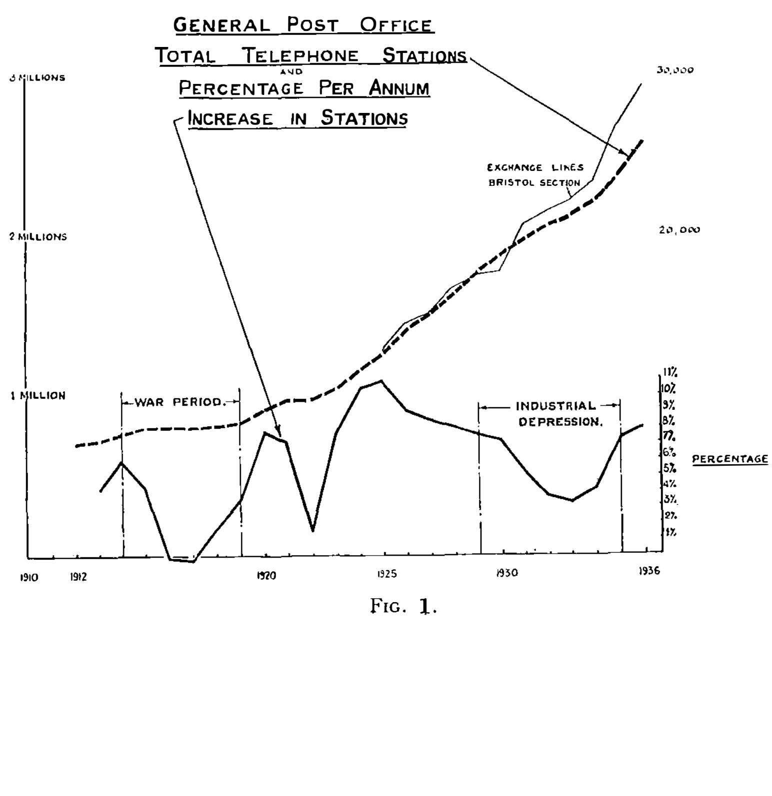

FIG. 1.

[1] "District Jointing and Fitting Schools." G. B. W. Harrison and F. Guest. Vol. 28, p. 232, Oct., 1935.

[2] "The Snow Storm of February, 1933." J. G. Hines. *P.O.E.E. Journal*, Vol. 26. p. 133.

[3] "Storm Damage, 1935-36." J. Stratton. *P.O.E.E. Journal*, Vol. 29, p. 66, April, 1936.

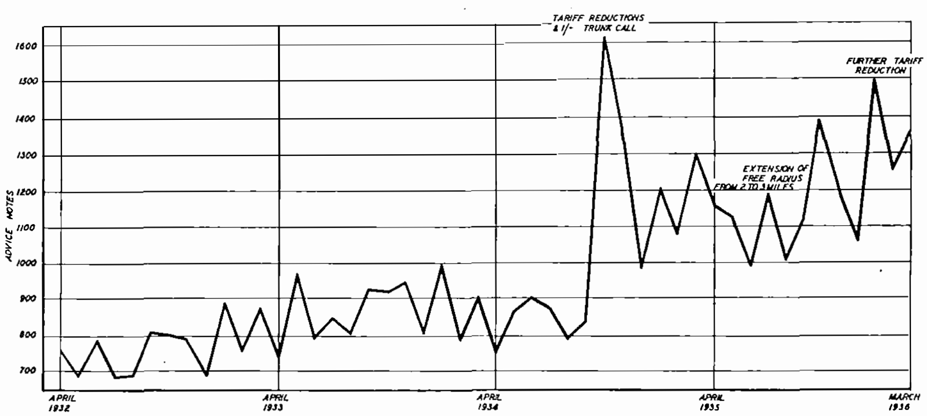

Fig. 2.—Total Advice Notes per Month.

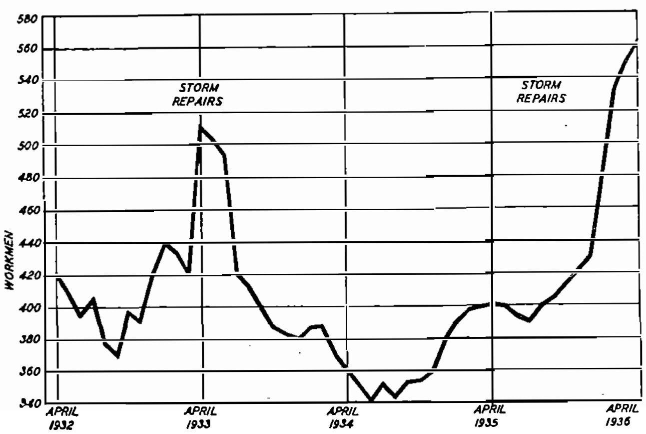

Fig. 3.—Total Workmen in Bristol Section.

tendencies it should be possible to forecast with some accuracy the staff requirements in any particular Section for some time ahead and to make the necessary arrangements for their recruitment and training.

Analysis of Workmen into Groups.

Post Office workmen may be divided broadly into groups as follows :—

1. Labourers—overhead and cabling gangs.
2. Wiremen—overhead construction and maintenance.
3. Jointers—cabling construction and maintenance.
4. Fitters—subscribers' apparatus.
5. Dual linemen—subscribers' apparatus, small exchange, and line maintenance.
6. Skilled fitters—switchboard and automatic apparatus construction.
7. Internal Maintenance Staff—switchboard and automatic apparatus maintenance.

Various specialist groups are derived from members of one or other of these main groups, *e.g.*, survey officers and clerks of underground works from the first three, P.B.X. and P.A.B.X. maintenance men from the fourth and fifth, fault control officers from the fifth, and repeater station maintenance men from the sixth and seventh groups. There are also such special groups as skilled mechanics for machine overhaul centres and electric light and power staff.

Workmen in Groups 2 and 3 are recruited normally from the more skilled men of Group 1. Subscribers' apparatus fitters may be similarly recruited or may be re-graded Youths-in-training. Similarly, maintenance men or linemen may be taken from the experienced men in Group 2 or 4 or from re-graded Youths-in-training. Groups 6 and 7 are recruited from Youths-in-training with good technical ability and from the more skilled and experienced men of Groups 4 and 5.

Normal Recruitment.

From the foregoing analysis it will be seen that the normal recruitment is of Youths-in-training and Labourers with subsequent training of the more skilled among them for the more difficult and technical classes of work. The procedure governing the recruitment and training of Youths is well known[4] and little more need be said than that Youths must normally have had a sound secondary school course with an emphasis on the scientific subjects and that they must follow a prescribed course of training on actual works and at special courses at the Engineer-in-Chief's training school, before being re-graded as skilled workmen. Youths are also expected to follow, at a Technical Evening Institute, a course which is designed to cover the syllabuses of the examinations of the City and Guilds of London Institute in Electricity and Magnetism, Telephony, Telegraphy, or Radio. In large centres of industry there are often day courses of a similar nature, usually organized for works apprentices of the more enterprising industrial concerns, which necessitate attendance on one day only each week. It is thought that the use of this type of course for Youths-in-training merits investigation.

Labourers are normally recruited from Boy Messengers or from the Labour Exchanges as required to replace the normal wastage. Occasionally a man skilled in a trade similar to Post Office work may be taken on, *e.g.*, an electric light wireman for a telephone fitter or a plumber for a plumber-jointer. A difficulty arises here, however, since the rates for unestablished skilled workmen in the Post Office are in some cases less than Trade Union rates and a fully skilled man is therefore not often attracted to Post Office employment unless he has confidence in his ability to qualify rapidly for the higher grades of work, or alternatively, an appreciation of the advantages of Post Office employment such as permanency, free tools and protective clothing, free transport and subsistence allowance when working away from headquarters. A special example of the latter type of

[4] Engineering Instruction, Staff, General, I 0501.

recruitment is afforded by the operations of the National Association for the Employment of Regular Sailors, Soldiers and Airmen which works in close co-operation with the Post Office. Many ex-service men have had technical training of one sort or another during their period of service which forms a good foundation on which to build the more specialized training for telecommunication work.

Normal Training.

Labourers are normally trained on works while associated with qualified skilled workmen. Since the number of men being trained in this manner at any given time is normally a small proportion of the total staff, no special account is taken of the trainees' time and the cost of training is divided between the various accounting subheads according to the classes of work on which the trainees are occupied. Workmen are encouraged to attend Technical Evening Classes, but in rural areas these are usually not available. To meet this difficulty correspondence courses, conducted by the Engineer-in-Chief's training school, are available.

Apart from the special courses at the Engineer-in-Chief's training school, Youths are trained in a similar manner except that they must cover a variety of classes of work during their training period. Their time during their first two years of service is charged to a Training works order.

Exceptional Recruitment.

Under conditions of great expansion of work, the rate of recruitment must be enormously accelerated. The following details describe recent activities in the Bristol Section of the South Western District which may be peculiar to that Section in degree, but are probably typical of activities of a similar nature all over the country.

It was found that examination of any batch of applicants sent by the Labour Exchange produced a small proportion only of men suitable for training for skilled or semi-skilled duties. The main recruitment was for gang-hands and subscribers' apparatus fitters to deal with the advice note work, but additional switchboard fitters were urgently required to cope with the heavy Internal programme and a need was forseen at no distant date for additional jointers to deal with an accelerated underground development programme. In addition, the recent heavy rate of promotion had greatly thinned the ranks of qualified skilled workmen. The necessity for obtaining a large number of applications from as diverse sources as possible became apparent and accordingly a large-type advertisement inviting applications from wiremen, fitters, "skilled fitters" and jointers was inserted in two evening and one daily local papers for three successive days, the degree of skill desirable and the training to be given being briefly indicated. At the same time some suitable publicity material was placed in the columns of one of the evening papers.

Within a few days over a thousand applications had been received, and in order to deal with them in a uniform manner and as quickly as possible a form, of the "erase words not required" type, was designed which served also as an appraisal form for those applicants who were interviewed. From the attached reproduction of the form (Form 1) it will be seen that the main items of interest in each application are noted together with a statement of the action taken. A note giving guidance in the interpretation of the appraisal part of the form was circulated to officers conducting interviews in order to secure uniformity of appraisement. The forms, associated with the usual application forms and any relevant correspondence were filed in alphabetical order and, in the case of successful applicants, are the opening pages of their Departmental history.

Of the 1,200 applications received some 700 were rejected after a scrutiny of the letter of application and the applicants informed immediately. The remainder were divided, after having been acknowledged, into groups according to the relative urgency of the requirements and further scrutinized with a view to arranging interviews with the more promising applicants. The selection and interviewing of candidates for employment were naturally spread over a considerable period, but, including men recruited from the Labour Exchange and men recruited as a result of advertisement, in six months some 120 labourers, 48 fitters and 13 jointers were engaged. Out of the total applications not more than five skilled fitters were found although a greater number would have been attracted had it been possible to offer them wages equivalent to their present earnings. The majority of men engaged for

Fig. 4.—Fitting Practice Frame.

Form 1.

BRISTOL SECTION RECRUITMENT.

Application No.................................... Date................................

for

Y-in-T. Labourer. Sub's Fitter. Skilled Fitter. Jointer.

Name.. Age..............

Address ....

Present job ....

Length of experience ....

Pay required................................

References : None. Average. Good. Exceptional.

Character of Application : Poor. Fair. Good. V. Good Excellent.

Reply to Application : "No." "Later." Interview....................................

Date and time..................................

....

Interviewed by .... Date..................................

					Marks.
PHYSIQUE.	Poor.	Average.	Strong.	Heavy.	....
ADDRESS.	Repellent.	Nondescript.	Pleasant.	Attractive.	....
INTELLIGENCE.	Dull.	Ordinary.	Alert.	Bright.	....
INITIATIVE.	Poor.	Fair.	Good.	V. Good.	....
ZEAL.	Poor.	Fair.	Good.	V. Good.	....
EDUCATION.	Poor.	Fair.	Good.	V. Good.	....
TRADE KNOWLEDGE.	Poor.	Fair.	Good.	V. Good.	....
TECHNICAL KNOWLEDGE.	Poor.	Fair.	Good.	V. Good.	....
MATHEMATICAL KNOWLEDGE.	Poor.	Fair.	Good.	V. Good	....
CRAFTSMANSHIP.	Poor.	Fair.	Good.	V. Good.	....
PENMANSHIP.	Poor.	Fair.	Good.	V. Good.	....

REMARKS :—

RECOMMENDATION. Reject. Call up later. Employ after training. Employ direct.

Report to .... on .... at ....

Starting Pay ....

Notes :—

fitting work were therefore young men of similar type to re-graded Youths-in-training.

Special Training Classes.

Special training classes of a fortnight's duration were set up for subscribers' apparatus fitters and for external wiremen. These were conducted in improvized accommodation at the Central Exchange and afterwards at the Regional School, Shirehampton, by an Inspector transferred from the Engineer-in-Chief's Training School assisted by specially chosen skilled workmen.

(1) *Fitting Course for New Recruits.*

Experience shows that it is desirable to limit the scope of the course to direct exchange lines and Plan Nos. 1 and 1A in order that the students should not be confused with a variety of circuits. Emphasis is placed on the desirability of the students handling the apparatus and gaining a certain familiarity with its appearance and construction before hearing lectures on the theory of its functioning. Rate book titles and descriptions are taught from the outset. Practical fitting work is done first of all on timber frames (Fig. **4**) and these can be made with advantage and economy by the students themselves. Considerable practice is desirable in the use of "Rawl plugs" and wooden plugs on wall surfaces of various materials and in a "shock course" one of the difficulties is to find adequate wall space for this practice. Bristol was fortunate in having some partition walls (due for demolition) available at the right time. In general, attention was confined to the C.B. system and the syllabus in Table I was found to be a useful basis for the course.

(2) *Overhead Construction Course.*

This course is limited to medium routes and wiring typical of subscribers' services. Emphasis is placed on the correct use of tools and on the constant observance of proper precautions. Each student is required to erect, dress and wire his own practice pole which is just high enough to necessitate his working off the ground (Fig. **5**). After experience in work on the short poles the student proceeds to learn pole climbing and working at normal heights.

Table II gives a brief syllabus of a typical course.

TABLE I.

ABRIDGED SYLLABUS FOR TWO WEEKS' COURSE IN SUBSCRIBERS' APPARATUS FITTING.

Day.	Theoretical.	Practical.
1	Engineering Department. Good workmanship. Introduction to Telephony. Resumé of syllabus.	Demonstration of tools used in fitting, correct use. Rate book descriptions. Introduction to apparatus components.
2	Leclanché cells. Testing. Ohm's Law. Principle and use of Detector and resistances.	Making up cells. Testing. Measuring P.D's and currents. Apparatus dismantling.
3	Cable and wire, use, colour schemes. Wall surfaces, method of attaching cables and apparatus.	Plugging walls. Fixing apparatus. Running and fixing cables.
4	Subscribers' internal service, precautions *re* other services. Location of apparatus.	Jointing and soldering wires. Blowpipe work on small cables. Fixing terminal strips.
5	Protectors, fuses, heat coils, distribution cases and terminal block.	Fixing cabling, wiring protectors, distribution cases and terminal blocks. Plugging practice.
6	Receiver, transmitter, magneto bell, induction coil and condenser. Loose leaf diagrams.	Fixing protector, wires and apparatus and joining up to simple exchange line diagram.
7	Conversion of schematic to wiring diagrams. Direct exchange lines, wall and table type. Facilities.	As 6. Each student to deal with Telephones Nos. 121, 150 and 162 with Bell Sets No. 5. Extension bells.
8	Plan No. 1. Facilities, theory and fitting.	Provide Plan No. 1 in combinations of wall and table instruments.
9	Advice Notes. Requisitions. Stores Vouchers. Progress Reports. Regulation No. 71.	As 8. Preparation of Advice Notes, Progress Reports and Requisitions.
10	Plan No. 1A. Facilities and fitting. Miscellaneous apparatus.	Provide Plan No. 1A. As 8.
11	Examination in practical work.	Miscellaneous apparatus. Simple adjustment. The location and clearing of a simple fault.
12	Closing Talk. Emphasis on good construction to avoid necessity for maintenance attention.	Clearing up, handing-in tools, apparatus and literature.

Literature for study :—Rg. 40, 41, 71.
Workmen's Pamphlets Nos. A5 and 6, D1, 3 and 11, F1 and 8.
Loose Leaf Diagrams. As appropriate.

FIG. 5.—EXTERNAL WORK ON SHORT POLES.

TABLE II.

ABRIDGED SYLLABUS FOR TWO WEEKS' COURSE IN OVERHEAD LINE CONSTRUCTION.

Day.	Theoretical.	Practical.
1	Engineering Department. Good workmanship. Introduction to Telephony. Composition of telephone line.	Examination and handling of tools and stores. Rate book titles.
2	Safety precautions. Use of tools. Poles and pole fittings.	Demonstration of earth auger, bar and spoon methods. Fitting short pole.
3	Excavation of pole holes and erection of poles. Spindles, design and use.	Erection of short pole. Cutting-in arms. Fitting spindles.
4	Insulators. Line stability.	Fitting stays. Excavation for stays and block poles. Stay guards.
5	Types and uses of conductors. Erection, jointing and regulation.	Spurs and crutches. Paying-out wire. Stringing tool. Jointing. Pole climbing practice.
6	Binding-in wires. Single and double terminations. Road and rail crossings.	Binding-in, single and double terminations (up to 150 lb. wire). Regulating wires.
7	Cabling on poles and arms. Connexion to open wires.	Running leads on poles and arms. Preparation of long poles and excavating holes.
8	Transposition and twist systems.	Inserting crosses in twist and transposition systems. Erection of tall poles and wiring.
9	Covered wires. Binding-in and terminating. Covered drop-wire distribution.	Covered wire practice. Examples in covered drop-wire distribution.
10	Light line construction. Regulation of existing routes.	Fitting light line items on short pole route.
11	Primary vouchers. Regulations.	Continuation of any outstanding work.
12	Maintenance aspect of work. Co-operation in gangs.	Recovery of poles and clearing construction park.

Literature—Rg. 41, 40, 71.
Workmen's Pamphlets Nos. H1 and 2.

Observation of New Recruits.

New recruits are not retained after the end of the training course if they do not prove sufficiently adaptable to the work, and those who are taken on are carefully watched during their early career. The recruits who promise well may be selected for further training, *e.g.*, as skilled fitters, and others may prove fitted for special classes of work, *e.g.*, House exchange systems. Reports are furnished by their Inspectors monthly up to three months and then at the end of six months' experience. A record is kept of the progress of each new entrant on a form. (Form 2).

The great majority of new recruits are graded as " Labourers " when first engaged, but steps are taken to regrade them as Unestablished Skilled Workmen as soon as they are sufficiently skilled to perform satisfactory work unassisted.

The experience in Bristol has been that only 30% of the new recruits in fitting and overhead construction rapidly qualify as good workmen.

Comparison of New Recruits with Experienced Workmen.

In general it is not desirable to associate men of widely different degrees of experience in one course, but in one fitting class it happened that new men were mixed with men who had had considerable experience in fitting and the opportunity was taken to compare their performance in the test at the end of the course. The test was to fit and wire a Telephone No. 121 with a given length of cable to a protector on the fitting frame. The time taken by each student was noted and the completed work appraised and given marks for workmanship. In the comparative table which follows a performance rating derived from the time taken and the relative excellence of workmanship is also given.

FORM 2.

BRISTOL SECTION.

Local Staff Record. NEW ENTRANTS.

NAME .... Date of Birth ....

Class of Work .... H.Q. ....

Date of Entry ....

Dates of School Course. From .... To................................

Report of Inspector in Charge :—

Other notes *re* Training :—

Inspector's Reports :—(Should include work employed on and performance, *i.e.*, " V.G.," " G," " Fair " or " Poor ")

Period.	Inspr.	Noted by Engr.
1st Month.		
2nd Month.		
3rd Month.		
3rd to 6th Month.		

Engineer's Final Report—6 months' after training course :—

Workman.	Time mins.	Marks.	Performance Rating.
A.	18	7	25
B.	18	5.5	28
C.	22	6	31
D.	22	8.5	25
E.	26.5	8.5	30
F.	28.5	8	33

The first three men were experienced fitters and completed the test more quickly than the three new men, but the new men did better work. The adjusted performance rating shows that there is little to choose between the best new man and the best experienced man.

PART II.

REGIONAL TRAINING SCHOOLS.

General.

Specialized training for Post Office workmen and general training for Youths-in-training and Probationary Inspectors and Engineers has been provided in the Engineer-in-Chief's Training School.[5] Whereas the workmen's courses at the Engineer-in-Chief's school are all designed to cover the more specialized and technical subjects, those of the Regional schools are designed to cover the day to day work of the Engineering Department. This is because a need has been felt for a general upgrading of the standard of workmanship and the level of technical knowledge displayed by the average workman. The need arises partly from the increase in complication of telephone apparatus and the introduction of new methods of construction and partly from the higher standard of maintenance now demanded by the Department.

Thus the basic courses to be taken at the Regional schools are :—

I. Overhead Construction (normally with reference to the provision of subscribers' circuits).
II. Plumbing and Jointing.
III. Subscribers' Apparatus Fitting.
IV. Switchboard Fitting (with special reference to U.A.X. work).

A course for linemen can be made from I and III with emphasis on the testing and fault clearing aspect of the work, whereas a course for Youths-in-training can be made from a combination of all the basic courses.

Consideration is to be given at a later date to the provision of short courses in more specialized subjects such as

Stamp Selling Machines,
Office Machinery Maintenance, and
House Exchange Systems.

[5] References.
Description of School.
A. Akester, *P.O.E.E. Journal,* Vol. 27, p. 129, July, 1934.
Post Office Green Paper No. 16(A). 19. July, 1935.
Training Courses. E.I. Staff General I 0503.

The Regional Training School, Shirehampton, Bristol.

The prospect of adapting an existing house to the purposes of a Regional School was approached with some misgiving until the possibilities of "The Wylands" at Shirehampton had been explored. It can truly be said of this building, however, that it might almost have been designed for the purpose for which it is at present used.

"The Wylands" was built in 1907 as a country residence. It is soundly constructed and whereas the interior has large, well proportioned rooms the exterior is dignified and pleasing. (Fig. 6). The grounds are not extensive, but there is a space of

FIG. 6.—REGIONAL SCHOOL, SHIREHAMPTON.

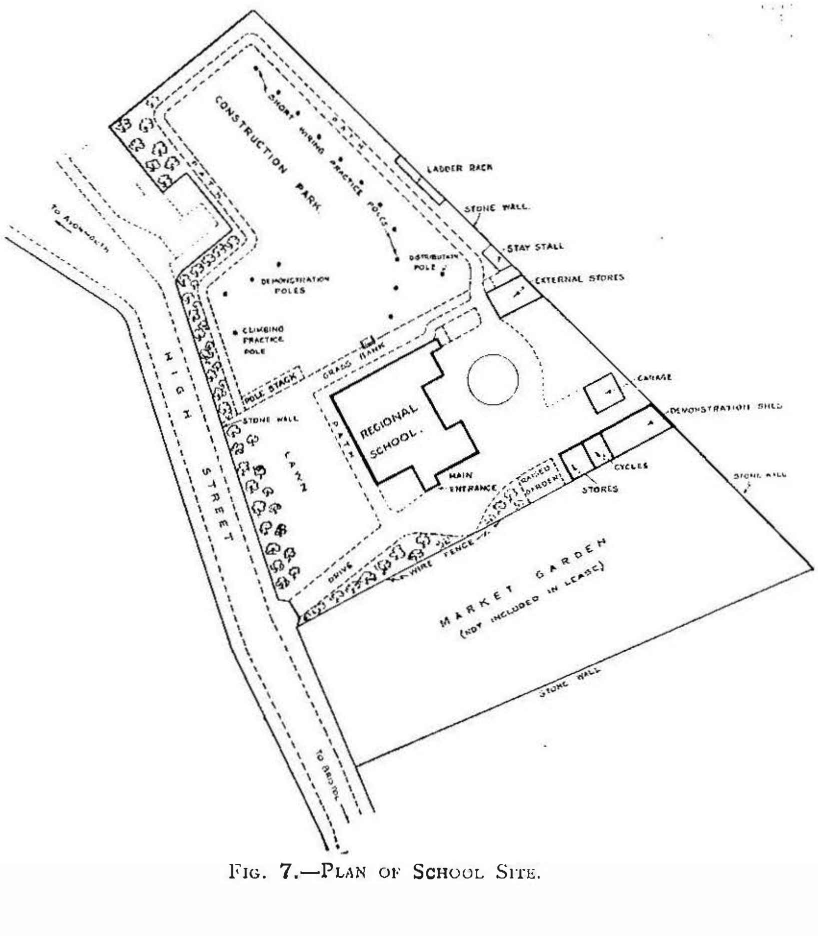

FIG. 7.—PLAN OF SCHOOL SITE.

suitable size to one side of the house for a construction park and there are useful outbuildings to the rear. A plan of the site is given in Fig. **7**.

The Lay-out of the Building.

The arrangement of the rooms can be seen from the plan in Fig. **8**. The main entrance leads to a hall

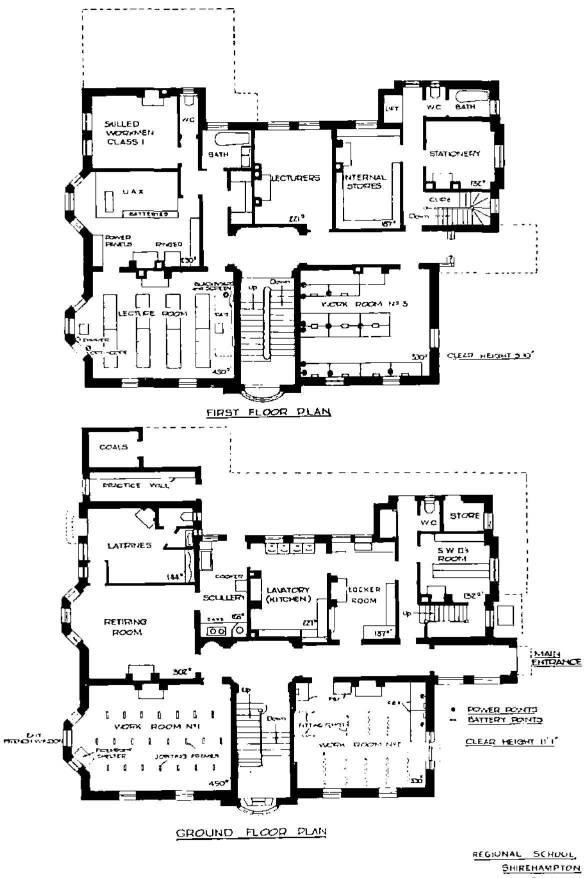

Fig. **8**.—Lay-out of School.

off which there is a passage to the men's locker room, washing and cooking rooms and a back staircase to the first floor. In the hall are notice boards giving the school time-table and detailed daily instructions for each course. At the far end of the hall is the men's retiring room from which access is had variously to the cooking quarters, the lavatory and the construction park. There are two workrooms on the ground floor, one for jointing and plumbing lead cables and the other for fitting subscribers' apparatus. The former is furnished with cable stands and chairs, the floor being protected by sheets of asbestos board. Here the walls exhibit typical cabling diagrams, details of which are abstracted on mounted diagrams for the use of individual students as members of a team.

The subscribers' apparatus fitting room has a number of timber frames spaced for students to work each side. Typical switchboards are provided for the interconnexion of completed circuits and wiring facilities are provided by means of distribution cases and flexible leads so that any frame may be connected to any of the switchboards. The wiring diagram is given in Fig. **9**.

The first floor is reached by a wide staircase lighted by a noble window and provides a lecture room, a workroom, a U.A.X. room and offices for the staff, besides storerooms. The third workroom is furnished with tables each having access to battery supplies and a power point with soldering iron furnace. The battery supplies are tapped from the 50 volt battery which also serves the U.A.X. The lecture room is also used as a writing room and has a file of Engineering Instructions.

The rooms as arranged will accommodate a maximum of 20 students per course, and the school is at present organized to run courses simultaneously in three different subjects.

The second floor of the building has 4 rooms, two of which are large and well lighted. This floor is available for development.

The outbuildings comprise a small cottage, used for external tools and stores, a garage, a shed fitted for external demonstrations in bad weather and a cycle shed.

Special Fittings.

(1) *Apparatus Fitting Frames.* (Fig. **4**). Originally designed at the Engineer-in-Chief's school to fulfill the dual purpose of fitting and jointing frames, these are now simply a surface of timber on which the student practices running cables and fitting instruments. A shelf is provided to hold small tools and stores and the terminals provided are connected to the distribution circuit by three-way cords.

(2) *Wall Plugging.* (Fig. **10**). For plugging various wall surfaces the dairy room at the rear of the house was converted to a practice wall. The wall is high in order to provide for work above

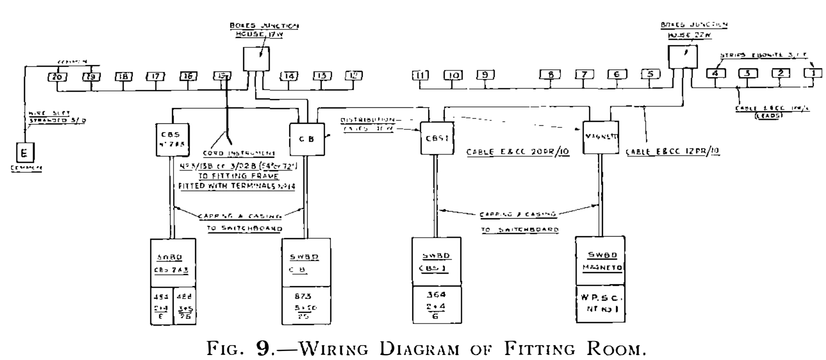

Fig. **9**.—Wiring Diagram of Fitting Room.

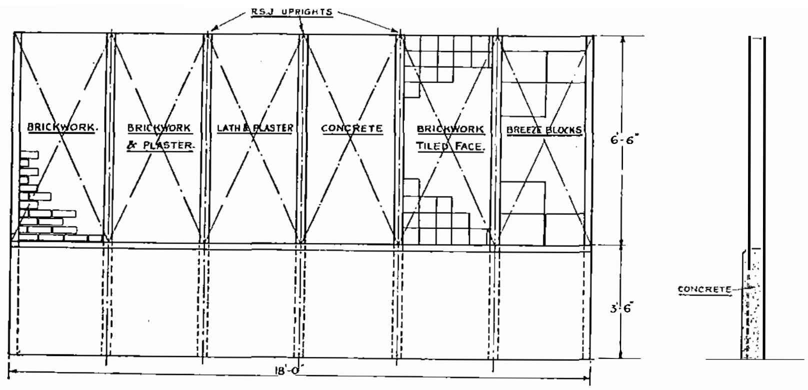

FIG. 10.—FRAME FOR WALL PLUGGING PRACTICE.

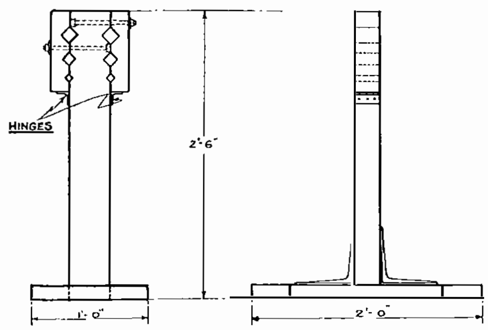

FIG. 11.—JOINTING FRAME.

(3) *Jointing Frames.* (Fig. **11**). The main support has 3 V slots on each side and its width is such that the cables in the slots are separated approximately as they would be in multiple way duct. The bases of the stands are protected with heat resisting paint.

(4) *Wax Bath.* (Fig. **12**). A thermostat controlled, electrically heated wax bath was designed since no gas supply is provided at the school. The heating elements are arranged in series-parallel to provide variable rates of heating.

(5) *Fire Proof Shelter.* (Fig. **13**). This was designed for torch blowing lamps, furnaces or the wax bath, and the ventilating cowl is arranged to exhaust at a window. The construction is of iron and asbestos sheet, a double panel with air space being provided at the back.

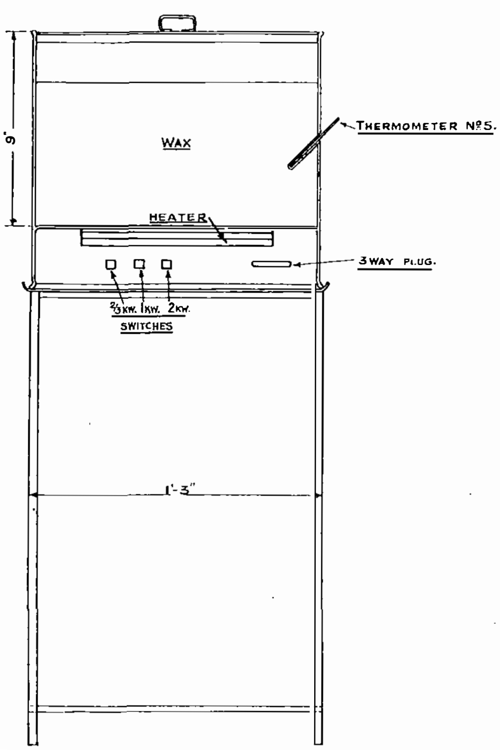

FIG. 12.—WAX BATH.

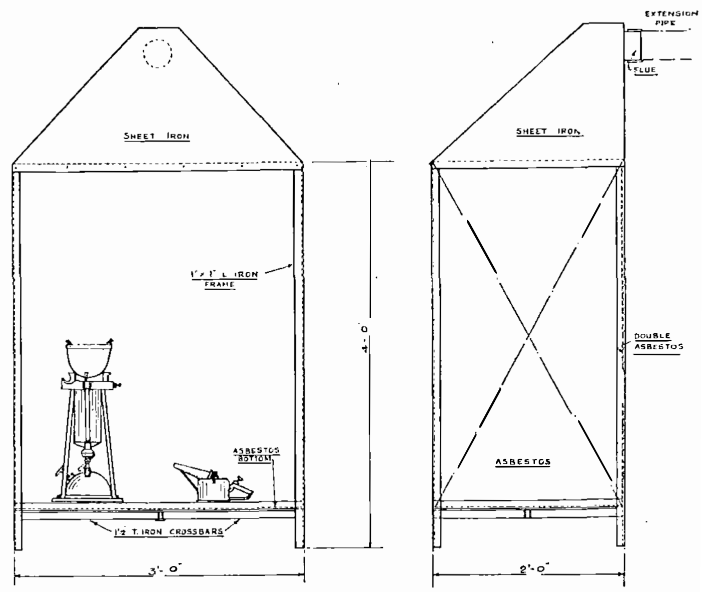

FIG. 13.—FIRE PROOF SHELTER.

standing height and provision is made for good lighting.

(6) *External Construction Park.* (Fig. **7**). The main features are :—

(*a*) Line of short poles for wiring practice. Each student must erect and dress his own pole.

(*b*) Line of demonstration poles.
(*c*) D.P.'s with drops to the cottage.
(*d*) Tall poles for practice aloft.
(*e*) Tall poles for climbing practice.
(*f*) *Staystall.* (Fig. **14**). Several stay rods are cemented into the ground and eyes into the wall at a suitable height. Practice in making-off stays can be done under the correct conditions.

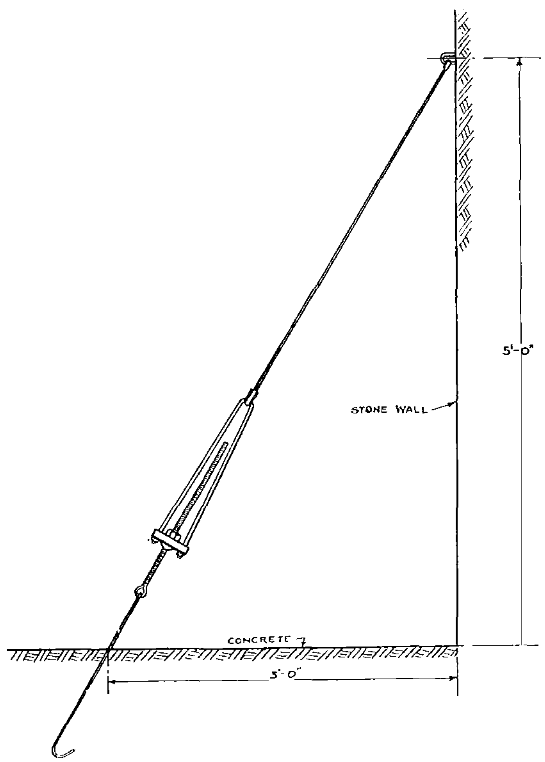

FIG. **14**.—STAYSTALL.

(7) *Device for Detecting Broken Circuit while Cutting and Regulating Wires.* This device is a relay circuit placed in series with a looped line which the student is required to cut and regulate. A break in the circuit operates the relay which actuates a loud buzzer calling attention to the student's fault.

School Staff.

The school staff is at present constituted as follows :—

1 Inspector in Charge.
1 S.W.I. (Fitting).
1 S.W.I. (Maintenance).
1 S.W.I. (Jointing).
1 S.W.I. (External Construction).
1 Clerical Officer (Welfare and office work).
2 S.W.II's (General Assistance).
3 Labourers (Stores and Cleaning).

This staff will be modified as experience dictates. It is probable that two Inspectors and two S.W.I's for each course will prove to be required.

Welfare.

Shirehampton is some five miles from Bristol, in pleasant country above the River Avon. There is adequate lodging accommodation in and about the village and each student is provided with a list of addresses. Each lodging was visited before being admitted to the panel. The washing and cooking facilities at " The Wylands " are liberal. The water heating is by the usual type of coke fired boiler and the cooker is electric. Sports activities are encouraged and an excellent swimming bath is available in Shirehampton.

Policy of the School.

Emphasis is placed on the teaching of self-respect as a member of the Post Office Engineering Department, and nothing but the best possible work is expected from each student. The importance of good workmanship from the maintenance point of view is stressed and the importance of a reasonable performance rating is not lost to sight. An endeavour has been made to bring the decoration and equipment of the school up to a high standard in order to inculcate in the students a pride of place and a desire to keep their workrooms in good order and appearance. For similar reasons each student is provided on arrival at the school with clean protective clothing and a full kit of tools. The correct use of tools is taught at the outset of the course and the ideal of craftsmanship is presented throughout. At the same time an attempt is made to interest the students in the fundamental principles underlying the design and construction of apparatus and circuits, and full information in the form of technical pamphlets and diagrams is made available to each man. In teaching circuits, approach is made *via* the facility schedule, through the schematic diagram built up from fundamental principles, to the actual wiring diagram as used in practice.

Public relations and the service aspect of the Engineering Department are not forgotten and the student is encouraged to think of himself not only as a public servant, but also as a working part of the largest business organization in the country.

Acknowledgements.

The author's thanks are due to Mr. Geo. Moore, Inspector in charge of the school, for much of the material of the article.

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An Outline of the Principles of Atomic Physics

F. C. MEAD, B.Sc. (Hons.), A.R.C.S.

II. The Phenomena of Ionization in Gases and their Significance

In the second article of this series the discussion of ionization in gases leads to a description of the conception of the photon and an explanation of Einstein's principle of the equivalence of mass and energy. The experimental value of the Wilson Cloud Chamber is also described.

Ionization in Gases.

ANY individual particle, atom, molecule or group of molecules which exhibits a free electric charge, positive or negative, is known as an " ion." When a gas contains appreciable numbers of these charged particles it is capable of conducting electricity and it is said to be " ionized." An ionized gas has different properties from an un-ionized gas in several respects other than electrical conductivity, and these properties are made use of in experimental atomic physics.

We shall need to study briefly the main conditions which determine the ionization of a gas. When a gas becomes ionized during an experiment, we may then be in a position to draw conclusions as to the probable cause of the ionization.

Positive Ions and Atomic Nuclei.

It is not desired to confuse the main issue of these articles by discussing in any detail the theory of atomic structure, it is necessary, however, to consider the broad scope of this theory. There is ample evidence that atoms consist in part of electrons. On applying an electric field to matter under appropriate conditions, *e.g.*, in a cathode ray tube, a stream of electrons appears. We have been able to examine the evidence for assigning a mass to these electrons which is more than a thousand times smaller than that of the lightest known atom, hydrogen. It is difficult to avoid any conclusion except that these electrons are in some way drawn out of the atoms of gas. Each electron carries a negative charge and since ordinary matter is electrically neutral, it is not unreasonable to assume that the atom contains positive charges corresponding to the negatively charged electrons.

The mass spectrograph provides evidence in support of this assumption and beams of positive ions, having charges equal in magnitude to the charge on the electron or small integral multiples of it, can invariably be detected in a gas through which an electric discharge is passing. These beams of positive ions are known as " positive rays." We may confidently assume, therefore, that when an atom loses an electron it becomes ionized and exhibits a positive charge equal in magnitude, but opposite in sign to the negative charge of the electron it has lost. Ions are also observed carrying negative charges and it is consistent with our theory to picture them as atoms, molecules or groups of molecules which have acquired an additional electron or electrons.

It is an experimental fact that when an atom is ionized electrons are emitted which have a mass thousands of times less than the mass of the atom, leaving a positively charged ion approximately equal to the mass of the parent atom. Failure to observe the opposite process, namely, the emission from the atom of positive charges of small mass, leads to the belief that the bulk of the mass of an atom is associated with a positive charge. The structure of the atom is thus conceived as a heavy positively charged " nucleus," with which are associated a sufficient number of negatively charged electrons to neutralize this positive charge.

Each atom is found to be capable of losing by ionization a definite number of electrons, the number of electrons which can be lost increasing with increase of atomic weight. Experimental evidence indicates that the hydrogen atom can only lose one electron, the evidence being that the maximum positive charge carried by a hydrogen ion is $+1.59 \times 10^{-19}$ coulombs. In the case of helium the maximum positive ionic charge is $+3.18 \times 10^{-19}$ coulombs. The ionized atom of a substance which carries the maximum positive charge is accordingly identified with the nucleus of that atom. It must be clearly noted that this is not intended to mean that the nucleus does not contain electrons. Such electrons, however, as may be contained in the nucleus must be more tightly bound than the electrons which are removable by ionization.

The lightest particle carrying a positive charge which is found in a discharge tube is the ionized atom of the lightest element, hydrogen. This particle which appears to be the nucleus of the hydrogen atom is accordingly regarded as an elementary particle and is given the name " proton."

Its mass is 1.65×10^{-24} grams and its positive charge is 1.59×10^{-19} coulombs.

It is convenient to denote the electronic charge, which is now a recognized Physical Constant, by the symbol e. In addition the masses of the elementary particles are conveniently expressed on the atomic weight scale used in Chemistry. This scale expresses masses in terms of the mass of the oxygen atom which is defined as equal to 16. In cases where no units of mass are specified it is to be understood that the atomic weight scale of units is implied.

Thus the mass of the electron is 0.000548 atomic weight units and its charge is $-e$. The mass of the proton is 1.008 atomic weight units and its charge is $+e$.

Another positively charged particle which must be mentioned at this stage is the alpha particle. As we shall discuss in more detail in the next article, the element radium emits spontaneously several streams of rays, one of which, known as alpha rays, is found to consist of positively charged particles carrying a charge of $+2e$ and having a mass of 4.003. This value is equal to the mass of the helium atom. As no other particle of this mass has been encountered which carries a greater positive charge than $+2e$, the alpha particle is identified with the nucleus of the helium atom.

Ionization by Collision.

When a gas is continuously carrying an electric discharge, the ions and electrons which act as carriers will continually reach the electrodes and become discharged. It would be expected, therefore, that eventually all the ions will become discharged and the gas will cease to conduct. The fact that it is unusual for conduction to cease in this manner indicates that the ions reaching the electrodes are being continually replaced, *i.e.,* that ionization is continually taking place. We must proceed to enquire, therefore, as to how this takes place; what is the mechanism of ionization in these circumstances?

It is common knowledge among communications engineers that any gas discharge tube, *e.g.,* a thermionic valve, possesses a " saturation current "; it does not obey Ohm's Law.

If the voltage across the electrode is increased, the current increases with the voltage at first, but eventually the current reaches a constant value quite independent of the applied voltage. This can be explained in terms of the rate of ionization in the tube.

As the voltage across the electrodes increases, the ions move faster and faster towards the electrodes in accordance with the equation

$$\tfrac{1}{2}mv.^2 = Vq \times 10^7 \text{ ergs} \qquad (5)$$

which was quoted as equation (1) in the first article of this series. Eventually when the voltage reaches a certain value the ions are moving so quickly that they are discharged as fast as they form. The value of the saturation current is accordingly a measure of the rate of ionization.

In the case of a thermionic valve the rate of supply of ions can be increased by raising the temperature of the cathode, and the value of the saturation current is observed to increase in these circumstances. In the earliest forms of cathode ray tube a hot cathode was not employed, the electron stream was obtained merely by the application of a sufficiently high voltage between the anode and cathode. The phenomenon observed experimentally in such a tube is that as the voltage is increased the current reaches the saturation value, and a small increase of voltage then causes no further increase of current. If the voltage is continually increased, however, a point is reached where there is a sudden increase of current to a value many times the saturation value and a luminous discharge appears in the tube. This phenomenon was very noticeable in the soft valves used as detectors in early post-war radio receivers.

In order to explain this increase of current beyond the saturation value, the formation of large numbers of electrons is postulated and a theory of " ionization by collision " has been put forward and which is amply justified by experimental evidence. The conductivity of a gas although inappreciably small under some conditions is never quite zero, and it appears that there are always a few free electrons available.

As the voltage across the electrodes is increased, the kinetic energy which the electrons acquire in passing across the gas will increase in accordance with equation (5) and if an electron with a sufficiently high kinetic energy collides with a molecule of gas, the molecule may be disrupted and lose one or more electrons. The liberated electrons will be accelerated by the electric field towards the anode and the corresponding positive ions towards the cathode. These in their turn will acquire sufficient kinetic energy to be capable of ionizing other gas molecules with which they collide. This is the manner in which ionization is supposed to be maintained.

The Energy required to effect Ionization.

This theory of ionization by collision is found to be in quantitative accord with experiment and for each gas a constant known as the " ionization potential " can be measured.

In order to ionize a normal atom (or normal molecule) not less than a certain definite amount of energy, characteristic of the atom itself, must be transferred to it.

This can be proved by projecting electrons of known and controlled speed into the gas under study and testing for positive ions by means of an electrode of high negative potential. No positive ions can be detected until the velocity of the projected electrons exceeds a certain value which is characteristic of the gas in question. The kinetic energy of each projected electron must then be equal to the energy necessary to ionize each molecule of the gas. It is convenient to measure this energy in " equivalent electron volts," one equivalent electron volt being defined as the kinetic energy acquired by an electron in being accelerated by a potential of one volt. The value of the equivalent electron volt in ergs may be obtained from equation (5) as follows :—

$$\begin{aligned} \text{Energy} &= Vq \times 10^7 \\ \text{But } e &= Vq \text{ by definition} \\ \therefore \text{Energy} &= e \times 10^7 \\ &= 1.59 \times 10^{-19} \times 10^7 \\ &= 1.59 \times 10^{-12} \text{ ergs.} \end{aligned}$$

The voltage necessary to accelerate the electrons until they are capable of ionizing the gas is known as the " ionization potential," and is numerically equal to the limiting energy measured in equivalent electron volts of the electrons which will cause ionization. In order to give some idea of the magnitude of this energy, it may be mentioned in passing that the ionization potential of hydrogen is 13.5 volts, and that of helium 24.5 volts. The importance of equation (5) is now apparent, it illustrates the way in which the energies of ions and electrons are conveniently expressed and also the meaning of " ionization potential."

It should be noted that the term " equivalent electron volts " is often improperly contracted to " volts," but in any case there is seldom any doubt as to what unit is intended when reference is made to a moving particle with an energy of so many volts.

The measurement of " ionization potential " is an important landmark in experimental atomic physics, it is a measure of the energy necessary to break down the atom into some at least of its fundamental constituents. Before passing to a description of the additional experimental methods which depend upon the ionization of gases, it is necessary to discuss briefly the conception of the photon.

The Conception of the Photon.

At the conclusion of the first article of the series, three classes of particles were enumerated, the properties of which were not ascertainable by deflection experiments in magnetic and electric fields owing to absence of deflection under these conditions. One of these classes of particles included photons.

The term photon is applied to a " packet of radiant energy " and may be identified with the light corpuscle which Newton postulated to explain optical phenomena. The development of the wave theory of light and the experimental phenomena of interference, diffraction and polarization, which have been discussed previously,[1] seemed at first to dispose of the corpuscular theory of light completely. More recent attempts to explain the mechanism of the characteristic optical and X-ray spectra of the elements have, however, revived this theory in a modified form. In order to explain the experimental laws of the radiation of energy, Planck formulated what is known as the Quantum Theory of Radiation. According to this theory, energy is not radiated continuously, but discontinuously in finite quantities which have been called " quanta of energy." The value of energy contained in each quantum is determined by the frequency of the radiation by means of the relation

$$W = h.f \quad \dots\dots\dots (6)$$

where W is the energy in ergs.

f is the frequency in cycles per second

h is a physical constant (Planck's constant) equal to 6.55×10^{-27} erg. secs.

Einstein further postulated that these quanta of energy could be conveniently considered to be particles which he called " photons." These particles move through space with the characteristic velocity of light.

As an example of experimental work, which is in striking accord with such a theory, may be instanced the photo-electric effect. It is found that if light of a particular frequency falls on the surface of a metal, electrons are emitted from the metal. These electrons are only emitted if the frequency of the light exceeds a certain critical value, f_0 cycles per second, which is characteristic of the metal in question. The number of electrons emitted is proportional to the intensity of the incident light and, if the frequency of the incident light is greater than the critical frequency f_0, the electrons are emitted with a definite value of kinetic energy which can be measured. This value is found to be equal to $h(f - f_0)$ ergs where f is the frequency of the incident light in cycles per second. This fact clearly supports the conception of light as a stream of photons each carrying a definite quantity of energy depending upon the frequency in accordance with equation (6). It will be seen that this conception is a very convenient one in dealing with the interaction of radiant energy and matter, and it enables the mechanism of ionization by photons to be explained in terms of the same mental picture as that of ionization by collision.

Consider a collision between a photon and an electron. The transfer of energy between two colliding particles is determined by :—

(1) the principle of conservation of energy;

(2) the principle of conservation of momentum (Newton's Third Law of Motion).

In the observed effect of a collision between a photon and an electron (known as the Compton effect) it is found that the electron gains kinetic energy while the photon changes its frequency. The product of the change of frequency and Planck's constant is found to be equal to the increase of kinetic energy of the electron, which is in accordance with equation (6). The conservation of momentum is maintained if it is assumed that the photon has a momentum of hf/c c.g.s. units, where f is its frequency in cycles per second and c is the velocity of light in cms. per second. The association of momentum with the particles immediately infers that they have mechanical inertia or mass. This is an inference which needs careful consideration.

The Equivalence of Mass and Energy.

According to the theory of relativity the mass of a moving particle increases with its velocity. This rather extraordinary fact can fortunately be experimentally verified. If we measure the masses of electrons by means of electric and magnetic deflections as described in the first article of this series, it is found that the value of mass obtained is substantially the same for small velocities up to velocities of approximately one tenth that of light. Above this velocity there is a rapid increase of mass, the relation between mass and velocity being exactly that predicted by the theory of relativity. As the velocity of light is approached the mass approaches infinity.

The explanation of this phenomenon is, possibly, strange, because as engineers we are used to dealing with velocities far removed from that of light to which the principles of Newtonian mechanics may be applied. It must not be thought, however, that because a new phenomenon involves strange ideas its explanation is necessarily difficult. It is really unusually simple in this case. According to Einstein, the mass of a particle is potential energy just as by

[1] Author's article on " Wave Mechanics." *P.O.E.E. Journal*, Vol. 27, Part 1.

the first law of thermodynamics heat is potential energy. It is possible for a particle of matter to be transformed, or to disappear, and to reappear as a quantum of energy, in fact to become a photon. We shall actually discuss examples of this transformation which have been observed, in later articles.

If W is the total energy in ergs which is equivalent to a mass of m grams, Einstein's relation is :—

$$W = mc^2 \quad \text{...(7)}$$

where c is the velocity of light in cms. per second, thus a mass of 1 gram is equivalent to 9×10^{20} ergs or 25,000 kilowatt hours and the mass of electron to 8.1×10^{-7}ergs or 511,000 equivalent electron volts.

This total energy includes all the energy of a particle, the potential energy due to its mass when at rest and also kinetic energy due to motion. We can now see why the mass must increase with velocity.

Let m_0 grams be the mass of a particle when at rest (this is generally known as rest mass) and m grams the mass of the particle when its velocity is v cms. per second.

Then referring to equation (7), the increase in energy due to its motion is given by

$$K = (m - m_0)c^2 \quad \text{....................................(8)}$$

It is clear that this increase, K, must be the kinetic energy of the particle.

Transposing equation (8) we derive

$$m = m_0 + \frac{K}{c^2} \quad \text{.......................................(9)}$$

This equation is the key to the situation. An electron or other material particle possesses rest mass and its mechanical inertia when moving is increased by virtue of its kinetic energy. On account of the equivalence of mass and energy given by equation (7), the increase of energy due to the kinetic energy of the particle must involve an increase in its effective mass.

In the case of a photon, the rest mass is zero and the effective kinetic energy is hf ergs. The effective mass of a photon by virtue of its energy is accordingly hf/c^2 according to equation (9).

It is hoped that this simple explanation of relativistic mass and its significance will help to remove difficulties in the way of accepting two facts :

(1) The mass of a material elementary particle may, under some conditions, be transformed into a quantum of energy.

(2) A photon, which is generally described as a particle without mass, possesses momentum and mass by virtue of its kinetic energy, but has zero rest mass.

These facts are both capable of experimental verification and are used in the theoretical argument which accounts for the existence of the more elusive elementary particles, the positron, the neutron and the neutrino. This argument will be discussed in a later article.

The Wilson Cloud Chamber.

We have now to describe what may be called without reserve a magnificent piece of apparatus for detecting the presence and effect of rapidly moving charged particles. By means of this apparatus the presence of a rapidly moving particle is detected in effect by the appearance of a thin trail of " mist " along the track of the particle. When a charged particle moves with such a velocity across a gas that it causes ionization by collision, pairs of ions are found along its track until its energy is exhausted at which point the track usually ends abruptly.

At the moment we are concerned with revealing the ion pairs formed along the track so as to make the track visible and enable it to be photographed. We have already stated that the track appears as a thin trail of " mist." How does this " mist " come to be formed? If damp air is cooled, water vapour condenses in minute droplets and forms a mist. It is known that the formation of these droplets is favoured by the presence of so called " condensation nuclei." The presence of dust in air accelerates the formation of dense mist or fog and in air containing dust particles a mist will be formed more easily, that is, by less cooling than in a dust free atmosphere. C. T. R. Wilson discovered that mist is produced very easily indeed in a dust free gas which has been ionized, the ions acting as condensation nuclei, and he arranged to cool the gas when it was desired to observe the presence of ions. The cooling process is effected by a sudden reduction of pressure in the chamber, when immediately if there are any flying charged particles passing through the chamber their presence is manifested by the presence of a silvery white trail of mist. The appearance of these tracks is very characteristic of the particles which produce the ionization, and after very little practical experience, it is easy to see at once from the appearance of the mist track, its density, length, etc., what type of particle is responsible for it.

If a fast electron with an energy of the order of 10^4 equivalent electron volts passes across the chamber as the expansion is taking place it will leave a thin trail of mist in which the separate droplets may be seen under the microscope. The usual method of observing a cloud track is to take a flash light photograph a moment or so after the expansion has occurred. In practice, the passage of a single particle across the chamber can be made to actuate a relay which automatically effects the expansion and takes the photograph. If, in addition, an electric field is applied across the chamber so as to separate the positive and negative ions as soon as they are formed, it is easy to see, by means of the microscope, that the mist droplets are formed in pairs. These cloud photographs are very convincing evidence of ionization by collision. It is difficult to believe that anybody who has ever seen a cloud track photographed and examined it afterwards could fail to be convinced of the reality of the existence of ions.

The track of an alpha particle is very much more dense than an electron track. It is evident that an alpha particle ionizes far more readily than an electron. The track also appears to be thicker than that of an electron. Examination with a microscope shows that this is due to short feathery trails at an oblique angle to the main trail. These are evidently due to ionization by electrons removed from atoms by the alpha particle and endowed with sufficient energy to produce a short cloud track themselves. The track of a photon differs characteristically from the tracks produced by a charged particle. A photon produces isolated bunches of feathery cloud. The microscope reveals that these consist of minute tracks in random directions, each bunch originating in a single point. Each of these minute tracks can be identified as being due to an electron evidently set free by the parent photon. This characteristic cloud track of photons leads to an important conclusion which must be noted for future consideration. Photons pass through a gas with only infrequent ionization; when ionization does occur, however, the electrons are flung out with very much greater energy than in the case of ionization by alpha particles or electrons.

The quantitative data provided by the Wilson cloud chamber include measurement of

(1) range, and
(2) ionizing power or specific ionization.

The range of a particle is merely the length of the cloud track it produces. This quantity varies with the nature of the particle and its kinetic energy and also with the nature and density of the gas in the cloud chamber.

The ionizing power or specific ionization may be defined as the number of pairs of ions formed per centimetre length of the cloud track. The ionizing power will depend on the density of the gas, and the nature of the particle.

In subsequent articles we shall consider the experimental evidence provided by the Wilson cloud chamber which has led to the discovery of the neutron and the positron.

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 MARCH, 1936.

Number of Telephones owned and maintained by the Post Office.	Overhead Wire Mileages.				Engineering District.	Underground Wire Mileages.			
	Telegraph.	Trunk.	Exchange.*	Spare.		Telegraph.	Trunk.	Exchange.†	Spare.
949,572	437	5,265	51,239	6,200	London	38,148	255,586	3,976,271	92,709
119,555	2,153	15,451	51,391	7,806	S. Eastern	6,197	98,198	397,023	54,182
138,826	4,459	35,850	90,350	6,795	S. Western	25,325	75,358	312,460	84,463
96,542	4,203	37,690	80,735	13,342	Eastern	15,564	85,437	193,370	51,296
148,322	4,228	34,974	67,562	25,196	N. Midland	6,082	222,198	358,018	130,889
120,435	3,085	21,554	72,942	15,116	S. Midland	9,887	109,158	353,940	42,129
80,315	3,036	25,671	66,154	9,298	S. Wales	6,804	71,837	171,611	49,695
160,655	4,252	19,491	66,673	17,757	N. Wales	9,063	142,539	486,867	104,224
204,593	1,151	3,929	29,932	10,047	S. Lancs.	7,560	135,256	714,093	65,781
134,925	5,127	22,485	46,108	7,590	N. Eastern	10,669	104,726	371,365	48,409
87,199	1,123	10,453	31,880	17,779	N. Western	6,173	94,938	267,815	79,495
68,035	1,135	12,820	24,791	7,433	Northern	4,873	61,133	205,764	21,906
33,540	3,179	11,451	14,552	1,203	Ireland N.	443	8,014	83,390	21,274
221,321	8,748	45,279	86,853	19,517	Scot. Region	12,795	172,814	482,734	143,242
2,563,835	46,316	302,363	781,162	165,079	Totals.	159,583	1,637,192	8,374,721	989,694
2,508,988	46,492	308,443	760,904	162,290	Totals as at 31 Dec., 1935	158,385	1,548,187	8,306,437	990,887

* Includes low gauge spare wires (*i.e.*, 40 lb. bronze in open routes and 20 lb. or less in aerial cables).
† Includes all spare wires in local underground cables.

Hardness Testing

GEO. F. TANNER, M.I.E.E.

A review is given of the present methods in use in this country and elsewhere for the precise determination of hardness.

General.

HARDNESS is possibly best defined as that quality which offers resistance to mechanical penetration. The ancient Greeks applied the word αδάμας to this property, meaning anything inflexible or firm. Pliny speaks of the diamond as adamas, and in early English the diamond was called adamant. There are many different aspects of hardness—resistance to temporary deformation, resistance to permanent deformation, resistance to abrasion or wear. This article describes the more well-known types of hardness testing machines which give a quantitative measure for the resistance of materials to permanent deformation by indentation. The first known tables of relative hardness were probably those compiled by those "wise-hearted" workers of the tribe of Judah who constructed the Urim and Thummim or breastplate of Aaron the high priest. On each of the twelve different precious stones that adorned the breastplate was scratched the name of one of the tribes of Israel. For many centuries after, the names of those precious stones remained as standards of hardness. When one stone could be made to scratch another but could not be scratched by it, the former was classified as harder than the latter. In fact, although numerous attempts were made to devise a means of accurately measuring the hardness of bodies, they met with little success. Even the more recent scale of Mohs followed ancient practice in arranging certain bodies in a given position relative to one another, the first being the softest. Mohs' scale is still used and is as follows :—

1, talc; 2, crystallized gypsum; 3, calcite; 4, fluorspar; 5, apatite; 6, felspar; 7, quartz; 8, topaz; 9, sapphire; 10, diamond.

A body in this scale having a hardness of 6.5 would be one which would scratch felspar and be scratched with about the same ease by quartz.

The advent of the steel age brought with it the problem of being able to determine definitely the relative hardness of various metals and many systems were proposed for this purpose, and a few of the principal which have emerged successfully from the test of time are cited.

The Scleroscope or Shore Method.

This system measures hardness by a comparison of the effect of the drop and rebound of a diamond-tipped hammer dropping by gravity from a fixed height.

Turner's Sclerometer.

This instrument has a jewelled point that can be weighted till a movement over the surface of the metal produces a scratch of a standard depth.

The Monotron Hardness Indicator.

This apparatus is a static mechanical pressure machine employing a small diamond ball impressor point for measuring hardness of various substances. Two dials are used to take the readings, the one measuring the pressure applied and the other the depths of impression under load.

The Rockwell Hardness Tester.

This machine measures hardness by determining the depth of penetration under load of a steel ball or diamond cone in the material being tested. Rockwell hardness is expressed as a number which is read on a graduated gauge. The machine is similar in principle to the Avery Direct Reading Hardness Testing Machine described later.

The Brinell Test of Hardness.

This system has been adopted in the construction of many machines. It consists in indenting the smooth surface of the metal with a hardened steel ball, 1, 2, 5 or 10 mm. in diameter, when subjecting it to a stated pressure. The diameter of the indentation is used as a basis for calculating comparative figures. The figures obtained by the Brinell method are called Brinell Hardness Numbers and have received international recognition. Standard tables of these numbers have been drawn up by the British Standards Institution, B.S.S. No. 240.

Actually the Brinell Hardness Number is the quotient of the applied load divided by the spherical area of the impression. It is given by the following formula :—

$$H = \frac{P}{\frac{\pi D}{2}\left(D - \sqrt{D^2 - d^2}\right)}$$

$$= \left(\frac{P}{D^2}\right)\left(\frac{2/\pi}{1 - \sqrt{1 - (d/D)^2}}\right)$$

Where P = Load (in kilogrammes)
D = Diameter of ball (in millimetres)
d = Diameter of impression (in millimetres)
H = Brinell Hardness Number.

The spherical area is calculated from the average diameter of the impression obtained by taking two readings at right angles and not from the depth of the impression. The micrometer microscope or other measuring device used must be capable of measuring the diameter of the impression to ± 0.5 per cent.

The balls used in Brinell Hardness testing must be of hardened steel or some harder material. When ordinary hardened commercial steel balls are used Brinell Hardness Numbers exceeding 500 may be subject to error owing to permanent distortion of the ball. The error increases with increasing hardness of the material tested. With Hardness Numbers above 500 care should be taken to see that the balls are considerably harder than the material to be tested. Diamond indenters made to the B.S.I. standard angle of 136° between opposite faces are now generally used for testing steel of over 550 Brinell.

The standard balls and loads used for Brinell Hardness testing are as follows :—

Diameter of ball.	Load.			
	$\frac{P}{D^2} = 1$	$\frac{P}{D^2} = 5$	$\frac{P}{D^2} = 10$	$\frac{P}{D^2} = 30$
mm.	Kg.	Kg.	Kg.	Kg.
1	1	5	10	30
2	4	20	40	120
5	25	125	250	750
10	100	500	1000	3000

The limit on the diameter of the balls is ± 0.0025 mm. (0.0001 in.) and it should be noted that the same Brinell Hardness Number is given by tests on the same uniform material with balls of different diameters when the same ratio $\frac{P}{D^2}$ is used.

Magnitude and Application of Load.

The value of the ratio $\frac{P}{D^2}$ should be as follows :—

For steel and materials of similar hardness ... 30
,, copper alloys and materials of like hardness ... 10
,, copper ... 5
,, lead, tin and materials of similar hardness ... 1

It is advisable to see that the following provisions with regard to application of the load are applied :—

(*a*) That the ratio of the diameter of the impression to the diameter of the ball shall not exceed 0.5.

(*b*) That the load is applied to the test specimen slowly and progressively.

(*c*) That the full load is maintained for at least 15 seconds when the ratio $\frac{P}{D^2}$ is 30 and for 30 seconds when the ratio = 10, 5 or 1.

Precautions to be taken with Test Specimens.

(*a*) The centre of the impression should be not less than two and a half times the diameter of the impression from any edge of the test specimen.

(*b*) The thickness of the specimen should be at least seven times the depth t, of the impression as given by the formula $t = \frac{P}{\pi DH}$ or alternatively it should be such that no bulge or other marking showing the effect of the load appears on the side of the piece opposite the impression.

(*c*) With thin specimens care should be taken to ensure that the under surface of the specimen is smooth and in perfect contact with a smooth supporting surface of hardened steel.

(*d*) The surface on which the impression is made should be polished if the diameter of the ball used is 2 mm. or less. Even if the diameter of the ball used is 5 or 10 mm., it is still best to use a polished surface, but if a high order of accuracy is not required the surface may be filed, ground or smoothly machined.

(*e*) Care should be taken to ensure that the surface tested is truly representative of the material and that its hardness is not affected by decarbonization, carburization or by any machining or grinding process applied to it.

Method of Specifying Hardness.

Brinell hardness is always expressed by the Brinell Hardness Number and not by the diameter of the impression. The diameter of the ball used should be stated in each case, *e.g.*, H 10/3000. For non-ferrous materials the time in seconds for which the full load is maintained should also be stated, *e.g.*, H 10/1000/30.

Tensile Strength of Steels and Brinell Hardness.

Experiment has shown that an approximate indication of the tensile strength in tons per square inch can be obtained by multiplying the B.H. numbers by 0.22. In cold-worked material and in exceptional cases there may be a wide divergence.

Standard Tables of Brinell Hardness Numbers.

A complete set of tables giving the B.H. numbers for various effective diameters of impression is published by the B.S.I. as B.S.S. No. 240, price post free 2/2.

TYPICAL MACHINES.

Broadly speaking, there are two classes of machine, viz., Direct - reading hardness testing machines, which are machines having a dial and pointer which visually indicates a numeral corresponding to the depth of penetration of a penetrator. These numerals are not Brinell hardness numbers. It is possible, however, by means of a graph to establish a relationship between these numerals and the true Brinell numbers. They are useful for rapid comparative work in the workshop. The Rockwell and Avery direct reading hardness testing machines are representative of these.

The second class produces a crater with the ball or indenter, the diameter or diagonal of which is measured and from this figure the hardness number is obtained by reference to standard tables.

A description of representative machines of each type follows :—

THE AVERY DIRECT READING HARDNESS TESTING MACHINE.

This machine has been specially designed for rapidly determining the hardness of materials in the terms of standard penetration numerals. These numerals are based on the depth of impression produced by a standard penetration under the action of a definite major load superimposed on the impression produced by a definite minor load, so that errors due to surface imperfections of the work are eliminated. The machine consists essentially of a frame, an adjustable table, a loading device for the penetrators, a depth measuring gauge, a weight lifting and releasing mechanism, and a loading speed controller. The machine is shown in Fig. 1.

FIG. 1.—AVERY'S DIRECT READING HARDNESS TESTING MACHINE.

Penetrator and Loading Device.

Two standard forms of penetrator are used, one being a steel ball of 1/16″ diameter, and the other a diamond cone of 120° face angle, terminating on a spherical end. Both major and minor loads are imposed by means of weights acting through a sensitive and accurate weighing lever which is fitted with hardened steel knife edges. The standard minor load is 10 kg., and is applied automatically when the specimen is set up. Two standard major loads are used, 100 kg. for use with 1/16″ steel ball and 150 kg., for use with the diamond cone penetrator. These are applied by means of proportional weights suspended from the end of the weighing lever, and are under control of the operator. Provision is made for reducing the major load to 60 kg. All major loads, *i.e.*, 60,100, and 150 kg. are inclusive of the 10 kg. minor load.

Depth Measuring Gauge.

This is an extremely accurate dial instrument which gives direct readings in terms of the two standard penetration scales B & C. Scale B applies to the 1/16″ diameter ball penetrator and 100 kg. load, and scale C to the diamond cone and 150 kg. load. Graduations range from zero up to 100 for each scale, corresponding with one revolution of the main indicating hand, and 0.2 mm. movement of the penetrator. The setting is such that the highest readings are B 130 and C 100.

Weight Lifting and Releasing Mechanism.

The proportional weights are raised by a crank and lifting ram operated by a handle convenient for the operator. When the weights are in the raised position, the handle is held by a spring plunger which it is necessary to release in order to apply the load.

Hydraulic Speed Controller.

A plunger is attached to the weight supporting table, and is depressed when the load is being applied. This plunger works in a hydraulic cylinder and the fluid which it displaces passes through a needle valve to the container.

Exceedingly fine speed control is obtainable by this valve. Additional spring controlled valves enable the fluid to flow back into the cylinder when the weights are raised.

Method of Operation.

(*a*) Position specimen upon anvil.
(*b*) Raise specimen to contact with penetrator and further until the subsidiary pointer on gauge indicates " set."
(*c*) Main pointer must also indicate " set " before applying major load; if adjustment is necessary, turn bezel.
(*d*) Withdraw spring plunger to apply proportional weights. (The main pointer of gauge moves in anticlockwise direction as penetrator sinks into specimen).
(*e*) Raise the proportional weights when main pointer has ceased to move.
(*f*) The minor load still applied, read the hardness numeral. It is essential to prefix the reading obtained by either B or C, signifying tests by either ball or cone penetrator, respectively.

THE AVERY PATENT HARDNESS TESTING MACHINE.

The Avery No. 691 machine, shown in Fig. 2, is designed to carry out the Brinell test and is guaranteed to apply the correct pressure to the specimen. The construction of the machine will be apparent from Fig. 3, and is similar to that of a platform weighing machine. The seating lever on which the specimen is placed, is supported by a lever in the base of the machine by means of hardened steel knife edges and bearings. This lever is in turn connected to a transfer lever, at the end of which is a tension rod connecting the two steelyards. Pressure applied to the seating is transmitted by means of accurately gauged levers to the weighing steelyards, on which the load is balanced by means

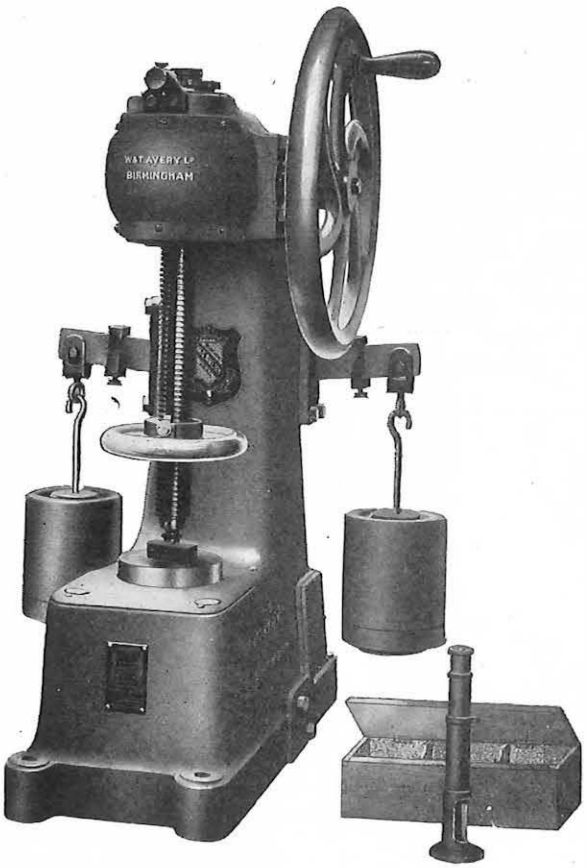


FIG. 2.—AVERY NO. 691 BRINELL TESTING MACHINE.

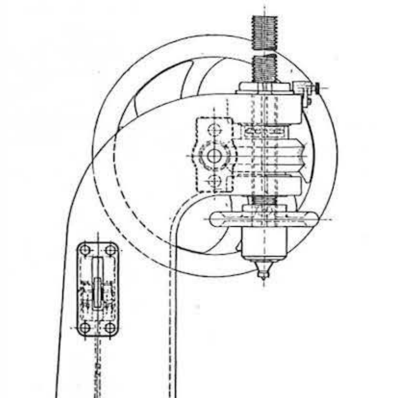


FIG. 3.

of the proportional weights. The mechanism for applying the load is shown in Fig. 4. The load is gradually applied by means of the vertical hand-wheel through a worm drive. The ball can be set in contact with the specimen quickly before making a test, by releasing a catch and turning the screw by means of the horizontal hand-wheel.

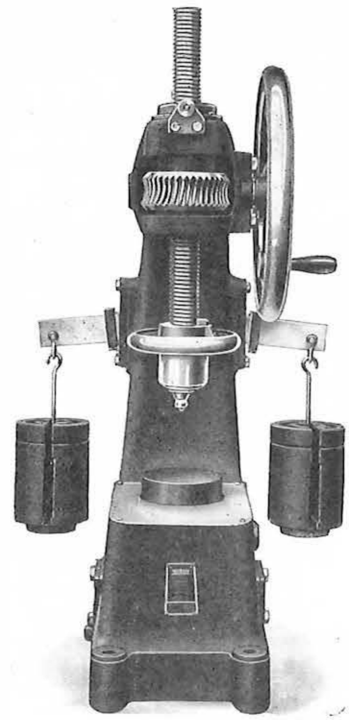


FIG. 4.—VIEW SHOWING WORM DRIVE.

Method of Making Test.

The specimen is placed on the seating and the ball is brought almost into contact with its surface by turning the horizontal hand-wheel. The catch is replaced in position and the vertical hand-wheel is turned a few times until the steelyards rise to a horizontal position. After the prescribed time period, the pressure is released by turning the hand-wheel in the opposite direction and the diameter of the impression is measured by means of the microscope shown in Fig. 2. Standard Tables are used to obtain the Brinell Hardness Number.

Split weights and interchangeable ball holders are available so that the following tests can be made :—3000 kg. with 10 mm. ball, 1000 kg. with 10 mm. ball, 500 kg. with 10 mm. ball, 750 kg. with 5 mm. ball, 120 kg. with 2 mm. ball, and 30 kg. with 1 mm. ball. Each machine is calibrated and tested to its full capacity by the application of 3000 kg. dead weight before issue.

THE "FIRTH HARDOMETER" (Patent No. 280292).

As in the case of other machines of the Brinell type where the diameter or diagonal of the impression has to be determined, this measurement is made with the aid of a microscope in which is fitted a micrometer scale, but on account of the eyestrain which frequently results from the continued use of the microscope, the makers of the Firth Hardometer have obviated this disadvantage by arranging, if desired, for the projection of the magnified image of the impression upon a screen so as to permit the operator to read the impression while comfortably seated.

By reference to Fig. 5, it will be seen that the apparatus consists of a light projector head which

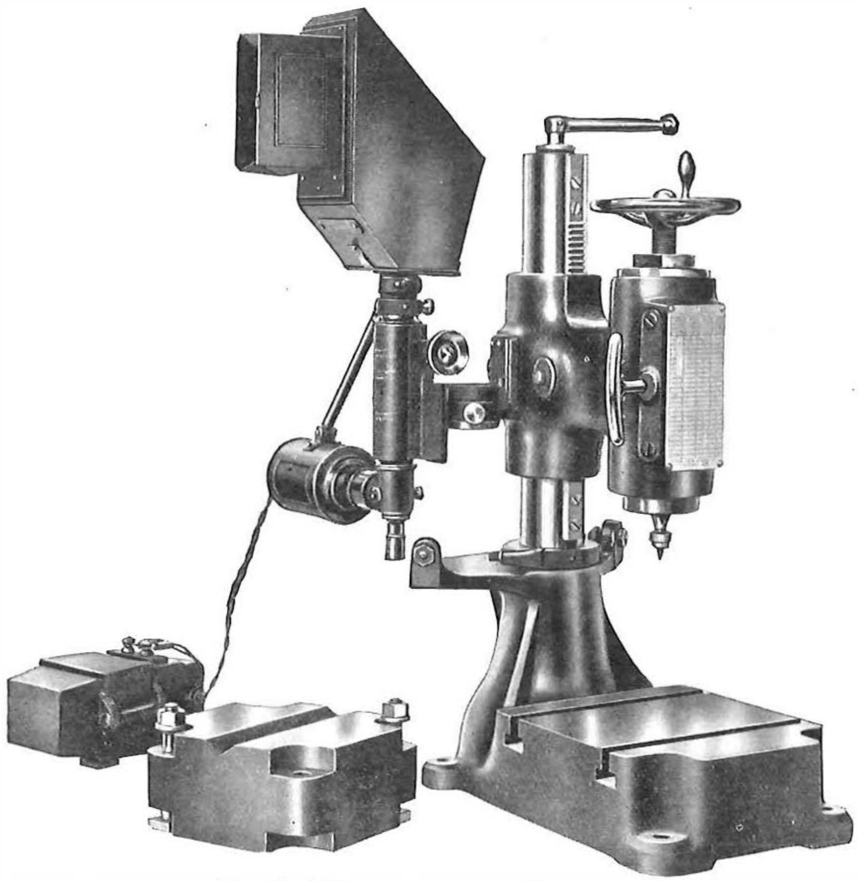


FIG. 5.—" FIRTH HARDOMETER."

fits over the eyepiece of the microscope, the interior of the head being provided with a plain mirror suitably positioned to reflect an enlarged image of the impression on to a hooded ground-glass screen which is fitted in the front vertical face of the head. The screen is marked with accurately divided cross scales. The actual size reproduction is shown in Fig. 6. The requisite brilliance of illumination of the impression and the screen is secured by a specially designed illuminator tube with adjustable reflecting prism carrying a special 6 volt lamp which can be operated from the lighting mains through a suitable transformer or resistance.

Fig. 5 illustrates the general lines upon which the machine is constructed and it will be observed that a sliding head is provided which is readily adjusted by means of a rack and pinion to accommodate objects of different sizes. The base of the normal type of machine is provided with an adjustable anvil which permits of irregular-shaped articles being tested. As an alternative the machine may be furnished with a flat table type base provided with tee slots on which may be accommodated holding devices to suit the user's requirements. In the illustration a specially designed combined V-block and flat table is shown. The load is applied through a specially calibrated spring and patented trip mechanism in such a manner that only the exact load can be applied. The trip mechanism automatically arrests the motion of the hand-wheel as soon as the correct load has been applied.

Referring to Fig. 7, it will be seen that when the load cylinder is forced down (carrying with it the trigger M) by means of the hand-wheel and screw, the trigger M engages the recess in the inner bushing, which immediately allows the stop L to engage the ratchet wheel K. Provision is made by means of the adjustable spigot J for calibrating the load (a very rare necessity). By unscrewing the nut D the load cylinder may be withdrawn entirely from the machine body and, if desired, returned to the makers for recalibration. For the purpose of checking the constancy of the load a standard check test piece of known hardness is supplied with each machine for verification in case of doubt.

To make an impression the head is swung into position against the stop, Fig. 5, and the column locked by means of the clamping lever. The article is supported suitably and the ball or diamond

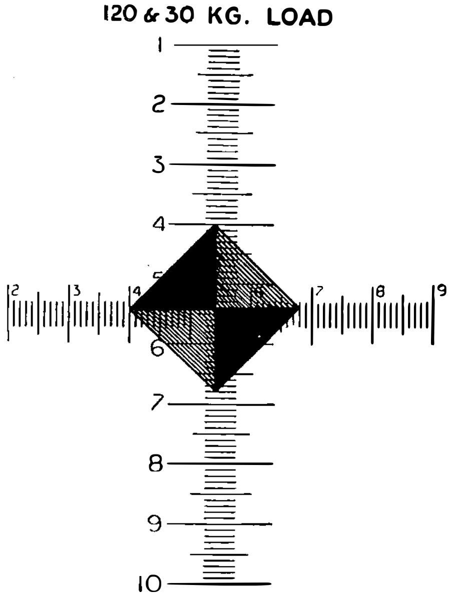


Fig. 6.
Above shows a reading of 2.80 divisions
= 710 Diamond Hardness No.

brought into contact with the prepared surface of the specimen by means of the hand-wheel, which after making approximately one more complete turn, will become arrested. The exact load has then been applied. The hand-wheel is turned in the opposite direction in order to withdraw the indenter.

The reading may be taken without removing the specimen from the anvil. To secure this the column carrying the head swings on its axis until the microscope comes into position immediately over the impression.

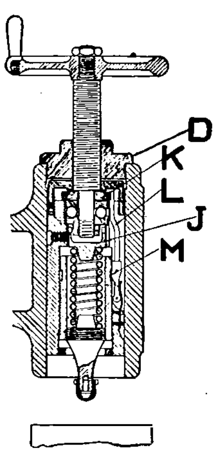


Fig. 7.—Load Mechanism of Firth Hardometer.

Fig. 8 shows the scale produced when reading directly with the various objectives. The example shows a reading of 3.2 divisions = Brinell No. 364. The measurement of the diamond impression is measured diagonally; across the corners of the impression. The diamond should be used on all measurements of hardness above Brinell No. 550. The ball should be changed often when taking measurements averaging Brinell No. 500. Occasional use of the standard check test piece is advised. The graphs, Fig. 9, show the relationship existing between the numbers produced by the diamond

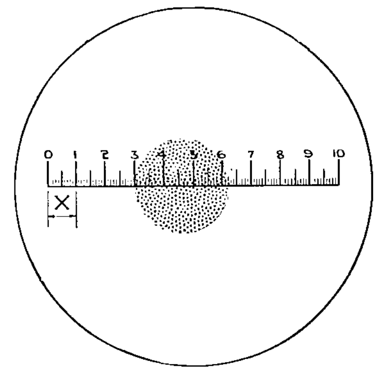


Fig. 8.
Above shows a reading of 3.2 divisions = Brinell No. 364
when using a 1″ objective × = 0.2 mm.
,, ,, ,, ½″ ,, ,, = 0.1 mm.
,, ,, ,, ¼″ ,, ,, = 0.05 mm.

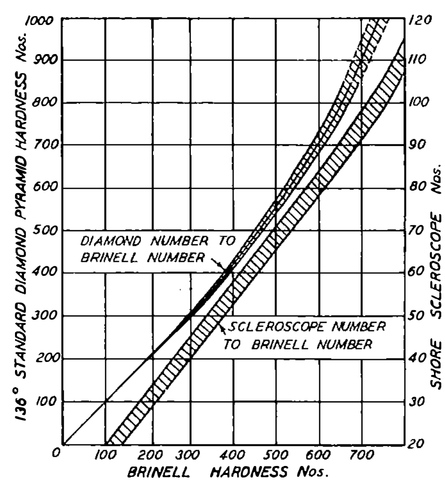


Fig. 9.—Graph showing Approximate Comparison between Brinell Hardness Nos., Standard Diamond Hardness Nos. and Shore Scleroscope Hardness Nos.

indenter and the Brinell Hardness Numbers. The approximate relationship between the numbers and those produced by the Shore Scleroscope, previously mentioned, is also shown. The machine is supplied in two types, Type 1 may be fitted with either a 120 kg. load cylinder and 1 inch microscope objective for testing medium and hard steels down to 1 mm. thick, or with a 30 kg. load cylinder and ½ inch objective for testing medium and hard steels down to below ½ mm. thick or soft metals down to below 1 mm. thick. Type 2 is fitted with a cylinder giving a 10 kg. load and a ¼ inch objective for use when testing very thin materials with a diamond indenter or certain soft non-ferrous alloys with a 1 mm. ball.

Vickers Pyramid Hardness Testing Machine (Pat. No. 196962).

This machine is an indentation hardness tester and expresses hardness as the quotient of the applied load divided by the surface area of the impression, thus conforming to the Brinell principle of $\frac{\text{load}}{\text{impressed area}}$. The Vickers machine, however, is designed to eliminate the various disturbing factors operating in the Brinell test. The indenter employed with the Vickers system is a diamond, accurately polished to the form of a square-based pyramid (although 1 mm. and 2 mm. balls may be used with the machine) and the impressions are, therefore, square. The load is light, varying from 1 to 120 kg., and is automatically applied. The numerals so obtained are corrected Brinell numbers which are stated to be strictly proportional whether the material tested is the softest of metals or the hardest of steels.

The diamond pyramid is adopted for the following reasons :—

(*a*) That the surface impression is extremely well-defined and, being square, can be measured with great accuracy across the diagonal corners (see Fig. **10**).

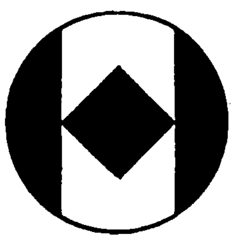


Fig. **10**.

(*b*) That the impressions are geometrically similar, irrespective of size.

(*c*) That the deformation of the indenter is practically nil, owing to its enormous hardness, even when compared with the hardest of steels.

The hardness numbers obtained are dependent upon the angularity of the pyramid and the angle selected as standard is 136° which, as may be seen from Fig. **11**, is identical with the angularity of a

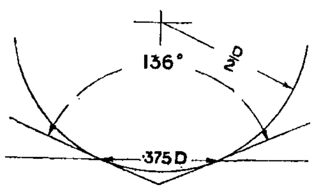


Fig. **11**.

ball impression of exactly 0.375 times the ball diameter. It is found, as might be expected, that in the soft regions of hardness the numbers obtained with this angularity are identical with those obtained with the Brinell test, when the latter is regulated to the foregoing ideal conditions.

The similarity in hardness numbers obtains, however, only in the lower regions of hardness. Between 500 and 600 Brinell Hardness the deformation of the steel ball, as has already been mentioned, tends to yield slightly lower readings than the diamond pyramid and this tendency increases with the hardness.

The machine is illustrated in Fig. **12** and is shown diagrammatically in Fig. **13**. It consists of a main frame F, of " U " section, which carries the stage S and a simple lever L, of 20 to 1 ratio, applying the load through a thrust rod T*r* to a tube T, which is free to reciprocate vertically, and carries the diamond indenter D at its lower end.

Attached to the main frame is a smaller frame F*m*, which contains all the control mechanism. The plunger P*l*, reciprocates vertically under the influence of a rotating cam C, its purpose being to apply and release the test load. The cam is mounted on a drum, and when the starting handle S*h* has been depressed, the whole is rotated by a weight W attached by a flexible wire, the speed of rotation being controlled by a piston and dashpot of oil. The rate of displacement of the oil is regulated by an adjustable control valve. The plunger carries a rubber pad at its upper end, which engages with a cone mounted in the beam, thereby ensuring a very slow and diminishing rate of application for the last portion of the load. Since the cam both lowers and raises the plunger, it will be seen that uniformity of loading and duration of the load is maintained, all errors due to inertia and premature removal of the load being eliminated. Depression of the foot pedal returns the cam, drum and weight to their original positions. A tripping piece T*p* supports the beam during this latter operation, and drops out as soon as the plunger returns to its top position. The machine is then ready for another test.

The stage or anvil, which is of ample dimensions, is fitted with a Vee-slide on each side and a hole in the centre to accommodate special fixings. A Vee-block may be used to centre cylindrical work correctly under the indenter.

The measuring microscope is capable of measuring to 0.001 mm. It is mounted upon a hinged bracket so arranged that it may be swung over the impression taken, thus no resetting of the work is required. The impression is illuminated by a vertical beam of light obtained from a lamp, condenser and vertical illuminator, all of which are mounted in the microscope. The light is switched off automatically in swinging the microscope out of position.

Instead of the more usual scale or eyepiece micrometer, a specially designed micrometer ocular is provided. The impressions are read to knife edges, thus avoiding eyestrain, and readings are taken entirely from a digit counter, mounted on the side of the ocular. (See Fig. **14**). These readings are converted direct to Vickers Pyramid Numbers by means of tables. The focussing of the knife edges to suit personal requirements is readily carried out by rotating the eyepiece lens, and the zero reading of the digit counter lends itself to immediate checking by adjusting the knife edges until they just touch, when the ocular should read 000.

The microscope is useful for metallurgical or other

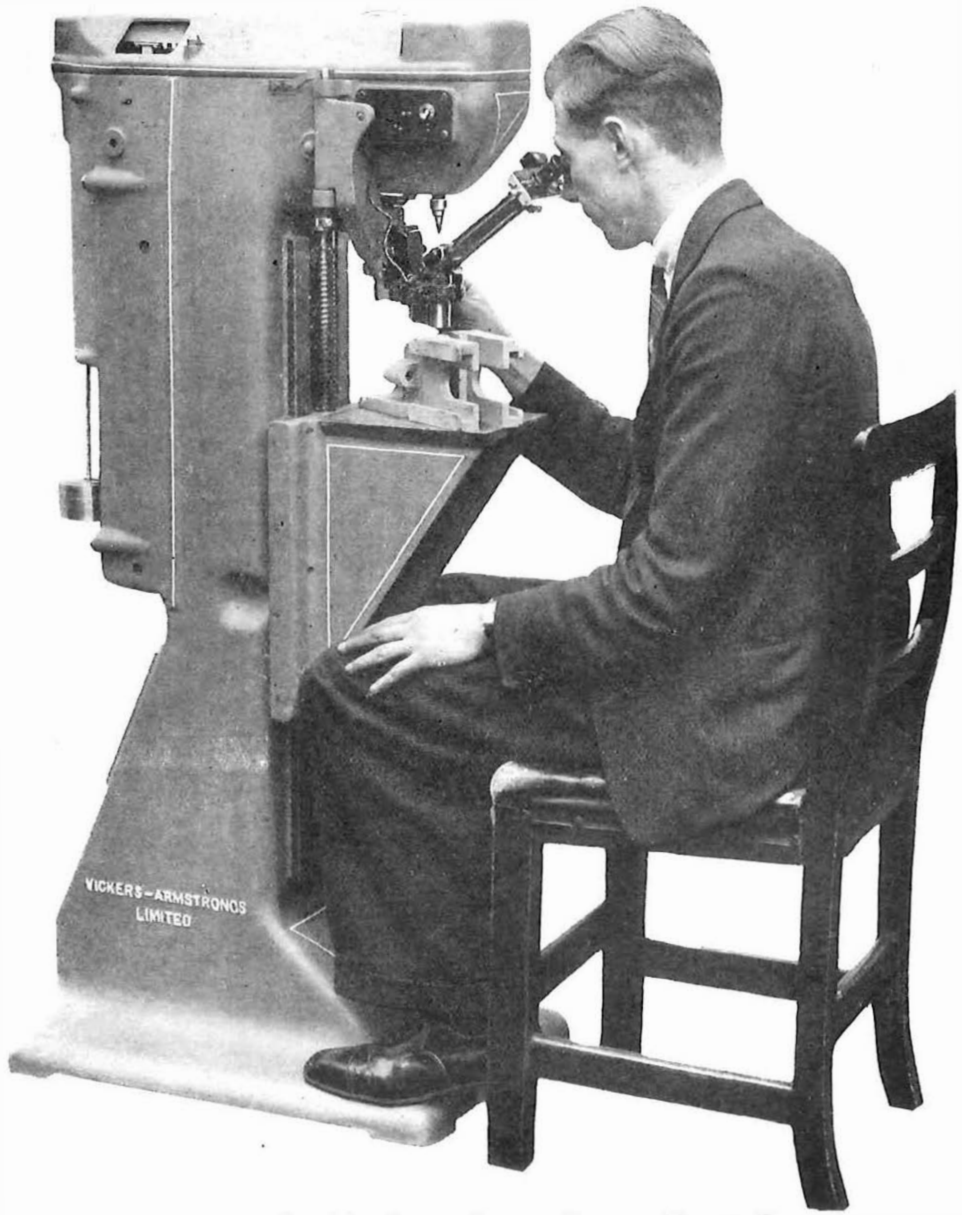


FIG. 12.—VICKERS PYRAMID HARDNESS TESTING MACHINE.

work and it is also immediately available as an accurate optical micrometer.

Should it be desirable to read each diagonal of an impression the headpiece is fitted with a stop which enables it to be rotated through 90°. When used for purposes other than hardness testing this stop may be thrown out of action. Where it is necessary to ascertain whether work conforms to a specified maximum or minimum limit of hardness, a third knife edge may be brought into use and set to correspond to the limit.

Arrangements are made so that if the load is not properly applied owing to any movement or warping of the specimen, the operator is warned by means of a buzzer.

The facilities for applying incremental loads are of assistance when determining the "case" of case-hardened work.

The diamond pyramid system of hardness testing is specified by the B.S.I. as the means of testing the hardness of steel balls to ascertain their suitability for use in Brinell testing.

Conclusion and Acknowledgment.

The writer hopes that in this necessarily brief review of present-day methods for testing the hardness of materials, it has been possible to convey an idea of the precision with which the hardness of metals, the effect of alloying them, the effect of the tempering of tools and the suitability of manufactured articles for the work they are called upon to do, may be determined.

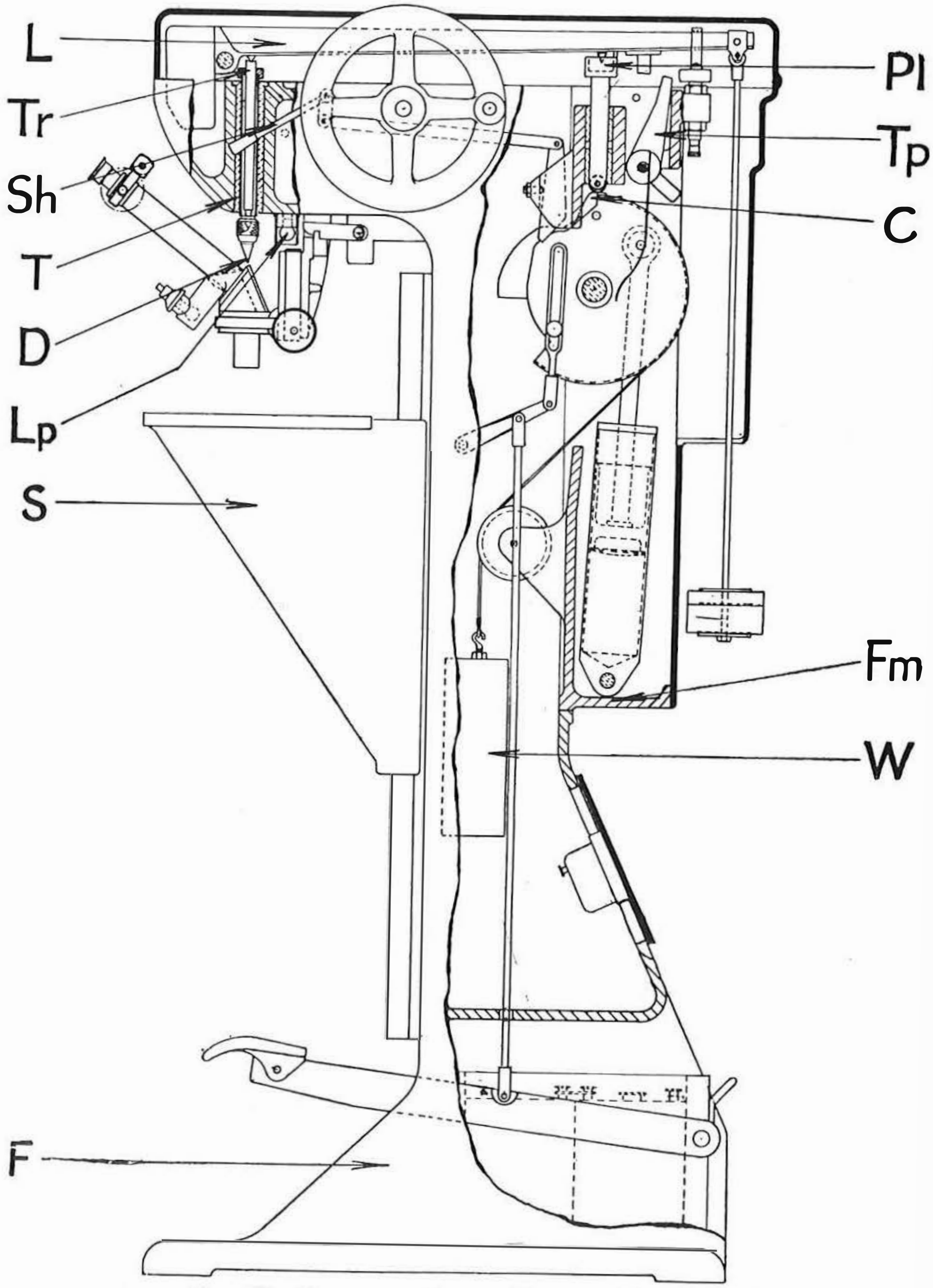


Fig. 13.—Diagram of Vickers Hardness Testing Machine.

Fig. 14.—Micrometer Ocular.

In conclusion, the author's thanks are due to the following firms for valuable assistance and for the loan of certain blocks for illustrating the article :—

Messrs. W. & T. Avery, Ltd., Soho Foundry, Birmingham.

Messrs. Firth & John Brown, Ltd., Atlas and Norfolk Works, Sheffield.

Messrs. Vickers-Armstrongs, Ltd., Crayford, Kent.

The Teleprinter Ancillary

S. G. LEWIS, A.M.I.E.E., and
C. E. EASTERLING, B.Sc. (Hons.)

The authors describe a new telegraph switchboard, on which the lines at a large office are multipled to enable any teleprinter to be connected to any line in accordance with traffic requirements.

Introduction.

DURING the ten years or so prior to the re-introduction of the sixpenny telegram, telegraph traffic had shown a progressive decline, and, as a consequence, the telegraph network of the country had been proportionately reduced. Many long distance circuits were withdrawn, since the amount of traffic did not justify their continuance, and minor local circuits were converted to telephone methods of working. It was difficult however to absorb all the redundant terminal equipment and staff and overhead charges remained substantially unchanged.

The introduction of the multi-channel voice frequency telegraph system in 1931, together with the conversion from Morse and Baudot to teleprinter working, considerably reduced the engineering costs of the provision of telegraph circuits.

The expansion of traffic following the reduction of charges in 1935 led to the desirability of converting a large number of telephone-telegram circuits to teleprinter working, as by this means traffic can be disposed of more rapidly. These circuits, however, will only be called upon to carry a relatively small load, and in a large percentage of cases the amount of traffic does not justify continuous staffing and the provision of separate apparatus.

When a number of such circuits radiate from a single transmitting centre, an advantage results from connecting the lines to a switchboard instead of appropriating a separate teleprinter to each line. Such a switchboard provides a means of connecting any line to an operating position when a message has to be sent or received, and under such conditions a considerable economy in teleprinters and office space can be effected. This method of working has the further advantage that the operators are relieved of the necessity of keeping a watch on several instruments, and of moving about from one to another.

To meet these needs a system of ancillary working has been devised, the operation of which may be regarded as being similar in principle to that of an ordinary telephone switchboard. The number of operating positions and the number of lines to which access is given are dependent upon the size of the telegraph office concerned and the busy hour traffic load.

To meet the traffic and engineering requirements, the system embodies the following facilities :—

1. Permits the concentration of all types of circuits, viz., V.F., two line simplex and duplex circuits.
2. Gives full availability to all circuits at any operating position for both incoming and outgoing traffic.
3. Includes an automatic distribution indicator.
4. Provides metering for traffic recording purposes.
5. Provides facilities for the rapid transfer of circuits to reserve positions during busy periods.

Circuit Requirements.

It should be mentioned that in most large telegraph offices all apparatus apart from the teleprinter has been removed from the instrument table and, in the case of physical circuits, this apparatus has been fitted on rack mounted panels, the local extensions being connected to the instrument table *via* a concentrator board. Consequently, from this board to the instrument table all types of circuits conform to a uniform standard as regards wiring and operation, *i.e.*, simple direct current sending and receiving local circuits, and this point was found to be the most suitable at which to introduce the ancillary apparatus.

The normal condition of a circuit with the distant station teleprinter at rest is negative current to line (in the case of V.F. circuits to the SEND relay) and negative current from the relay to the teleprinter at the receiving end. A calling relay, upon the operation of which all subsequent functions of the associated apparatus will depend, must therefore be introduced. This relay should be inoperative to a negative current, but should operate on a momentary reversal of current by the operation of any teleprinter key at the out-station.

This condition is obtained by using a telephone relay shunted by a rectifier to operate first on a positive impulse and then to be held operated by a locking circuit (see Fig. 1).

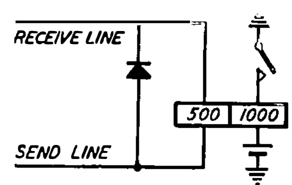


FIG. 1.—CIRCUIT OF CALLING RELAY.

Equipment.

The essential equipment of an ancillary system comprises :—

1. A suite of operating positions each fitted with a teleprinter and a small panel (Switchboard Teleprinter No. 1, Fig. 2) on which circuit jacks and signalling lamps are accommodated and which also affords various facilities which will be described later. The maximum capacity of this panel is 60 lines.

2. A distribution position with a panel (Switchboard Teleprinter No. 2, Fig. 3) indicating engaged circuits and positions.

3. A transfer panel (Switchboard Teleprinter No. 3, Fig. 4) providing for the transfer of circuits to adjacent reserve positions, synchroscope tests for checking the speeds of out-station teleprinters, and

bunching of circuits for the simultaneous transmission of the TIME signal.

4. A number of reserve positions terminated on jacks on the transfer panel.

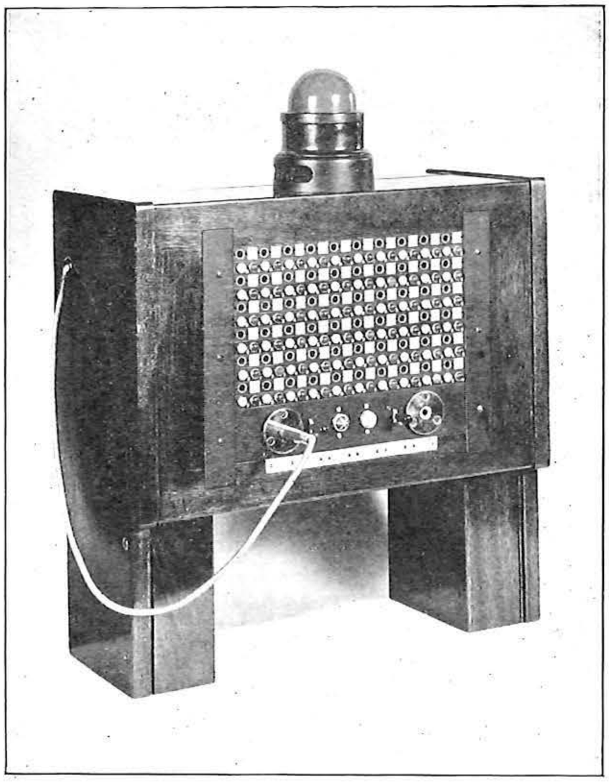


FIG. 2.—OPERATORS' SWITCHBOARD.

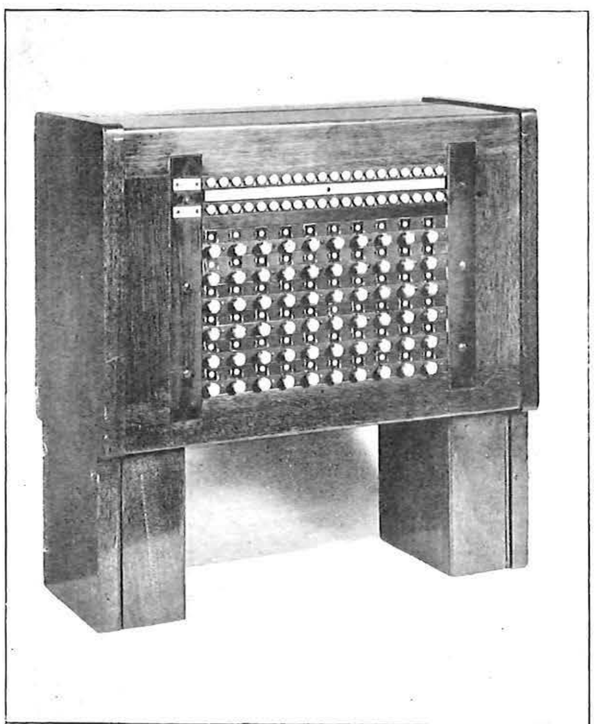


FIG. 3.—DISTRIBUTION BOARD.

5. Rack Equipment (Equipment Ancillary TG. 970). The apparatus associated with the ancillary is mounted on panels fitted on standard telegraph racks (see Fig. 5). The jack-in principle has been adopted for the line equipment, *i.e.*, the calling and engaged relays together with the flashing relays are mounted in a small unit on a telegraph relay base so as to jack into a Baseboard No. 26 (Fig. 6). These units are mounted on both sides of the rack.

On the front of the rack, above the line relay sets, are mounted three panels. The first carries the "position" relays, the second the meters, and the third the delayed call flashing equipment and the pulsing relays for metering purposes.

6. Power equipment. This is also rack mounted and provides the necessary fuses and transformers for the 6 v. A.C. supplies for the lamps.

Teleprinter Switchboard.

To enable the sequence of operations associated with a call to be followed it is desirable to describe the operator's switchboard. This is shown in Fig. 2. On it are mounted a labelled jack, a white calling lamp and a red engaged lamp associated with each circuit. Below the jack and lamp field is a key and jack strip accommodating two keys, (the "position-staffed" key and the "reset" key), two jacks for TIME and local test and two lamps (the white "circuit-hold" and red "duplicate-connexion" lamp). On the top of the switchboard is a unit containing two lamps, one a green lamp indicating that the position is staffed and the other a red lamp indicating that the position is busy. These lamps are brought into use by the operation of the "position-staffed" key when the position is opened for traffic purposes.

The teleprinter "Send" and "Receive" leads are connected to a plug and cord attached to the switchboard, and the instrument can be connected to any circuit by plugging into the corresponding jack.

The line circuits are connected from the concentrator and are multipled on all the switchboards.

Operating Procedure.

An incoming call on the ancillary equipment causes the calling lamp associated with the circuit to glow at every position. If the call is not answered within a period varying between 24 and 60 seconds this glow changes to a flash. During this calling period the "Send" and "Receive" lines are looped *via* the calling relay (L); consequently the calling station receives its own signals back as an indication that the call is awaiting attention.

The call is answered when any operator plugs into the associated line jack; this extinguishes the calling lamp and causes the engaged lamp on every position and on the distribution panel to glow. At the conclusion of the call the plug is withdrawn and the circuit restores to normal.

A connexion for outgoing traffic is made by plugging into the jack of the required circuit. This lights the engaged lamps as on an incoming call.

In order to eliminate ineffective operating time due to calling the out-station and awaiting acknowledg-

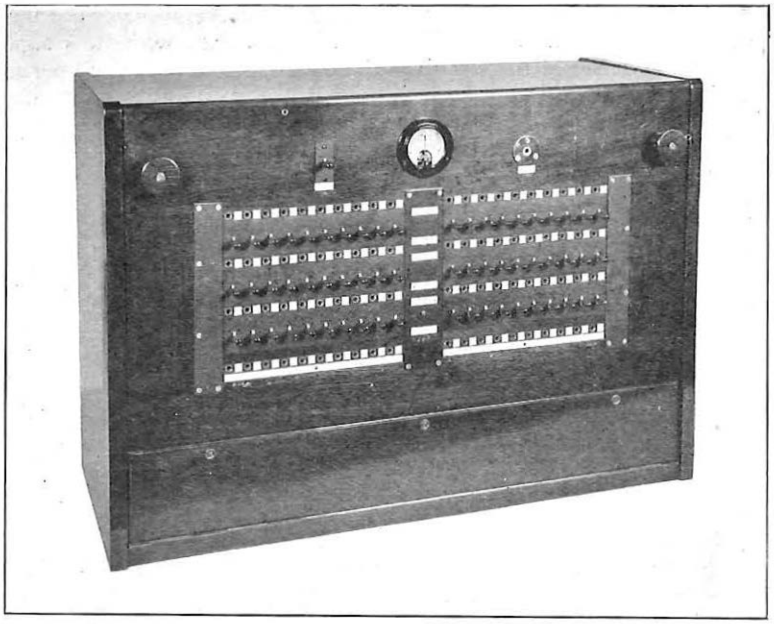


FIG. 4.—TRANSFER BOARD.

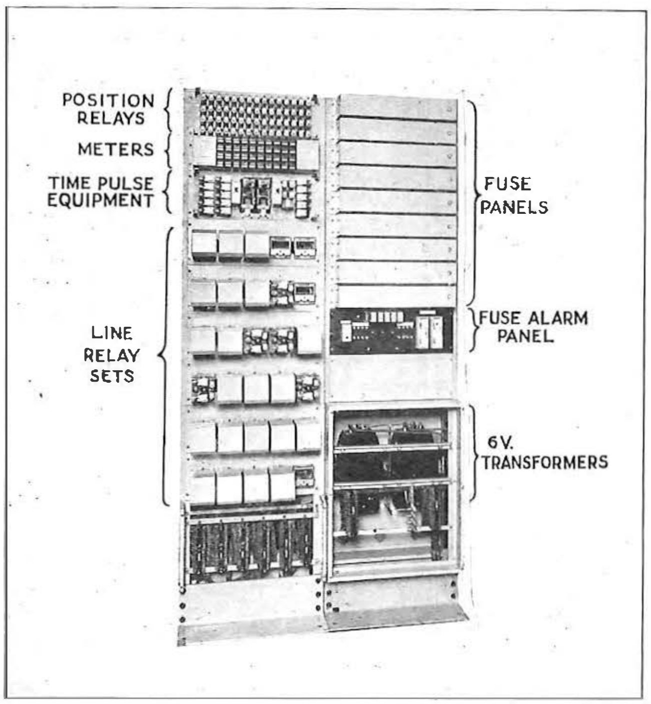


FIG. 5.—RACK EQUIPMENT AND FUSE BOARD.

ments, the teleprinters have been fitted with an "answer-back" device. On plugging into the jack of the required circuit the operator depresses a "who-are-you?" key on the teleprinter and the signal transmitted by this key actuates the "answer-back" unit on the out-station teleprinter. The unit automatically transmits the code of the called office and this is accepted as an indication by the calling operator that the distant teleprinter is functioning

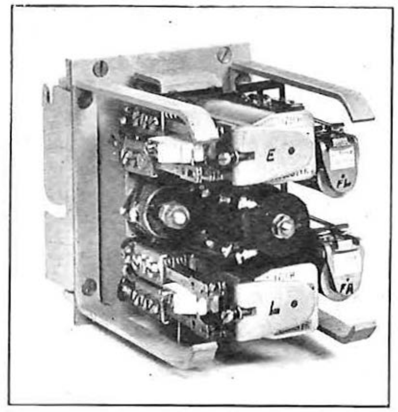


FIG. 6.—LINE RELAY SET.

correctly. The message or messages are transmitted forthwith without waiting for any further instruction or signal to proceed, and on completion of the transmission the "who-are-you?" key is again depressed. This time the reception of the code of the distant office is regarded as an indication that the distant teleprinter has functioned satisfactorily during the transmission and is accepted as an acknowledgment that the message or messages have been received.

The Duplicate Connexion Alarm Unit.

To prevent duplicate reception of messages due to two or more operators answering the same call, a duplicate connexion alarm unit has been fitted in each switchboard. This unit, consisting of two relays and a rectifier, is inserted in the teleprinter cord circuit; its operation is shown in Fig. 7.

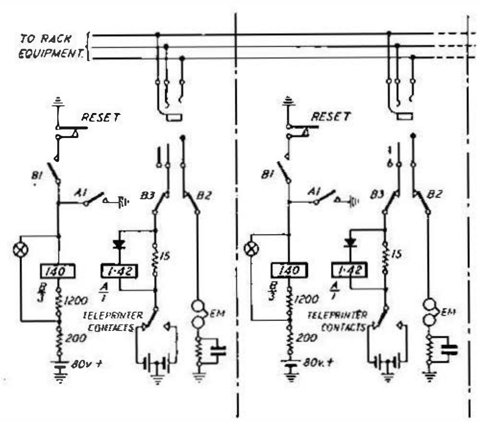


FIG. 7.—DUPLICATE CONNEXION ALARM UNIT SHOWING TWO OPERATORS' POSITIONS.

When a double connexion has been made, the 80 v. negative transmitting battery is connected to line *via* parallel paths, the current in each path being approximately 20 mA. and insufficient to operate relay A. On the reversal of battery at one position, *i.e.*, when the operator transmits the "G" signal, the positive battery on that position is momentarily connected through the line jacks to the negative battery on the other position. The current in the cord circuits rises to approximately 600 mA. and the direction of this current is such that relay A and in turn relay B of the second operator's unit only are operated. The second teleprinter is disconnected from the line to prevent interference with traffic, and the lamp indicates that a duplicate connexion has been made. On receipt of this indication the second operator withdraws the teleprinter plug from the line jack and extinguishes the lamp by operating the reset key.

Distribution of Traffic.

In order to expedite the distribution of outgoing traffic and to retain engaged circuits for which further traffic has been received, a distribution indicator panel has been incorporated. This panel (see Fig. **3**) is similar in size and appearance to the operator's switchboard and is located at the traffic circulation drop-point. It is fitted with engaged lamps and keys associated with each circuit on the ancillary, the lamp being operated in conjunction with the engaged lamps on the operator's switchboards. Above this lamp and key field are position lamps corresponding to the ancillary and reserve positions. On receipt of a message for an engaged circuit the distribution operator depresses the key associated with the line; this causes a lamp to glow to indicate the operator's position to which the required circuit is connected. At the same time the " circuit hold " lamp on the operator's switchboard glows to indicate that the circuit should be retained for further traffic. This lamp is extinguished by the operation of the reset key.

Reserve Positions.

During the peak traffic hours congestion on the ancillary positions may necessitate the transfer of certain busy circuits to reserve positions, and in order to effect this transfer quickly, and at the same time retain the distribution indicator facility, a transfer panel has been designed (see Fig. **4**). The reserve positions are connected to jacks on the transfer panel, and associated with each circuit are a key and line jack. By operating the key to " Reserve " and connecting the line jack and a position jack with a double-ended cord the circuit is transferred to a reserve position. The engaged lamp on the distribution panel glows and the indicator facility is obtained in a similar manner to that obtained with the ancillary position.

This panel is used also for the bunching of circuits for the simultaneous transmission of the time signal. By operating the keys to TIME, the " send " lines of a number of circuits are connected to a time-jack on the operator's switchboard and all engaged lamps associated with the bunched circuits are made to glow.

Facilities have also been provided to connect any out-station teleprinter to the synchroscope for speed check purposes.

A system of metering has been incorporated for traffic recording, one set of meters recording the number of connexions per position, while a second set of meters gives the aggregate duration of operating time per position. These meters are controlled by a master key and are brought into operation as required.

Outline of Circuit Operation (see Fig. **8**).

It has been previously explained that the operation of the ancillary equipment is dependent upon the calling relay (relay L) which operates on the first depression of a teleprinter key at the out-station, and then locks. This relay lights the calling lamps, and also starts the delayed call flashing equipment, which is controlled by the successive operation of relays FA and FL at an interval of approximately 30 seconds. The time interval between the operation of these relays is controlled by means of a uniselector, stepping once every six seconds.

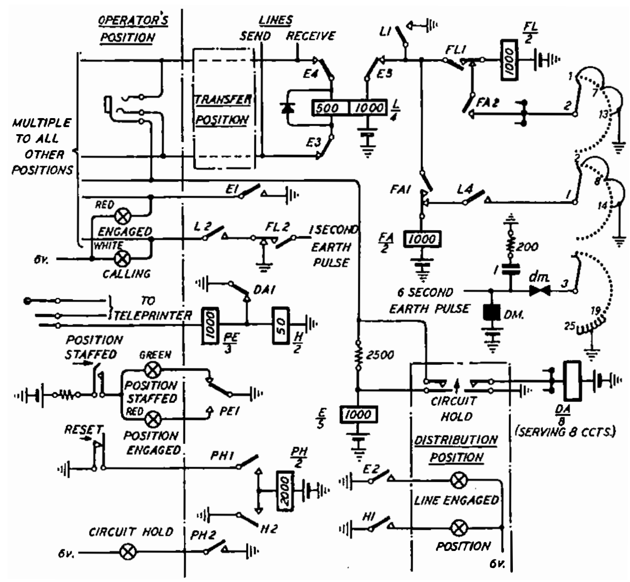


Fig. **8**.—Fundamental Circuit Conditions.

When any operator plugs into the calling circuit, relay E in the sleeve circuit operates and disconnects relay L. It also lights the engaged lamps on the operators' switchboards and the distribution panel. At the same time relay PE in the sleeve circuit of the operator's position will operate to change the green lamp on the top of the switchboard to red. This relay also controls the metering circuit.

The distribution facility is provided by inserting a resistance in the sleeve circuit which can be short-circuited by means of the press-button key at the distribution board. At the same time the operation of relay DA removes the short circuit from the H relays associated with each position, and the H relay in the sleeve circuit in which the resistance has been short-circuited will operate. This lights the corresponding position lamp on the distribution board, and also operates relay PH which lights the " circuit-hold " lamp at the operator's position.

When the plug is withdrawn from the multiple, relays E and PE restore, and the circuit is restored to normal.

Conclusion.

Experimental ancillary systems were installed at Bristol, Birmingham, Newcastle and Glasgow in July, 1935, and handled the summer peak traffic at these offices. A typical ancillary suite is shown in Fig. 9. Further equipments will be installed at most of the Telegraph zone centres during the present year.

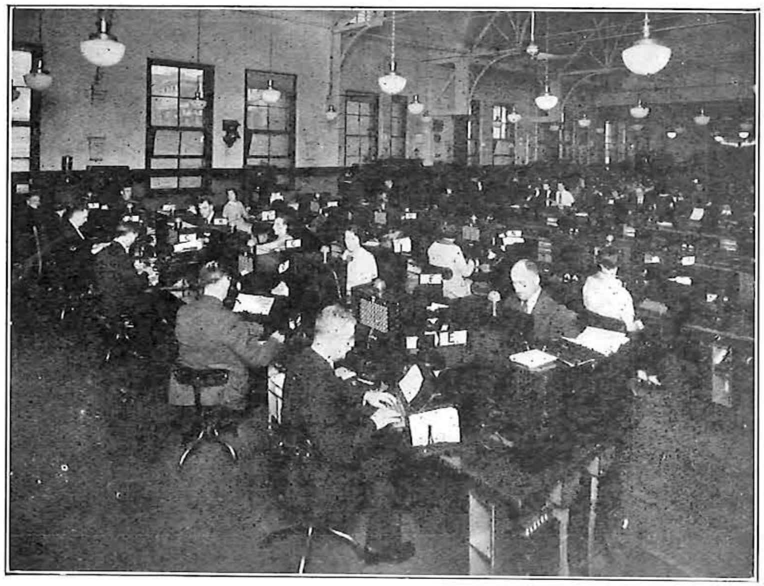


Fig. 9.—General View of Ancillary.

Aerial Cabling

The Department's present practice is to erect the smaller sizes of aerial cable in marline suspenders, and the larger sizes in cable rings of the now familiar self-gripping pattern.

About two years ago a small size of cable ring was introduced. Although not primarily intended for use with lead-covered aerial cable, its use in place of marline suspenders was seen to have evident advantages. Cable rings give an appreciably longer line than marline suspenders—about 15 years as against 8 for suspenders; and in addition the appearance of a cable erected in rings is, to most eyes, much superior to that of a cable in suspenders.

Trials, moreover, have shown the feasibility of drawing the smaller cables into rings by ordinary methods without undue stress; while the extra cost of the suspension strand and rings as compared with suspenders and twin steels is largely offset by savings in construction costs, such savings resulting principally from the smaller gang possible with a draw-in job. It is therefore the intention in the near future to dispense entirely with the use of marline suspenders and erect all aerial cables, large and small, in rings on a seven-fold strand of suitable size.

As regards the actual process of erection, present methods are based on the use of a " bosun's chair " for fixing the rings to the strand. The bosun's chair in use, however, induces a feeling of insecurity and it is on the whole not a rapid means of fixing the rings. It must be borne in mind that the man in the chair requires the attendance of men on the ground during the course of his work. For these and other reasons the bosun's chair method of ring-fixing is not too favourably regarded, and other methods, such as the use of ladders temporarily stayed, or rather balanced, against the strand by means of sash-lines, have been largely used.

The obvious way of avoiding the use of bosun's chair or ladders would be to fix the rings to the strand at ground level, the rings to embrace the draw-rope, and then to hoist strand, rope and rings into position. This method has been tried in the past with somewhat varying degrees of success, but has shown sufficient promise to warrant some investigation into its shortcomings.

The principal difficulty has been the tendency, during the raising of the strand, for the latter to twist so as to rotate the rings to varying degrees away from the vertical. This difficulty it is found can be largely overcome by the use of a heavy draw-rope. The weight of a $1\frac{1}{2}$-in. draw-rope is in most cases sufficient to keep the rings hanging true.

Where " spiralling " of the rings persists, despite the inclusion of a heavy draw-rope, it is usually restricted to the last span of the length being tensioned. The reason for this is not yet quite clear, but it appears to be bound up with the manner in which the tension is applied—*i.e.*, whether the tensioning tackle gives a direct pull, or whether the pull is " reversed " through snatch blocks at the top and bottom of the terminal pole. It may also be the case that different batches of strand wire have an inherent tendency to twist, but to different degrees.

Further tests are in hand to clear up these points, for if suspension strand can be satisfactorily ringed at ground level, the construction costs of aerial cable can be very appreciably reduced.

R.M.

The Guernsey-Chaldon Ultra Short Wave Radio Telephone Circuit

A. H. MUMFORD, B.Sc. (Eng.), A.M.I.E.E.

The new high power short wave radio circuits between Great Britain and Guernsey are described. The equipment differs from that of previous short wave links provided by the Post Office, since the distance is too great to permit of an optical path.

Introduction.

PREVIOUS articles[1] have described an experimental radio telephone circuit between Cardiff and Weston-super-Mare, and a commercial ultra short wave radio link between Belfast and Stranraer. Both these circuits were operated on wave-lengths of approximately 5 metres, the transmissions taking place along optical paths of relatively short length, 15 and 36 miles respectively. It was obvious that such radio links might also prove an economical alternative to cable circuits over much longer distances providing an optical path were not a necessity. In view of the need for additional telephone circuits between the island of Guernsey and the mainland, it was decided towards the end of 1933 to put in hand experiments to determine—(*a*) the power required, (*b*) the optimum wave-length, (*c*) the optimum polarization and (*d*) the grade of service possible for this particular case in which an optical path is not possible. It will be seen from Fig. **1** that the general direction of the mainland from Guernsey is to the north and that the nearest points on the mainland are Portland Bill and Start Point, each approximately 72 miles from St. Peter Port, Guernsey.

Experiments commenced in the spring and continued during the summer of 1934 with low power transmitters and super-regenerative receivers at Dartmouth and Guernsey using small aerials, the length of the radio transmission path being some 78 miles. It soon became apparent, since fading was experienced on the 5 and 8 metre wave-length used, that prolonged measurements would have to be made to obtain the data necessary for the setting up of a commercial circuit. The type of fading experienced was quite different from that experienced on short waves, say 12-100 metres, in so much as the shortest periods were of the order of two minutes. At times the fading was regular, at others erratic and sometimes non-existent. Fading has not been observed on the circuits previously mentioned, where the transmissions take place along optical paths.

In analysing the data for the determination of the usefulness of the transmission, the percentage of the total observed time on any particular condition for which the field strength was above certain levels was determined and plotted, and a typical case is shown in Fig. **2**. This method of analysis and presentation

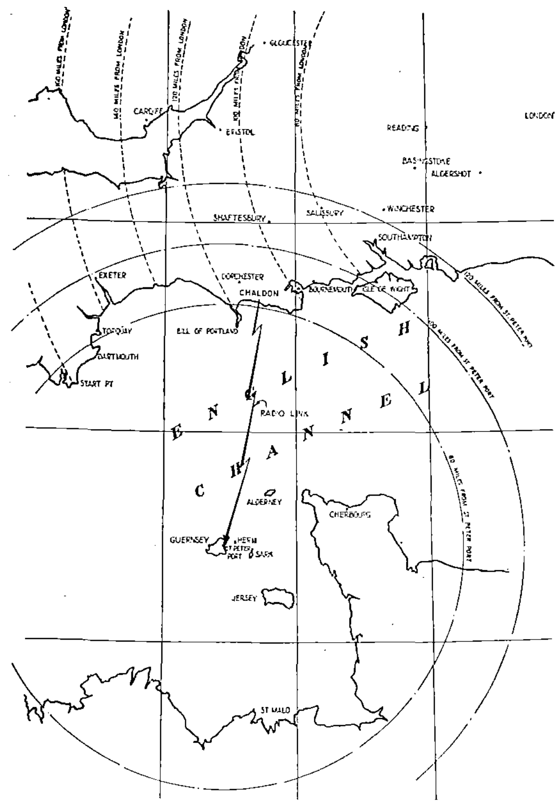


FIG. 1.—MAP SHOWING GENERAL LOCATION OF CHALDON AND GUERNSEY.

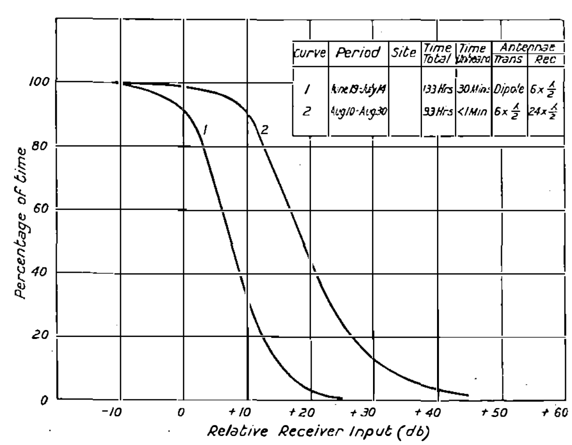


FIG. 2.—COMPARATIVE MEASUREMENTS, HORIZONTAL POLARIZATION.

[1] " Ultra Short Radio Waves." F. E. Nancarrow. *P.O.E.E. Journal,* Jan., 1933.
" Ultra Short Wave Radio Telephone Circuits to Northern Ireland." A. J. A. Gracie. *P.O.E.E. Journal,* July, 1935.

of the results is probably the most useful from a commercial point of view if the following points are borne in mind when comparing any one condition with another, (a) the duration of the periods of observation will probably differ in the various conditions, (b) the periods will not be coincident. Subject to the above reservations such graphs are useful in estimating the probable performance of a circuit operating on a given wave-length and type of polarization. These initial tests yielded results sufficiently promising to justify more extensive tests. Difficulties in the acquisition of sites at Dartmouth and the desirability of reducing the length of the land line to London resulted in further experimental work at Shaftesbury, the transmission path being increased to some 105 miles. A limited amount of data suggested that the Shaftesbury location, in the summer period, was not inferior to the Dartmouth site. Accordingly an experimental station was set up at Ashcombe, and large aerials were erected for 5 and 5.5 metres respectively. Test transmissions between Guernsey and Ashcombe were resumed in December, 1934. In spite of the larger aerials, the circuit was not as successful as had been anticipated, and arrangements were made for a portable field strength measuring set to tour the neighbourhood of Lulworth, near Bournemouth, to make comparisons with the Shaftesbury observations. As a result of the data obtained, it was decided to set up another experimental station at Chaldon, Dorset, on the cliff edge adjoining the sea. Observations were made over two months, and the results obtained indicated that the Chaldon location was much preferable to that at Shaftesbury. Arrangements were then made for the installations which are detailed below. The length of the transmission path is some 85 miles, the sites at Guernsey and Chaldon being 270 and 500 ft. above sea level respectively. Thus the actual path is about 1.73 times the optical range. The final arrangements make provision for four trunk circuits, all of which should comply with the specifications for such circuits in the matter of transmission equivalent and noise. The first of these circuits was handed over for traffic on May 8th, 1936. Although the remaining circuits have not yet been completed, this article describes the arrangements being made for the remaining circuits in order that the possibilities of such equipment may be fully realized.

A low power experimental ultra short wave telephone circuit has been in commercial operation between Guernsey and Shaftesbury since the 1st April, 1935. Although this circuit has been widely used for traffic and has given quite an amount of satisfaction, it has been necessary to have technical operators at each end to adjust the speech levels to appropriate values in view of the low signal-to-noise ratio experienced at times. The use of the high power equipment at Guernsey and Chaldon will permit, except for occasional valve changes, unattended operation and give a much more reliable circuit.

System used.

The traffic requirements for the trunk services to Guernsey were four telephone circuits. It was decided from the data obtained that high power transmitters of some 250 watts and super-heterodyne receivers each utilizing large aerial systems were essential if the radio link were to be reliable at all times of the year. At the same time it was thought that advantage might be taken of the high signal-to-noise ratio offered with such equipment to superimpose two speech channels on each transmitter. This is known as the Diplex system of working. Thus, with modulator and receiver equipment whose bandwidth extends from 100-10,000 c.p.s., it should be possible to have two separate speech channels using the low frequency bands of 100 to 3,000 c.p.s. and 6,000 to 9,000 c.p.s. approximately. Coincident with this decision it was thought that there should be some form of privacy provided on the circuits. There had been at least one instance of the reception of the Guernsey transmission on a local broadcast receiver. Accordingly speech inverter type of equipment has been installed so that the two speech channels on each radio transmission operate on sidebands displaced 100-3,200 c.p.s. and 6,400 to 9,600 c.p.s. from the carrier, the speech frequencies being inverted in the first band. The arrangement is illustrated diagrammatically in Fig. **3**. Each radio channel therefore provides two speech channels, four radio channels

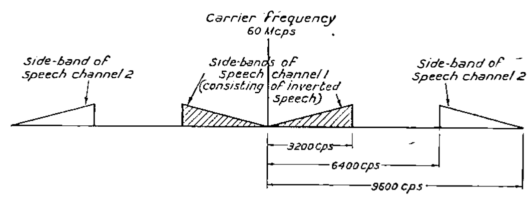


FIG. 3.—SPECTRUM OF TRANSMITTED WAVE.

being necessary to provide the four bothway telephone speech channels specified.

Since the wave-lengths employed in each circuit must be different it has been arranged that the two transmitters in Guernsey operate on the 5 and 8 metre wave-lengths and the Chaldon transmitters on the $5\frac{1}{2}$ and $8\frac{1}{2}$ metre wave-lengths. One radio circuit uses the 5 and 5.5 metre channels and the second circuit uses the 8 and 8.5 metre channels. Wide spacing of the wave-lengths between the two radio circuits has been adopted mainly to ensure that there is at least one radio circuit, *i.e.*, two telephone circuits, available at any time since a period of poor transmission on 5 metres does not normally coincide with one on 8 metres and *vice-versa*. Normally, of course, two radio circuits of high quality will be available. Valuable data for the operation of future circuits will also be gathered from this arrangement.

Fading of the radio signals is compensated by the automatic gain control provided in the receivers.

Aerials.

The initial tests from Guernsey were made with arrays supported on 55 ft. poles erected on the rampart walls of Fort George. The size and orientation of these arrays were restricted by the shape and dimensions of the rampart. For the final installation larger arrays of the Koomans type have been erected for transmissions on the four wave-lengths selected. As a result of the experience which was gained in the Bristol Channel and North Channel experimental work, the transmitting and receiving arrays have been given a lateral separation of 100 yards. Such separation of large arrays was impossible inside the Fort at Guernsey. Accordingly, the new arrays and the huts to house the apparatus have been located in the Fort grounds, by the kind permission of the military authorities. In order to obviate interference between the aerials, the arrays for one circuit are of the horizontal type and those for the second circuit of the vertical type.

A horizontal array produces a beam which, in the vertical plane, is inclined to the horizontal by an amount dependent on the height of the array above the ground. The higher the array, the more nearly horizontal does the beam become. For this reason it is considered desirable to suspend the horizontal arrays above the ground as high as possible. Comparatively tall supporting structures have, therefore, been erected at Guernsey and Chaldon. Between these masts the horizontal arrays have been slung above the vertical arrays. Each horizontal array contains 8 " trees " connected in parallel, giving a total of 64 half-wave radiators. Each vertical aerial contains 24 half-wave radiators suitable for 8 or 8½ metre working. Reflectors, equal in size to the arrays, are slung a quarter of a wave-length behind. To facilitate maintenance it is desirable that the horizontal array should be capable of being lowered independently of the vertical array, and the feeder system has been designed to allow this being done.

The effect of large masses of metal in the vicinity of ultra short wave arrays is, at present, uncertain, and wooden structures, 90 feet high, have been used for the suspension of the aerials. For economic reasons these masts were constructed of standard telephone poles. Each leg of a mast consists of a 50 ft. light, a 28 ft. light and a 24 ft. light pole, spliced together end to end, giving a total length of 92 ft. Three such legs in the form of a tripod, with a 5 inch side at the top and a 10 ft. side at the base, make up a mast. Wooden double bracings are employed at the spliced points of the poles and in the lower half of the mast, and wire bracings in short, insulated lengths have been added to resist lateral and torsional stresses. The mast legs have been anchored to concrete blocks sunk in the ground, each block weighing approximately four tons.

The masts have been orientated relative to the arrays so that two legs are in compression and one in tension.

The effect of wind on the aerials is reduced by the provision of tension springs in the main anchor wires, and these introduce a degree of flexibility under gale conditions which prevents the overloading of any part of the arrays and masts.

The Diplex Equipment.

The diplex apparatus as developed by the Radio Branch functions by means of a single modulator for each channel at each radio terminal and both the input speech and carrier frequencies are balanced out to a high degree (some 40 db.) in a bridge type of modulator. This modulator uses indirectly heated diodes of low filament consumption. A high degree of freedom from distortion products in the wanted band is obtained, being of the order of 40 db. signal-to-noise ratio on a two tone input test for the inversion process; less distortion than this will be obtained for the translated band as compared with the inverted band.

Fig. 4 shows a schematic of the arrangement of the diplex equipment. The location in the overall

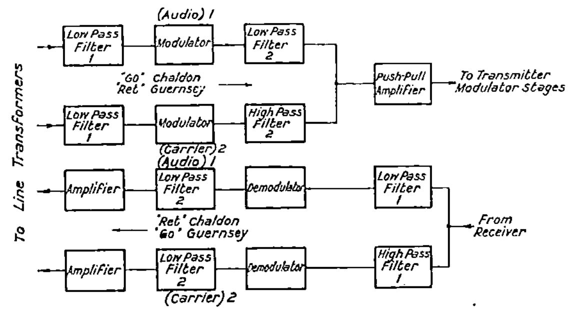


FIG. 4.—SCHEMATIC DIAGRAM OF DIPLEX EQUIPMENT.

circuit is also shown of the amplifiers which adjust the levels to the prescribed values. The whole of this equipment has been designed to operate from an A.C. supply of 230 volts 50 c.p.s.

It should be noted that it is possible to eliminate the diplex equipment and make use of the full low frequency characteristic of the radio circuit. Such a facility will provide a radio broadcast programme circuit from Guernsey.

In order to operate the diplex equipment satisfactorily without manual attention, except for valve replacements, etc., it is essential that the frequency of the carrier oscillators in the modulating and demodulating equipment should remain constant. As there are to be four circuits it has proved economical to achieve this constancy of frequency as follows :—

A valve driven elinvar tuning fork of 1600 c.p.s. is employed as the primary source, and its second and fourth harmonics are selected and amplified to produce the required tones. Each complete tone generator consists of tuning fork, selector amplifier for 3200 c.p.s., selector amplifier for 6400 c.p.s. and power suppy unit. The fork frequency is adjusted to within a few parts in a million of its nominal frequency at a temperature of about 20°C.

Transmitters.

These have been made to a specification which is outlined below :—

The transmitter is to have a carrier power of 250 watts, to be capable of 100% modulation, with no frequency modulation, and to be capable of operation over a frequency range of 5 to 8½ metres with a frequency stability of ±5 kilocycles/sec. The modulation response is to be uniform within limits of ±2 decibels from 30 to 10,000 c.p.s. to facilitate diplex working. The harmonic distortion of the modulator equipment is not to exceed 5% and the whole transmitting equipment is to operate off 230-250 volts 50 c.p.s. supply.

Some experimental work was carried out on the frequency control of the high power transmitter using a tuning circuit with a high " Q " value. It was found more satisfactory to use a crystal controlled drive circuit in the final arrangement.

A schematic of the high frequency circuit is shown in Fig. **5**. This shows a crystal oscillator, doubler stages with buffer amplifier, push-pull intermediate amplifiers and the modulated final amplifier.

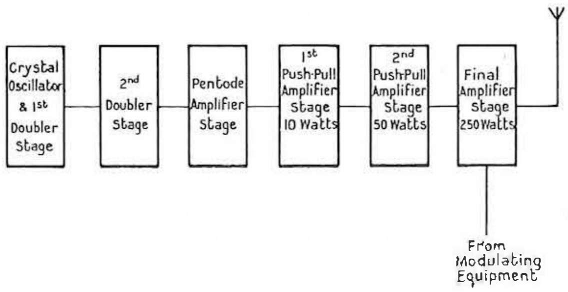


FIG. **5**.—BLOCK SCHEMATIC OF TRANSMITTER.

The oscillator is of the " tritet " type, controlled by an X-cut crystal whose natural oscillation frequency is one-quarter of the final frequency required for the transmitter. The crystal and holder are located in an oven whose temperature is thermostatically controlled to within ±1° of 50°C. The valves used in the oscillating and doubler stages are low frequency power pentodes with indirectly heated cathodes. The frequency in the anode stage of the third pentode valve is the same as the final frequency. Three successive stages of balanced push-pull high frequency amplification are used. The first push-pull amplifier uses VT 24 valves, the second ESW 501 and the third ESW 204 valves. These last two types are valves with graphite anodes which have been made specially for ultra high frequency work.

The whole of the transmitter excepting the final amplifier is assembled in one cubicle, which is then erected in a larger enclosure as shown in Figs. **6** and **7**.

The modulator consists of three successive push-pull low frequency amplifiers which, with an input level of **7** db. above one milliwatt, give an output sufficient to modulate fully the transmitter. The maximum low frequency output of the modulator is of the order of 400 watts. The final stage operates in a class A-B condition, driving into grid current. The modulation circuit combines an output transformer and modulator choke and overcomes distortion which is usual with Class B modulators using a modulation transformer.

The transmitter and modulator operate from an A.C. supply. The power supply units are identical and the main rectified current is provided by mercury vapour rectifiers.

Receivers.

Super-heterodyne receivers to a new design developed by the Post Office are used for this service. Fig. **8** is a photograph of the receiver. The apparatus has been assembled on a ⅛" steel panel suitable for mounting on a standard rack. Equipment is mounted on the back and front of this panel, which is 10½ inches deep.

The receiver comprises a push-pull frequency changer, three stages of intermediate frequency amplification, a double diode second detector, an automatic gain control valve and a low frequency output valve. Automatic gain control is applied to all the I.F. stages and the low frequency amplification is adjustable in steps of 2 db. to a maximum of 36 db. The intermediate frequency is 3 mega-

FIG. **6**.—TRANSMITTER BAYS.

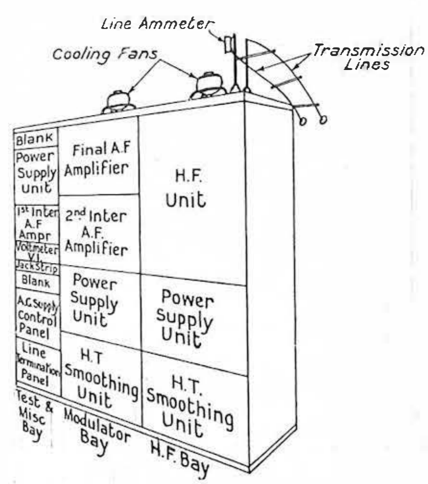


FIG. **7**.—KEY DIAGRAM FOR TRANSMITTER BAYS.

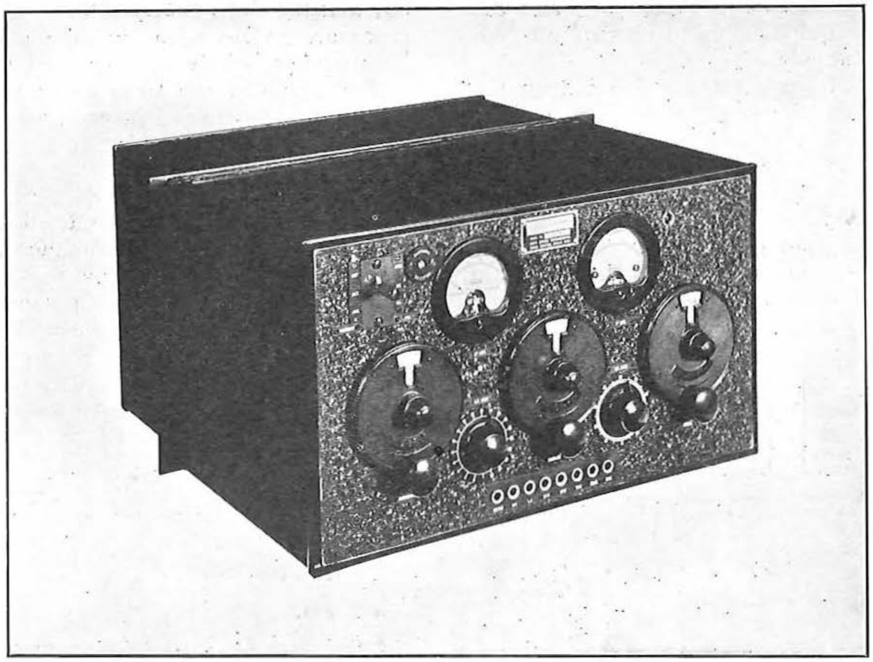


FIG. 8.—ULTRA SHORT WAVE SUPER-HETERODYNE RECEIVER.

cycles/sec. and the bandwidth of these stages has been made 50 kilocycles/sec. The first frequency changer employs a push-pull circuit which has the two-fold advantage that it reduces intermodulation products between two incoming signals and permits a more convenient coupling to the balanced transmission line. In the testing period it was found that the use of a push-pull oscillator and buffer valve to supply the first frequency changer, was not sufficiently stable over a period of days. This was so even when the tuned circuit was enclosed in a heat-insulated compartment. Accordingly, the frequency of the first beating oscillator has been crystal controlled. The arrangement used is a crystal oscillator and two doubler stages, identical, but for the valves, with the first two stages of the transmitter. The crystal in its holder is accommodated in an oven, the temperature of which is thermostatically controlled to 50°C. With this arrangement, and a similar arrangement on the transmitter, it is possible to hold the received carrier within the band of the intermediate frequency stage of the receiver.

When a signal is received which has the following characteristics :—(i) constant signal frequency, (ii) constant depth of modulation, and (iii) variable frequency of modulation from 100 to 10,000 c.p.s.—the low frequency output varies within limits of ± 1 db. from a mean value. This frequency characteristic is necessary because the two speech channels of each radio transmission are disposed 100 to 3,200 c.p.s. and 6,400 to 9,600 c.p.s. relative to the carrier frequency.

One important test of a receiver of this type is to measure the " de-tune ratio "—*i.e.*, the change in the level of the output noise when the aerial circuit is tuned through resonance with the aerial disconnected. At the highest frequency used, 60 megacycles/second, this change in the level of noise between resonance and non-resonance is 6 db. approximately. Thus any improvement in the signal-to-noise ratio of the output from the receiver can only be accomplished in future by an increase in input.

An individual power supply panel is mounted on the rack immediately below each receiver. The rack space occupied by this panel is 7 inches. A 230/4 volt mains transformer supplies the valve heaters and the heater element of the crystal oven. A stabilized H.T. supply incorporating a neon-tube maintains a constant 125 volt supply to the receiver over a wide range of input.

Power Supply.

One disadvantage of the Chaldon site was the absence of a power supply. The radio equipment will require a supply of the order of 8 kW finally, and arrangements have been made for a Grid supply to the site. In case this supply should fail, a Diesel-alternator set, rated at 10 kVA, has been installed on the site, the alternator providing a 240 volt 3-phase supply. The engine set has been housed in a brick building and a hand-operated pump enables the fuel reservoir to be refilled as required. A silencer pit has reduced any objectionable noise from the running of the engine. Arrangements have been made so that in the event of the Grid supply failing, there is an automatic switch over to the Diesel set, which is able to take up the full load in less than one minute. Fig. 9 shows a photograph of this set.

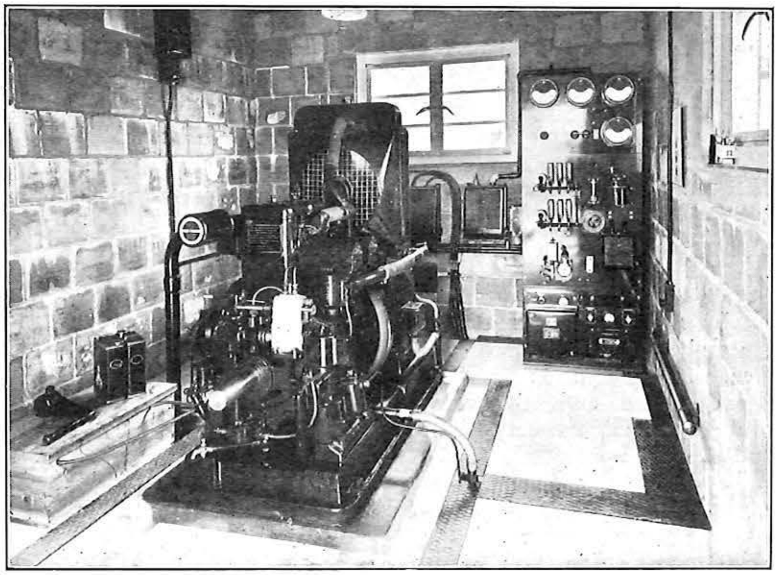


FIG. 9.—10 KVA DIESEL-ALTERNATOR SET.

It has been considered unnecessary to provide a reserve power supply at Guernsey, where the power is provided *via* underground cables from the Island power station which has reserve generating equipment.

Cable Circuits.

An underground cable has been laid to the site, and this is a 20 pr/10 spur to the Chaldon-Wareham-Southampton-London cable. 12 pairs have been terminated to provide the necessary four-wire circuits for the trunk connexions to London and a local telephone circuit to Wareham exchange.

Low frequency amplifiers have been provided at the transmitting and receiving stations. The gain of these amplifiers has been adjusted so that the radio link plus its associated apparatus offers transmission gains of 15 db. in the London-Guernsey direction and 8 db. in the Guernsey-London direction respectively.

Normal four-wire working has been adopted, connexion between the radio circuits and the land-line circuits being effected by suitable transformers; the hybrid coils are provided at the terminal exchanges in London and Guernsey. The overall transmission equivalent between London and Guernsey is 4 db. in each direction.

Conclusion.

The experimental low power ultra short wave link between Guernsey and Shaftesbury, which has been in commercial operation since the 1st April, 1936, has been supplemented by the first of the high power radio circuits of the Guernsey-Chaldon link. This link, operating on wave-lengths of 5 and $5\frac{1}{2}$ metres, has been brought into commercial operation although at present only the equipment for the first of the two speech channels has been installed. The design of the equipment is such that successful unattended working for long periods may be anticipated. The installation of the equipment for the second speech channel will be concluded shortly and the equipment for a second high power radio circuit, to operate on wave-lengths of 8 and 8.5 metres is now under construction.

It is of interest to note that it should be possible, by " patching out " the diplex equipment, to provide a programme transmission circuit *via* the radio link.

The new circuit was handed over for traffic on 8th May, 1936, and has since been giving every satisfaction.

In conclusion, the author's thanks are due to several members of the Radio Branch who have supplied material for this article.

The King's House Subscriber-Attended P.A.B.X.

W. A. PHILLIPS, A.M.I.E.E.
(Automatic Electric Co. Ltd.)

The P.A.B.X. equipment installed at the King's House, which is of novel design in that the manual board is dispensed with, is described and its facilities enumerated.

Introduction.

THE King's House, which was presented to King George V. by the Warrant Holders' Association in grateful commemoration of His Majesty's Silver Jubilee, is situated at Burhill, Surrey. Designed in accordance with the most modern English style and embodying the very latest ideas in construction and interior appointments, the King's House befittingly exemplifies the highest attainment of English craftsmanship and technique in every department. At the invitation of the Warrant Holders' Association the Automatic Electric Company, Ltd., arranged to provide the telephone equipment and in keeping with the modern appointments of the house it was decided to provide automatic facilities.

The King's House P.A.B.X. was designed in consultation with the engineers of the B.P.O. and is the first of a new and particularly novel type. It represents a striking departure from the designs and operating practices hitherto in use and, it is hoped, will set a new standard that will fulfil a long needed requirement.

The King's House P.A.B.X. is of the Strowger all-mains type and entirely dispenses with the manual switchboard and attendant hitherto necessary on P.A.B.Xs. Incoming calls from the main exchange are arranged to be answered and expeditiously transferred as may be necessary by certain of the extension telephones.

EQUIPMENT.

Automatic Equipment.

Figs. 1 and 2 are front and rear views of the equipment, which is contained in a sheet metal cabinet fitted with locks and is practically dustproof. The selecting mechanisms consist entirely of 25-point uniselectors, these being employed as line finders and final selectors (connectors). The line and cut-off relays are of the B.P.O. 600 miniature type, the remaining relays being of the B.P.O. 3000 type. The capacity of the equipment is as follows :—

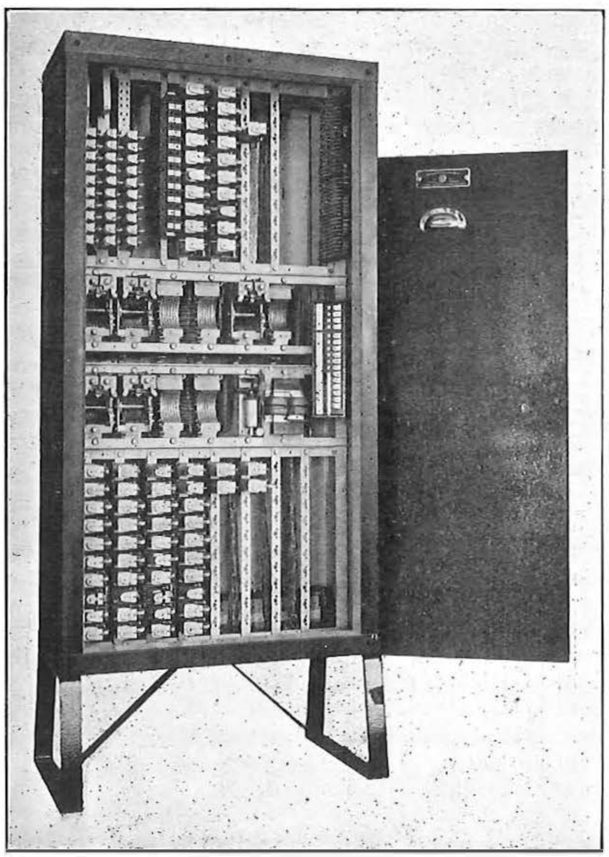


FIG. 1.—FRONT VIEW OF EQUIPMENT.

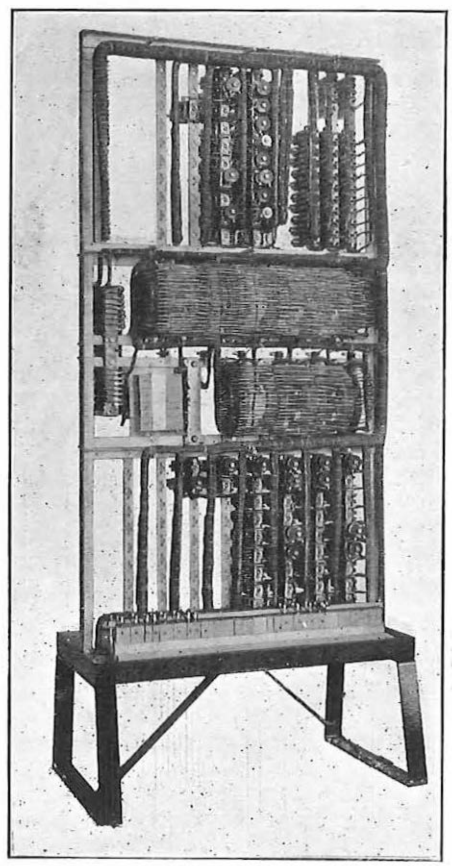


FIG. 2.—REAR VIEW OF EQUIPMENT.

	Quantity. Initial.	Ultimate.
Local extension lines ...	15	20
Local connecting links ...	2	4
Exchange connecting lines	1	2
Transfer circuit	1	1
Spare number circuit ...	1	1
Mains fail alarm circuit ...	1	1
Magnet release alarm circuit	1	1
Ringing and tone set ...	1	1

Telephone Instruments.

The telephone instruments are of the self-contained type and of the initial number supplied, eleven are of the desk type and three are wall instruments. Eight of the desk telephones have an ivory finish, two have a walnut finish and one has a red finish. The wall instruments are black.

A special feature of the telephone instruments is that each is fitted with a push button for the purpose of transferring exchange calls from one extension instrument to another. A desk type telephone is shown in Fig. 3.

Bell Sets.

In addition to the bell provided with the extension instrument, an additional magneto bell is fitted at those points where it is desired to receive incoming exchange calls. On this installation four stations have been equipped for this service. These bell sets are connected in parallel across a pair of wires extended from the equipment for the purpose of signalling incoming calls. Such calls are answered immediately the microtelephone of any one of the four selected stations is lifted and can be transferred to other extension instruments or not as required. Two of the bell sets have disconnexion keys for use when the assooiated telephones are unattended.

Numbering Scheme.

The numbers 20-39 are used for the extension instruments and the single digit " 9 " is dialled to obtain the public exchange.

OPERATIONAL FEATURES.

Fig. 4 shows the trunking diagram. A line finder and a final selector (connector) are associated with each local connecting link, and a further line finder with each exchange connecting link. The line finder uniselectors are of the non-homing type, but the final selectors utilize the 23rd set of contacts for the " home " position of the wipers.

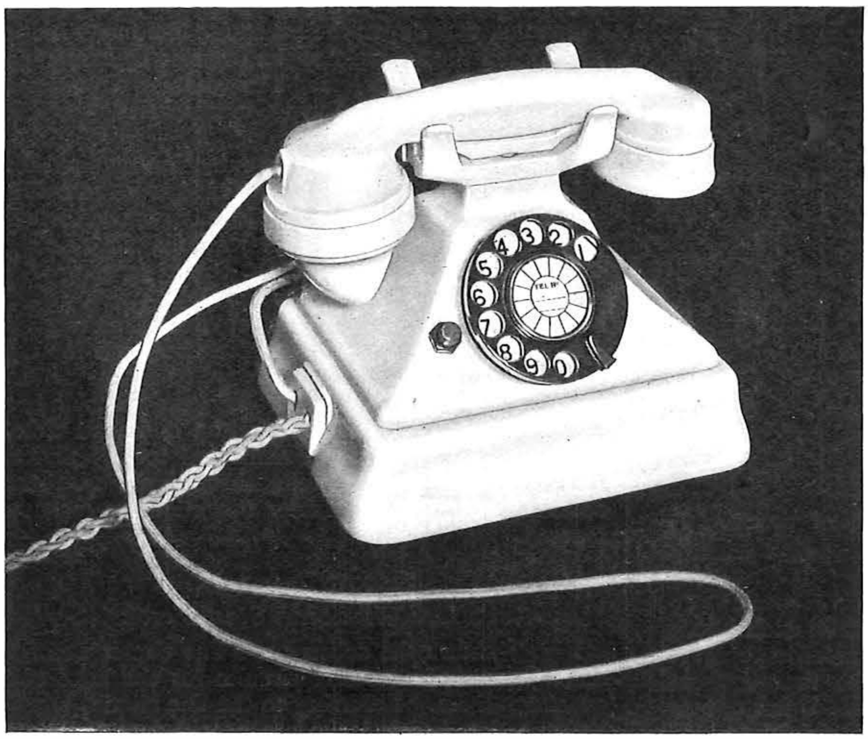


FIG. 3.—DESK TELEPHONE FITTED WITH PUSH BUTTON.

Local Call.

The allocation of the final selector contacts is given in Fig. 5. On purely local calls between the extension instruments the dialling of the first digit " 2 " steps the final selector to the 25th set of contacts and the connexion is finally completed when the second digit is dialled to step the wipers to the corresponding sets of contacts, 1 to 10. On the other hand, if the first digit is " 3," the wipers step from the 23rd to the 1st set of contacts and then hunt automatically within the interdigital pause to the 10th set, being finally positioned on the desired line in the 30 group when the second digit is dialled.

Telephone Lines.

Each extension instrument is connected to the equipment by an earth wire, in addition to the usual pair of line wires. This earth wire is required for transferring calls under the control of the push button. It is not essential that the earth wire should be extended back to the equipment, and any local earth connexion available may be used.

Call to Main Exchange.

If the out-service digit " 9 " is dialled, the final selector wipers step to the 7th set of contacts, whereupon relay OS (Fig. 5) operates and initiates a start signal to the exchange link. The associated line finder then hunts to find the calling line, whereupon the local link, line finder and final selector are cleared down. Under this condition battery is fed from the main exchange to the extension instrument.

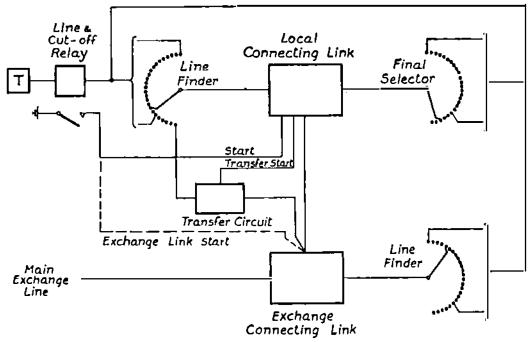


FIG. 4.—TRUNKING DIAGRAM.

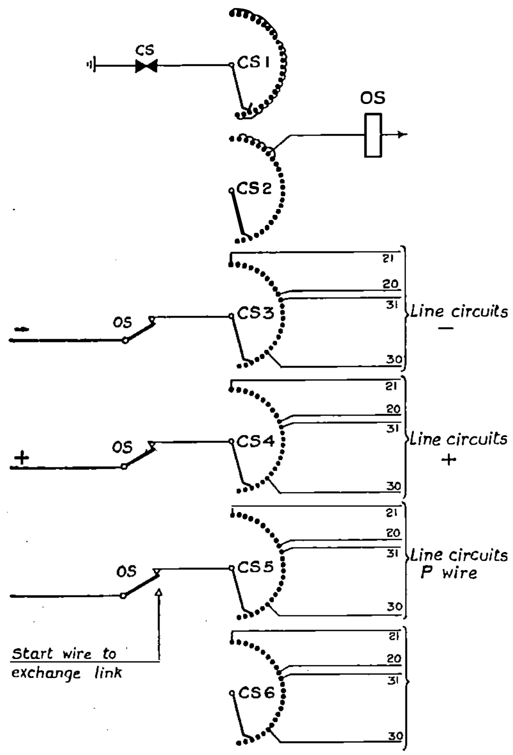


FIG. 5.—ALLOCATION OF FINAL SELECTOR CONTACTS.

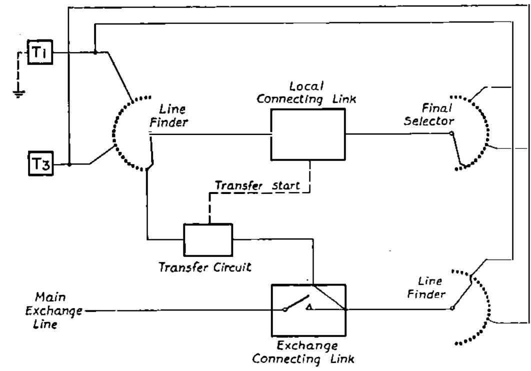


FIG. 6.—CALL TRANSFER CONDITIONS.

Incoming Calls from Main Exchange.

When an incoming call from the main exchange is received, the ringing vibrator is started to operate the exchange calling signals at the four selected stations having answering facilities. Upon one of the four stations replying, a start signal is given to the exchange connecting link and the associated line finder finds and switches through to the main exchange.

Transfer of Exchange Calls.

Fig. **6** shows the condition immediately after the push button on the extension instrument T1 has been depressed to initiate the first stage of the transfer operation. The exchange line is held and the transfer circuit has been introduced to give a start signal to a local connecting link. The associated line finder of the latter has hunted and switched through *via* exchange line finder and link, the transfer circuit, the local line finder and link to the associated final selector. T1 now dials the number of, say T3, whereupon the final selector steps accordingly. Under this condition T1 is enabled to offer the call to T3 if the latter is engaged. If disengaged, T1 hears the transmission of ringing current and waits until T3 replies. T1 then replaces his microtelephone, whereupon the exchange line finder hunts for T3 and thus completes the transfer by extending T3 to the exchange line. The transfer circuit and local link are cleared down upon completion of the transfer.

If it should happen that the extension required for an exchange call is found to be engaged, the call is offered to him, and if accepted he is required to replace his microtelephone and wait for the re-ring, which follows automatically. Upon replying the operation is then the same as above.

The case must also be considered in which there is either no reply from the extension required for the exchange call or he does not desire to accept it. In this case the extension controlling the transfer has merely to depress his push button a second time, whereupon the transfer circuit and local link are released and the conditions then revert to those obtaining before the transfer operations were commenced.

CIRCUIT FEATURES.

Subscriber's Line Circuit and Start Circuits.

Fig. **7** shows the subscriber's line circuit and the arrangement of the start circuits for the local and exchange links. Referring to the line circuit, it will be seen that break jacks are provided to facilitate testing and maintenance. Strapping terminals, S-RS and S-AS, provide a convenient means of enabling any extension instrument to be selected for answering purposes or not as desired. Terminals S-RS are strapped on extensions that are without answering facilities, whereas the terminals S-AS are strapped in the cases of the extensions selected for answering purposes.

In regard to the start circuits, it will be seen that these are on the " chain " contact principle, allotters being dispensed with. Relay EC in the exchange

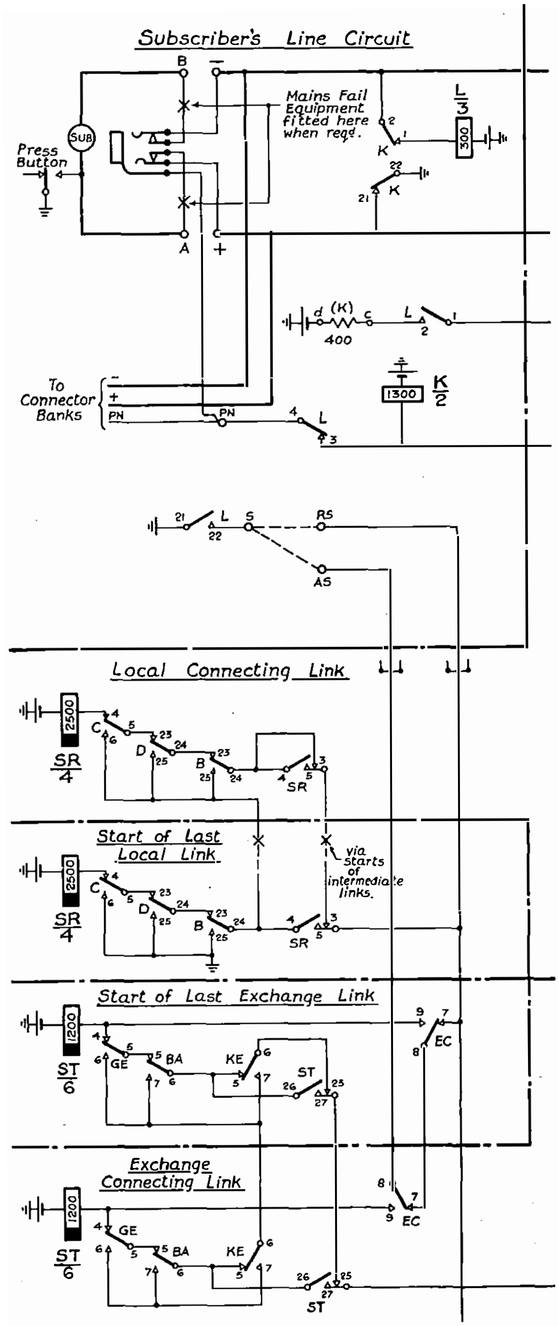


FIG. 7.—SUBSCRIBER'S LINE CIRCUIT AND START CIRCUITS.

link circuit operates upon the receipt of a call from the main exchange, thus breaking the local link start circuit, and introducing the exchange link start circuit which is completed immediately one of the selected stations lifts the microtelephone to reply.

Push Button Control Circuit.

Fig. 8 shows the two relays, LE and AE, one or the other of which is shunted down when the push button is depressed by the party initiating the transfer of an exchange call. Relay P is then caused to operate to switch the transferring party's line to the transfer circuit, and also to hold the exchange line.

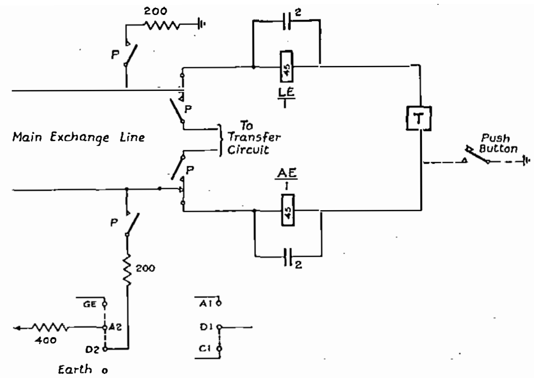


FIG. 8.—PUSH BUTTON CONTROL CIRCUIT.

If for any reason the party transferring the call requires to be re-connected to the exchange line, he again depresses the button, and this operates a relay R, not shown, which in turn clears down relay P to re-establish the connexion.

Although the King's House equipment will for the present be connected to a manual exchange, convenient strappings are provided whereby the equipment can be used on either manual or automatic exchange lines.

Mains Fail Telephone Connecting Circuit.

This is shown in Fig. 9. Relay MF is held operated so long as the supply mains and the supply from the rectifier remains intact. The normally made contacts of relay MF are connected in series with the line circuit of a selected extension (see Fig. 7). In the event of any abnormal condition arising in the supply to the equipment, any calls from the main exchange will thus be routed to the selected telephone, which can also call up the main exchange. Restoration of the supply to the equipment automatically restores the circuit to normal either immediately or at the expiry of any existing main exchange call.

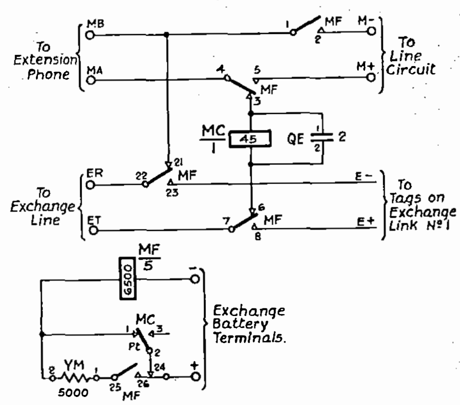


FIG. 9.—MAINS FAIL TELEPHONE CONNECTING CIRCUIT.

Power Supply Circuit.

The King's House equipment operates on 50 volts obtained from a battery eliminator of 3 amperes capacity, no batteries being required. The circuit is shown in Fig. **10**, and Fig. **11** shows the eliminator, which is mounted as a self-contained separate unit.

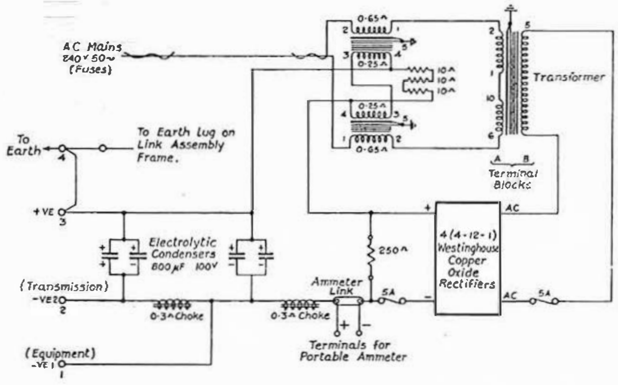


Fig. 10.—Power Supply Circuit.

Referring to Fig. **10**, it will be seen that separate leads are provided for the transmission and equipment supplies; also that a double-wound choke coil is connected in each lead on the primary side of the step down transformer. It will be observed that the secondary windings of the choke coils are connected in opposition on the output side of the rectifiers; this arrangement renders the eliminator self-regulating

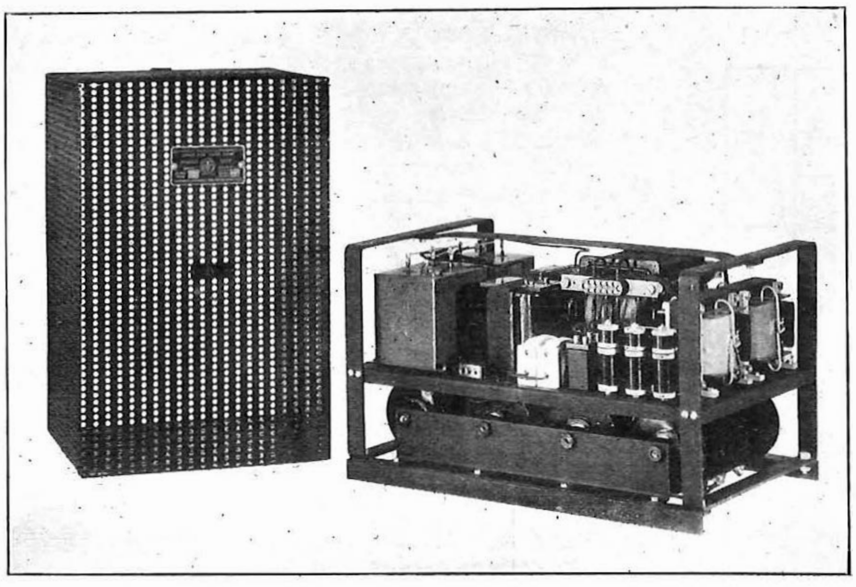


Fig. 11.—Battery Eliminator.

and ensures minimum overall variation of output voltage between zero and full load. This variation of voltage is within the limits of 45 and 53 volts.

Both the choke coils and the transformer are of the screened type, the screens and covers being earthed to minimise residual background noises.

Summary of Facilities Provided.

(1) Full automatic intercommunication between the extension instruments.

(2) Direct outgoing service to the main exchange for all or certain of the extension instruments by dialling " 9."

(3) The barring of direct outgoing service to any extension instruments.

(4) Immediate connexion with the main exchange when any of the selected answering stations lifts the microtelephone in response to the signal intimating an incoming call.

(5) Transfer of incoming and outgoing exchange calls to any other extension instrument.

(6) " Call-back " on exchange calls under push button control, the public exchange being meanwhile held automatically.

(7) Current to the extension instrument fed from the main exchange on exchange calls.

(8) Exchange line guarded until both the extension instrument and the main exchange have cleared.

(9) The trunk operator can " re-ring " any extension instrument as " on demand " working, the extension instrument and exchange line being guarded meanwhile.

(10) Standard tones, namely, dial tone, busy tone, ring-back tone and NU tone.

(11) Automatic busying of each local connecting link if the associated fuse blows.

(12) Automatic busying of the exchange connecting link and P.G. condition given to the main exchange if the associated fuse blows.

(13) Local alarm signal given if the magnet coil of a uniselector is energized for an excessive period.

(14) Circuit prepared between a certain selected extension instrument and the main exchange in the event of the current supply to the equipment failing. Exchange calls are then obtainable, and can be initiated or received by this particular instrument.

(15) N.U. tone transmitted to the caller if any spare digits, 1, 4, 5, 6, 7, 8 or 0 are dialled initially, also if any spare number is dialled.

Conclusion.

It is surely most appropriate that the presentation of the King's House—the Nation's leading home—should be the occasion for the introduction into public service of a new subscriber-attended operating principle, which it is hoped will, in due course, find extended application in industry as well as in domestic and social life with very beneficial results. The enhanced convenience and economy provided by this new type of apparatus is likely to make a very wide appeal to the owners of country houses and large residences.

The Test Desk serving Metropolitan, National and London Wall Exchanges

W. WOODCOCK and
H. L. CLAXTON

The test desk described is the largest in this country and represents a departure from previous practice in that the desk is in a room separate from the main frame and from the automatic equipment.

Introduction.

THE Telephone Exchange building at 84-89 Wood Street, London, E.C., accommodates the Metropolitan, National, and London Wall automatic exchanges together with 87 auto-manual "A" positions and 52 toll positions. The recent installation of the London Wall automatic exchange

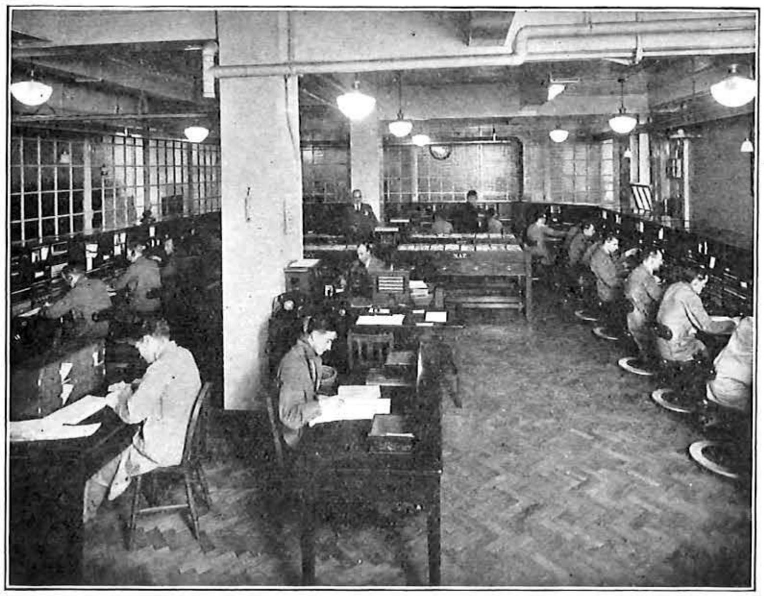


FIG. 1.—GENERAL VIEW OF TEST ROOM.

brings the total number of working subscribers' lines and junctions to 16,500 and 7,000 respectively.

It will be obvious that this amount of equipment requires a large testing staff and also an exceptional amount of testing equipment. The extension of the test desk required to deal with the additional equipment could not conveniently be installed on the same floor (2nd) as the existing desk. It was, therefore, decided to depart from the usual procedure of locating the test desk near the main distribution frame, and install a new one in a separate room (Fig. 1) on the first floor remote from any other equipment, for the combined use of the three exchanges.

This segregation of the test desk from the M.D.F. and automatic equipment is definitely an improvement in many ways, particularly as regards the working conditions for the staff since the absence of automatic apparatus in the test room reduces the noise very considerably. This is particularly important when a large amount of "ENG" traffic is dealt with, and it is, therefore, intended to adopt this scheme in large exchanges in the future wherever circumstances permit. (An article on "ENG" working has already appeared in this Journal.[1])

Arrangement and Equipment of the Desk.

The Wood Street test room, which is the largest in the British Isles, is approximately 48 ft. by 40 ft. A suite of 22 positions has been installed by Messrs. Automatic Electric Co., Ltd., and comprises :—

- 3 Junction Positions,
- 4 Advice Note Distribution Positions,
- 11 Engineering Fault Complaint Positions,
- 1 Plugging-up Position,
- 3 Fault Control Positions, and
- 17 Miscellaneous Sections.

The floor plan showing the lay-out of the desk is given in Fig. 2. It will be seen that the desk is in the form of a horseshoe, thus giving easy access to the card record cabinets which are located centrally between the stanchions.

The test positions are of the standard three-panel type and each is equipped with a test circuit, Fig. 3. The keys and lamps associated with this circuit are located in the centre panel immediately in front of the test clerk and the dial speed tester No. 43 is fitted

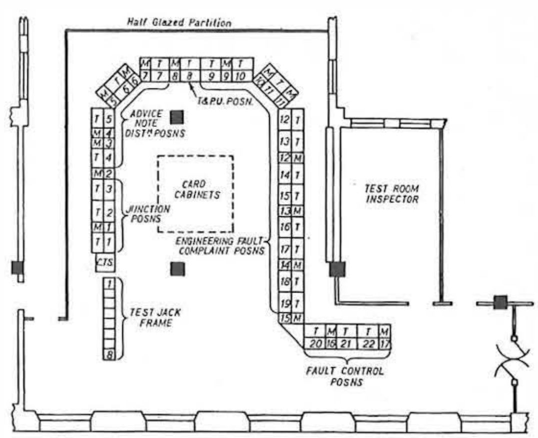


FIG. 2.—LAY-OUT.

[1] "Engineering Fault Complaint and Repair Service." H. Mortimer. *P.O.E.E.J.*, Vol. 27, July, 1934.

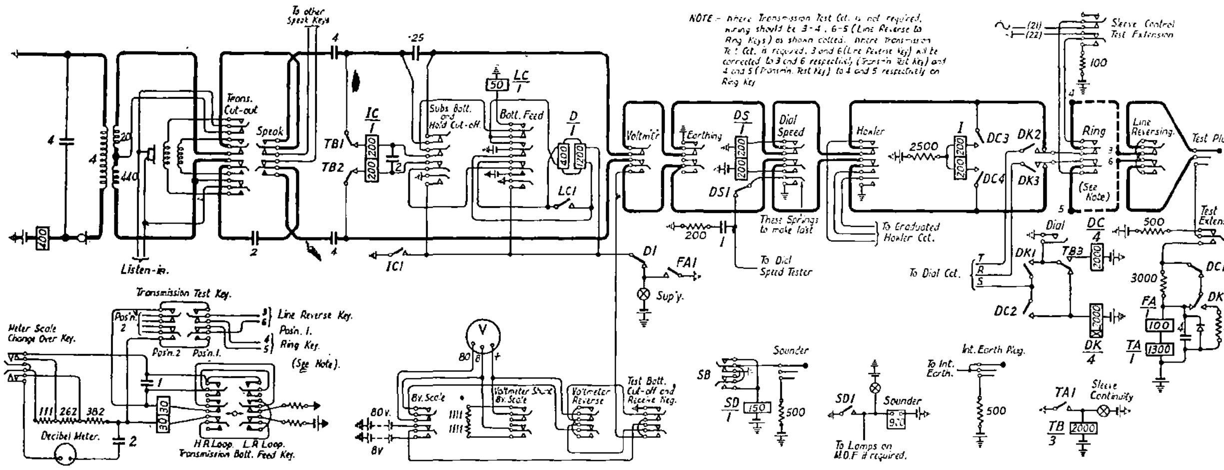


FIG. 3.—TEST CIRCUIT.

in a recess at the top of the first panel of each position. The functions of the keys in the test circuit are as follows :—

Line Reverse. Reverses the A and B lines.

Earthing. Connects earth to the A line of the circuit under test.

Voltmeter. Connects the voltmeter and 80 volt test battery to the B line and disconnects the A line.

8 *volt Scale.* Changes the scale reading of the voltmeter and the voltage of the test battery from 80 to 8.

Voltmeter Shunt. Connects a tenth shunt across the 8 volt coil of the voltmeter.

Voltmeter Reverse. Reverses the connexions of the voltmeter.

Ring. Connects generator signalling conditions to the test plug.

Howler. Connects the graduated howler (used for recalling subscriber who has not replaced receiver on the switch-hook) to the test plug.

Dial Test. Connects the dial speed tester for testing the frequency of dialled impulses.

Test Battery Cut Off and Receive Negative. Disconnects the testing battery and connects the voltmeter to the B line. One terminal of the voltmeter under this condition is earthed.

Battery Feed. Converts the normal loop conditions to a battery and earth feed *via* relays IC and LC.

Subs. Battery and Hold Cut Off. Disconnects the battery feed or loop condition whichever may be connected to the test plug.

Speak. Connects the test clerk's telephone circuit to the test plug.

Transmitter Cut Off. Connects the primary winding of a high impedance transformer to the A and B line and changes the connexions of the test clerk's receiver from the induction coil to the secondary winding of the monitoring transformer.

Dial. Connects loop dialling conditions.

Transmission Test Key. One transmission test circuit is fitted per two positions and this key is provided to switch the circuit to either position.

Transmission Battery Feed Key. Disconnects the transmission battery feed when required. When the key is thrown to position LR a dry loop condition is substituted and in the HR position a disconnexion.

Meter Scale Change Over. Changes over the scale of the decibelmeter from 5-20 db. to 0-15 db.

Test Extension. For use when testing a circuit *via* the manual board outgoing junction multiple. An extension circuit between the test desk and the manual board is used for this purpose.

Sounder. Connects the sounder relay to the A and B lines of the sounder cord. With the key normal the sounder relay is connected to the B line with an earth on the A line. This circuit is used for locating the termination of a circuit, only one end of which is known and for use in connexion with intermittent faults. When the circuit is found by means of a loop or an earth as the case may be or the fault re-appears, an audible signal is given on the sounder. Visual signals are also given on lamps which are multipled approximately every 20 ft. along both sides of the main distribution frames.

The miscellaneous sections, which are arranged to line up with the test positions, are of single panel design. One miscellaneous section serves two test positions and is therefore installed with a test position on either side, as shown on the lay-out plan (Fig. **2**).

Junction Positions.

The first three positions in the suite are wired for junction testing (one per exchange) and equipped in the standard manner, with the exception of panel No. 3 of the first position. In this panel are fitted duplicate Outgoing Junction Routiner Control keys and Fault Indicating and Access lamps, so that the routiner on the 2nd floor can still be under the control of the test room staff. The routiner has not been installed in the test room because this equipment is in constant service and the continuous operation of the uniselectors creates undesirable noise.

The junction positions deal with all types of junctions, namely, outgoing, incoming and through circuits, private wires and various miscellaneous circuits. Faults are localized and controlled, new junctions are tested, and the necessary connexions on the frames are arranged by the test clerks. Co-operation with other exchanges in carrying out their tests is also given. Each position is provided with full facilities for dealing with the various types of circuits. The outgoing junctions are tested over the extension circuits which terminate on plugs on the test jack frame, and jacks at the test positions. These circuits are provided in such a manner that each of the three junction test clerks has individual access to each of the eight bays of the test jack frame. For testing incoming junctions and miscellaneous circuits, two interception circuits are installed on each position. These circuits are terminated on jacks on the M.D.F. and are multipled along the frame to allow any particular junction to be connected to the desk. At the position end, the circuits terminate on three break jacks labelled "In," "Out," and "Intermediate." The "In" and "Out" jacks are for testing the exchange and line side of a circuit respectively, and the "Intermediate" jack permits the test clerk to tap across the circuit without causing interference to a call which may be in progress. The connexion between the junction and interception circuit is made by means of a four-way cord and plugs.

Advice Note Distribution Positions.

The next in order, after the junction positions, are four advice note distribution positions. These are arranged for advice note work connected with subscribers' lines such as Provisions, Recoveries, Removals, Area Transfers, etc. The testing officers at these positions control all these operations in conjunction with the relative external, installation, and exchange staff. They also carry out the necessary tests in accordance with the requirements of the advice notes which are received from the Traffic Department. Particulars of the work are entered on the advice notes which are passed to the record clerk who compiles the exchange records for the subscribers' circuits concerned. They are then returned to the Traffic Department.

Extension circuits to the main distribution frames known as "New Subscribers' Circuits" are installed on each of these positions for the purpose of connecting to the desk the new subscribers' lines which are to be tested. These circuits are terminated at the M.D.F. on jacks which are multipled on the line side of the frame, and connexion to the line required is made by means of two-way cords and plugs.

The circuits are arranged as follows :—

1st Position	20	Circuits	to Metropolitan Exchange M.D.F.
	10	,,	,, National-London Wall* Exchange M.D.F.
2nd Position	20	,,	,, Metropolitan Exchange M.D.F.
	10	,,	,, National-London Wall Exchange M.D.F.
3rd Position	20	,,	,, National-London Wall Exchange M.D.F.
	10	,,	,, Metropolitan Exchange M.D.F.
4th Position	20	,,	,, National-London Wall Exchange M.D.F.
	10	,,	,, Metropolitan Exchange M.D.F.

* The London Wall subscribers are accommodated on the National Exchange main distribution frame.

Each position has an associated advice note distributor section which has been modified to provide 16 horizontal pigeon-holes instead of the usual eight, in order to give a better arrangement for the filing of the advice notes while they are in the possession of the test clerk.

The advice note miscellaneous sections are equipped with the latest transmission test circuits[2] to enable the test clerks to test, in conjunction with the installation staff, the transmission efficiency of new subscribers' installations. A direct reading is obtained on the decibel-meter associated with the circuit.

[2] "Transmission Test Set for Subscribers' Instruments, Local Lines, and Exchange Apparatus." E. J. Barnes and R. W. Swift. *P.O.E.E.J.*, Vol. 27, October, 1934.

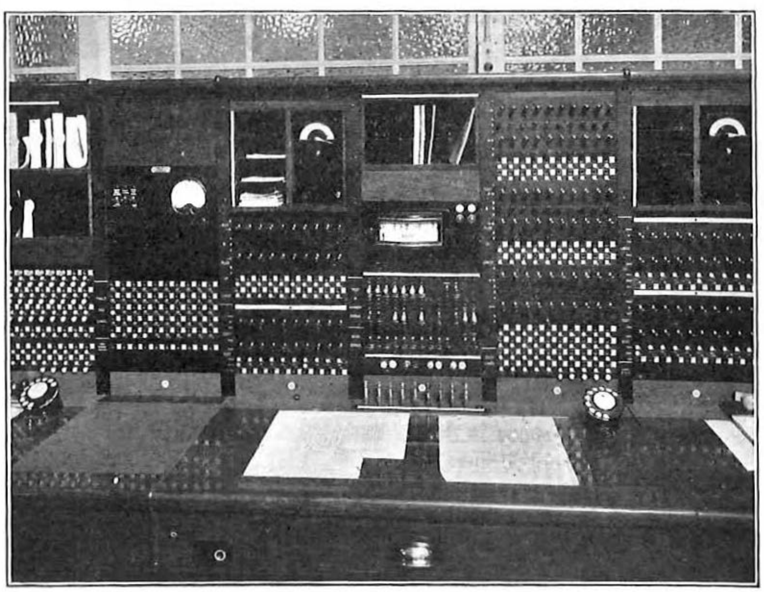


FIG. 4.—PANEL EQUIPMENT, T. AND P.U. POSITIONS.

Test and Plugging-Up Position.

It is usual for the test and plugging-up lines to be evenly distributed over all the subscribers' test positions, but when there is a large number of circuits they are concentrated on a separate position which, on this desk, is located between the advice note and " ENG " positions. The lay-out of the panel equipment is indicated in Fig. **4**.

The 80 test and plugging-up circuits fitted on this position (20 in the first Panel and 60 in the third) are common for the three exchanges, and therefore the jacks fitted on the exchange side of the main distribution frames are multipled over both frames.

Subscribers' lines which are faulty due to short-circuits, disconnexions, and earth, etc., are connected to the test and plugging-up circuits, Fig. **5**. Should a subscriber whose line is faulty be called, " Number Unobtainable " tone is transmitted to the calling party indicating that the line is out of order.

At the T. and P.U. position, keys associated with the T. and P.U. circuits are operated according to the particular fault; for example, if a line is found to be short-circuited, the key will be operated in the direction marked B (Fig. **5**). When the faulty

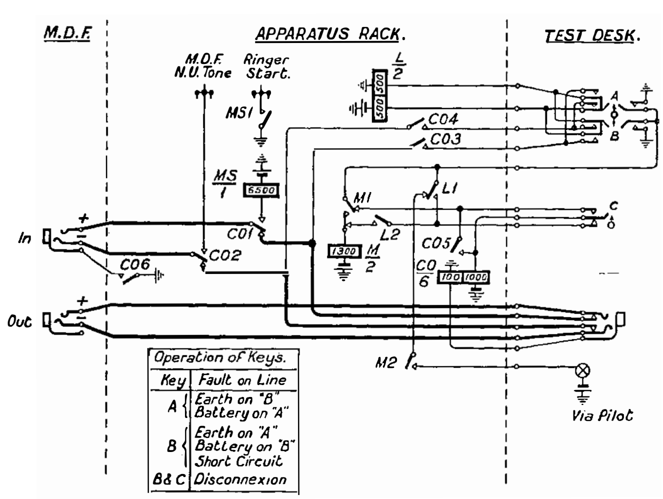


FIG. 5.—TEST AND PLUGGING-UP CIRCUIT.

circuit becomes clear the subscriber is given immediate service and, at the same time, a signal appears on the test position. The subscriber's circuit after being tested is disconnected from the T. and P.U. circuit and restored to normal working. Records are held at this position of all the circuits concerned and entries are made on subscribers' fault cards accordingly. The position is not used solely for this purpose, but also deals with ENG fault complaints.

Engineering Fault Complaint Positions.

As indicated in the title, the test clerks at these positions deal with fault complaints from subscribers and also from the auto-manual board. To obtain the attention of the test clerk, E.N.G. is dialled by the caller and the call is routed to an ENG position, particulars of the complaint are taken, and, if necessary, tests are carried out over the test distributor circuits. Full details of all complaints are recorded on the fault cards and particulars of the faults are distributed from these positions to the centres concerned by hand or by telephone.

The positions are equipped with 30 test distributor circuits, 10 of which are multipled over the remainder of the positions. On the associated miscellaneous sections are fitted the jacks and lamps for 40 ENG circuits from selector levels, and 10 circuits from the manual board. The 50 circuits are multipled over 10 miscellaneous sections, giving, if necessary, 10 appearances per calling signal. To provide the additional appearances ancillary relay equipment has been installed.

Fault Control Positions.

The test clerks at the fault control positions, which are situated at the end of the suite, control the faults localized outside the exchange and co-operate with the subscribers' apparatus staff, and external staff concerned. From these positions particulars of the faults are communicated to the faultsmen and tests of the faulty circuits made in conjunction with them. The faultsmen can get into touch with the controlling officers by means of circuits termed " Faultsmen's Lines," access to which is obtained by dialling XXA. A transmission test circuit similar to those on the advice note sections is fitted on each of the associated miscellaneous sections.

The fault card distributors fitted in the right-hand panel of these positions have been modified to provide 18 vertical pigeon-holes, making a total of 36 per position instead of the usual two sets of eight.

Test Jack Frame.

In order to prevent any serious disturbance to the traffic *via* the outgoing junctions from selector levels during the transfer of the junction test jacks from the old to the new test room, a new test jack frame of eight bays has been installed adjacent to the junction test positions (see Fig. **6**). Three bays have been allotted to each of Metropolitan and National Exchanges and two bays for London Wall.

The test jack frame, wired at present for 2,300 Metropolitan, 2,000 National, and 1,200 London Wall outgoing junctions, provides ultimately for 6,400 circuits. A rear view of the cabling is shown in Fig. **7**.

A point of interest with reference to the cabling from the jacks on the T.J.F. to the junction circuits is worthy of note. Due to the congestion of cables and jumper wire on the intermediate distribution frames, it was decided to cable the circuits direct to the outgoing junction access switch connexion strips on the access rack, and there connect to the junction circuits to the I.D.F. This method of cabling the outgoing junction circuits prevents any further congestion and, as the existing cables between the old test jack frame and both intermediate distribution frames have been recovered, jumpering facilities on these frames have been considerably improved. The arrangement is shown in Fig. **8**.

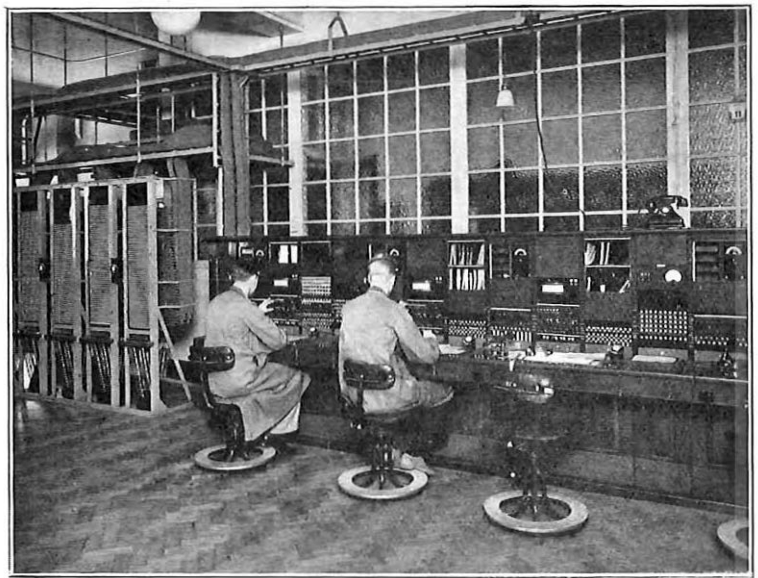


FIG. 6.—JUNCTION TEST POSITIONS SHOWING PART OF T.J.F.

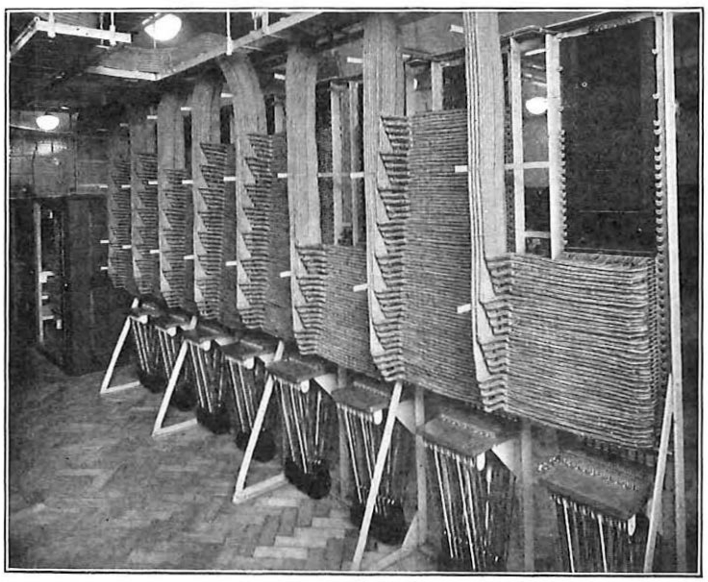


FIG. 7.—REAR VIEW OF TEST JACK FRAME.

Speaker Circuits to the Main Distribution Frames.

To enable the test clerks to get into communication with the staff working on the M.D.F's situated on the 2nd and 3rd floors, speaker circuits are being installed between the desk and the frames. At the test desk end the circuits terminate on order-wire keys which are multipled throughout the suite. By depressing a key the test clerk's telephone is connected to the circuit to the M.D.F. One circuit is provided to each frame.

On the M.D.F's the circuits terminate on telephone jacks which, with the calling lamps, are multipled every 20 ft. along both sides of the frame. Calls are

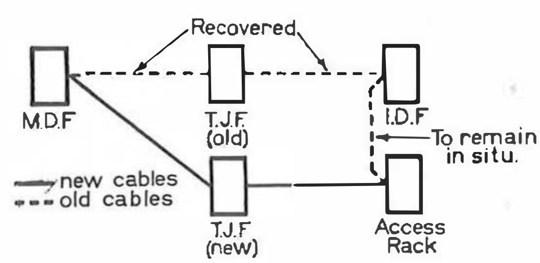


FIG. 8.—CABLING OF TEST JACK FRAME.

answered by plugging-in a hand set telephone, which causes the calling signal to be extinguished. Ringing tone is connected normally to the " B " line to give an indication to the test clerk that the circuit is disengaged. The circuit diagram is shown in Fig. 9.

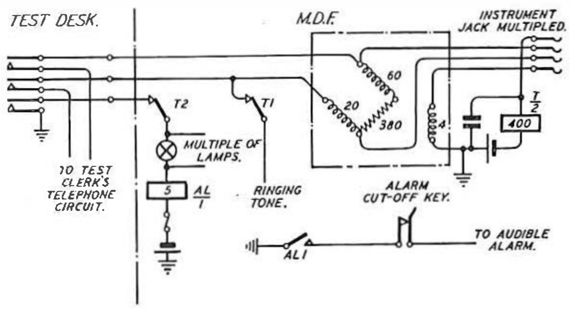


FIG. 9.—SPEAKER CIRCUIT TO M.D.F.

Voltmeters.

The voltmeters fitted on the desk are of the horizontal type which have a definite space-saving advantage.

Cabling.

The cabling of such a suite of test positions needed considerable forethought, as the normal cabling space in the lower part of the desk does not permit of a large number of cables being accommodated. The method of cabling the desk adopted is therefore of interest. A cable turning section has been installed adjacent to the first junction position, and it is here the cables serving the test positions Nos. 1-10 enter the suite. They are then divided into two groups, one group running along the bottom of the desk in the usual manner, the other along the centre in front of the cord connectors on a specially designed runway. Positions 11-22 are served by an overhead runway which enters the roof of the angle section between Positions Nos. 10 and 11 (Fig. 10). The cables are then run in the same way as those for Positions Nos. 1-10.

Ticket Tubes.

The ticket tubes for the distribution of fault dockets to the various floors of this building, which originally terminated on the second floor, have been extended to the new test room. The tubes are of the circular pressure type and employ the standard docket carrier.

Main Alarm.

The floor supervisory lamps, which are installed throughout the building, are also duplicated in the test room. These are provided in order that the staff on night duty are made aware of alarm conditions which may arise on any floor. The audible alarm can be disconnected by a key fitted on a junction test position, as it will not be required during the normal hours of duty.

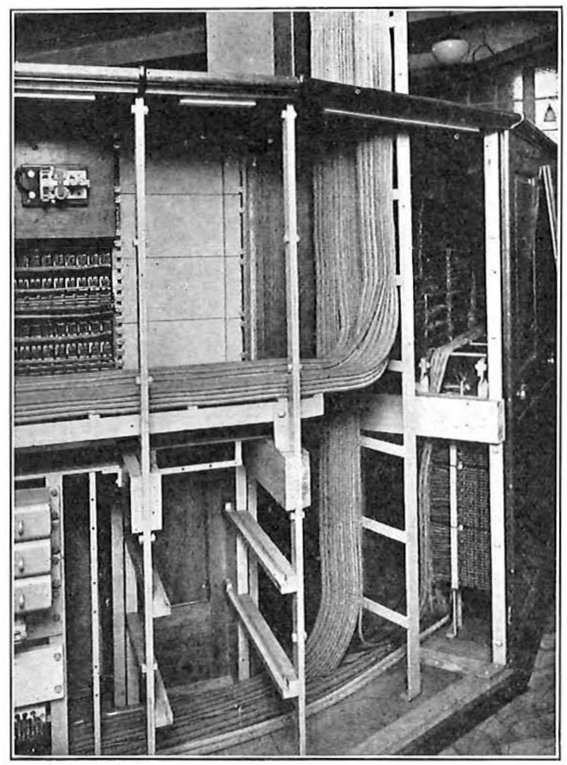


FIG. 10.—POSITION CABLING.

The Transfer.

The transfer of the working circuits from the old to the new desk was effected in a number of stages in order to avoid interference with the normal working. The junction positions were brought into service during the process of diverting the outgoing junction circuits from the old test jack frame to the new one and thus testing facilities were provided on all junction circuits during the transition period. The advice note distribution positions were opened later and the whole of the suite was brought into service on the 13th of January, 1936.

The Unit Automatic Exchange No. 13

C. G. GRANT and
A. J. C. HENK

A description is given of the U.A.X. No. 13, which has a capacity for 200 subscribers' lines and upwards of 40 junctions, and can function as a switching centre for other unit automatic exchanges. The major facilities are enumerated, the construction and equipment described and circuit details explained by means of simplified diagrams.

Introduction.

THE U.A.X. No. 13 has been designed for exchanges where the ultimate requirements will exceed the 100 lines capacity provided by the U.A.X. No. 12, but will not exceed 200 subscribers' lines.

In an article that appeared in the July, 1935, issue of this Journal the limitations of the U.A.X. No. 12 were dealt with and reasons were given why this equipment is unsuited for use as a tandem exchange or auto switching centre. The U.A.X. No. 13, however, has been so designed that it can be used as a switching centre for one or more unit auto or small manual exchanges.

Facilities and General.

Numbering Scheme. A 3-digit numbering scheme is used for subscribers' numbers, the initial digits of which are either 2 or 3 giving a multiple range of 200 to 399. The multiple range of 200 to 299 can be made available on the installation of the first 50 line unit. P.B.X. facilities (2 to 10 lines) are provided throughout the multiple.

On referring to the typical trunking diagram shown in Fig. 1, it will be seen that in the U.A.X. No. 13 both group and final selectors are employed. The group selector is normally arranged with its first level spare and levels 2 and 3 connected to final selectors. Of the remaining levels, 0 and 9 are used for the route to the parent exchange leaving levels 4 to 8 available for routes to adjacent exchanges.

The trunking scheme does not follow the lines of that used on the U.A.X. No. 12 with one rank of 200 outlet selectors arranged to absorb the initial subscribers' digits 2 and 3, because on such a scheme each outgoing junction uses an outlet on the selector multiple and as the U.A.X. No. 13 will have to cater for upwards of 40 junctions the resulting reduction in the multiple numbers available for subscribers' lines would seriously affect the capacity of the exchange.

The adopted trunking scheme for the U.A.X. No. 13 makes it possible to provide for a maximum of six groups of outgoing junctions without loss to the subscribers' multiple. With such a trunking scheme it would be possible to increase the size of the subscribers' multiple above 200 lines by the use of additional ranks of final selectors connected, for example, to levels 4 and 5, but it has been decided that exchanges above 200 lines could best be served by the introduction of a larger type of unit equipment, the U.A.X. No. 14, which will be described in a later article.

The U.A.X. No. 13 provides all the facilities that are given on the U.A.X. No. 12 and as these were dealt with at some length in the previous article it is proposed only to deal with the additional facilities provided by U.A.X. No. 13 equipment.

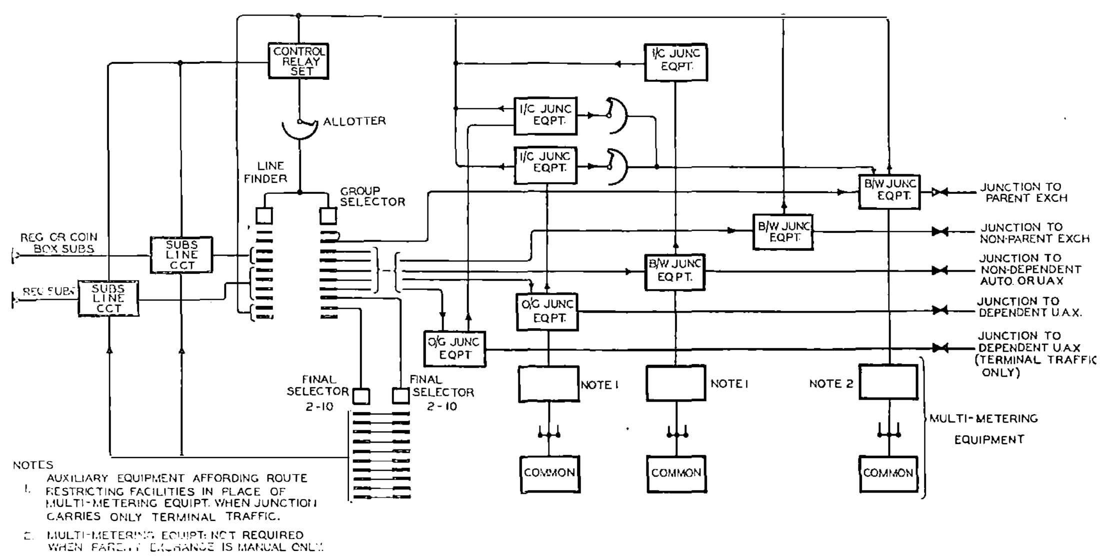


FIG. 1.—TYPICAL TRUNKING DIAGRAM.

Tandem Working.

The U.A.X. No. 13 has been designed so that it can act as a tandem exchange or auto switching centre for other small exchanges of either manual or unit auto type. When an adjacent unit auto exchange makes use of the U.A.X. No. 13 for routing its calls to a parent exchange the adjacent exchange is considered as being dependent on the U.A.X. No. 13. Arrangements are therefore made so that both ordinary subscribers and coin box users on the dependent exchange can obtain access to the parent exchange manual board by dialling 0 once only, the appropriate calling lamp being lit on the manual board. This entails the use of a hunter switch at the tandem exchange associated with the incoming junction equipment from the dependent exchange. When the digit 0 is dialled at a dependent exchange the 0 level signalling conditions are passed over the junction to the U.A.X. No. 13 tandem exchange and cause the uniselector associated with the incoming equipment to hunt for a free junction to the parent exchange. These arrangements are shown schematically in Fig. **2**.

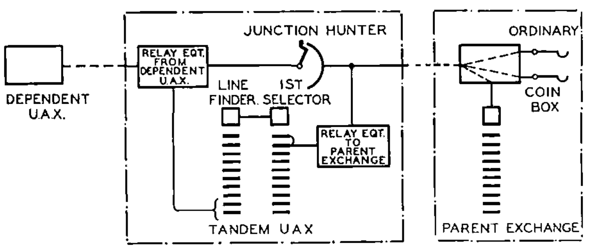


FIG. 2.—ROUTING OF 9 AND 0 LEVEL CALLS VIA TANDEM U.A.X.

When a subscriber on the dependent exchange dials the digit 9 he will be switched *via* the line finder to a group selector at the tandem exchange and will become virtually in the position of a subscriber on that exchange. He can then either dial a subscriber on the tandem exchange or obtain access to the parent exchange auto equipment by dialling a further digit 9. The relaying of calls to the parent exchange by the dialling of a single digit, only occurs when that digit is 0.

Multi-Metering.

The multi-metering equipment will, in general, follow on the lines of that used for the U.A.X. No. 12. As, however, the U.A.X. No. 13 can act as a switching centre for other small exchanges it is necessary that the multi-metering should be rendered inoperative on calls dialled by operators at nearby manual exchanges, in order that these operators should not be restricted in their routing of calls by the multi-metering equipment. Calls originated by subscribers on nearby auto exchanges will be controlled by the multi-metering equipment at the originating exchange and therefore the absence of any restriction at the U.A.X. No. 13 will not matter.

The unbarring of the multi-metering equipment is achieved by passing a positive battery discriminating signal from the incoming junction equipment *via* the line finder and group selector to the outgoing junction equipment where it effects circuit changes in the multi-metering equipment. These circuit changes affect only the metering and barring facilities as the equipment is still required to enable manual hold to be given on calls to manual boards.

Route Restricting Equipment.

When all calls passed over a route are to be assigned the same fee, it would appear that there is no need for a discriminating form of multi-metering equipment, but, for example, on routes outgoing to a dependent exchange it may be necessary to ensure that all traffic terminates at that exchange; firstly, in order to prevent a subscriber at the tandem exchange dialling back over another junction in the group to his own exchange; and, secondly, because it may not be permissible to use the dependent exchange as a switching centre even though it has routes to other exchanges. In order to provide these facilities in an economic manner a simplified form of multi-metering equipment known as a " Route-restricting " equipment has been developed.

The circuit is arranged to discriminate after the first digit dialled over the junction and to return N.U. tone if the digit is other than " 0 " or the first digit of a subscribers' number at the dependent exchange. The reason for unbarring " 0 " is to allow an operator at the parent exchange to routine the junctions by dialling into a dependent U.A.X. *via* the U.A.X. No. 13 and then back to the manual board.

This route restricting equipment is arranged not to respond to the unbarring signal from any incoming junctions, as it is required that the barring feature of this equipment should always be effective.

Traffic Incoming to the U.A.X.

With the U.A.X. No. 13 type of equipment the junctions will usually be in small groups worked on a both-way basis. The cost of terminating such junctions on individual selectors cannot be justified as the traffic carried per circuit is usually low, therefore the junction terminating equipment is joined to the banks of line finders of the two-motion type. As, however, the groups of junctions on the U.A.X. No. 13 are usually larger than those on the U.A.X. No. 12, both the hunting time at the originating exchange and the finding time at the U.A.X. No. 13 will be greater. Therefore, in order to avoid the danger of calls being lost due to the receipt of a digit before a group selector is connected to the junction, a pre-dial path is provided *via* the line finder allotter circuit. The allotter is arranged to be preselecting, so that it is normally connected to a free line finder and group selector. When the line finder finds the junction the impulsing is received over the normal circuit and the allotter is released.

CONSTRUCTION AND EQUIPMENT DETAILS.

Provision of Units.

The Unit Automatic Exchange No. 13 can be built up in unit form as the exchange area develops, and a complete 200 line exchange consists of the following units :—

4	Units Auto	No. 13A	(50 Line Units).
	,, ,,	No. 13B	(Junction Units, added as required).
1	,, ,,	No. 13C	(MDF, IDF, and common apparatus).

The units which are 8′ 3″ in height are normally arranged in two suites, as shown in Fig. 3.

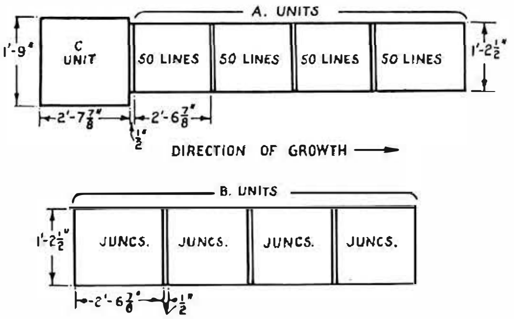


FIG. 3.—NORMAL EQUIPMENT LAY-OUT.

The two suites are arranged with the apparatus sides facing each other, and are interconnected by a sealed cable run.

General Construction.

The units are constructed of mild steel framework and sheet steel cavity cabinets, and the doors are clamped against fabric covered rubber cord, thus making the units reasonably airtight.

When the units are being lined up, the hardwood covers fitted over the cable holes in the C unit are removed and fitted over the cable holes in the non-growing end of the A and B units.

The aperture of each cable hole is lined with fabric covered rubber cord and a wooden gasket is placed between each pair of units and rests on this cord. After the units have been secured by the main bolts, the gasket is drawn tight on the fabric covered rubber cord by means of smaller bolts, an airtight joint being thus obtained. The sealed cable trough between the B and C unit is also secured by bolts.

The rack framework of each unit is constructed of 2″ × 2″ × 0.3125″ mild steel angles which are securely fastened to the interior of the cabinet. To ensure rigidity the top and bottom horizontal members are welded to the vertical members.

The selectors and relay sets are mounted on cradles which are secured to shelves of rolled steel channel section 2′ 4¾″ in length. In the A unit, brackets are fitted at intervals at the rear of the shelves for supporting the strips connexion, wiring forms and cables.

Apparatus Details.

The Post Office standard "2000" type equipment[1] is used for all two-motion selectors and jacked-in relay sets. The "600" type relay[2] is used for the subscribers' line circuits (L, K and P relays), all other relays are of the "3000" type,[3] and the meters are type 100 and 101.

Six of the circuits have been accommodated in the units on a jacked-in basis as follows :—

1. (*a*) Tone and Time Pulse Equipment—Relay Set No. 2/3409.
   (*b*) Ringing and Meter Pulse Equipment—Relay Set No. 2/3411.
2. Line Finder Selector—Selector No. 2/3161.
3. Control Relay Set—Relay Set No. 2/3410.
4. Group Selector—Selector No. 2/3163.
5. Final Selector (P.B.X. 2 to 10 lines)—Selector No. 2/3162.
6. Multi-Metering Common Equipment—Relay Set No. 2/3418.

The prefix figure "2" quoted in the codes indicate that these assemblies are of the "2000" type.

The multi-metering equipment has been accommodated on a strip-mounted basis similar to the scheme adopted for the junction units as described later under Unit Auto No. 13B.

On both the multi-metering assemblies a cross connexion field is provided to arrange for metering conditions. As with similar equipments in the U.A.X. No. 12 this is done by means of strappings on a single sided strip connexion which also terminates the bank connexions of the uniselector involved.

Unit Auto No. 13C. (Figs. 4 and 5).

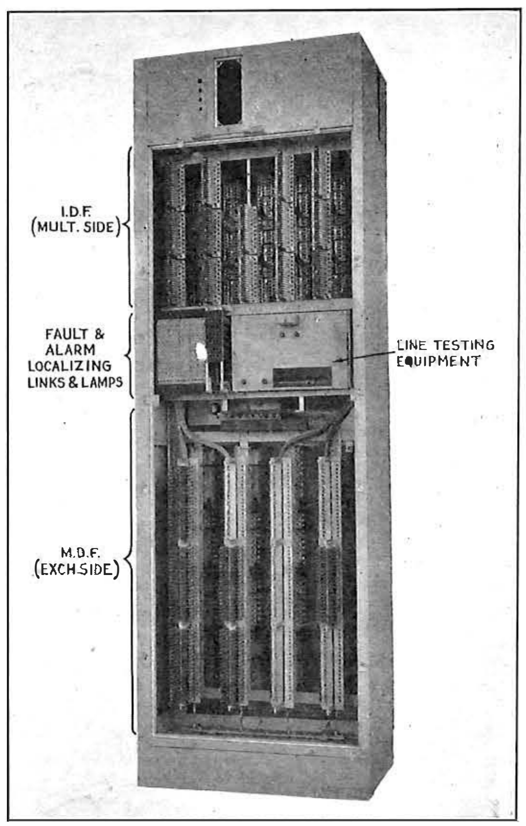


FIG. 4.—C UNIT. FRONT VIEW.

This unit accommodates the MDF, IDF, alarm localizing and line testing equipment, and relay sets

[1] "The Post Office 2000 Type Selector, its Development and Mechanical Details" and "The Post Office 2000 Type Selector, Mounting and Cabling Arrangements." Messrs. J. S. Young and W. H. Diack. *P.O.E.E. Journal*, Vol. 28, p. 257, Jan., 1936.

[2] "The Post Office 600 Type Relay." C. W. Clack. *P.O.E.E.J.*, Vol. 28, p. 293.

[3] "The Post Office 3000 Type Relay." R. W. Palmer. *P.O.E.E.J.*, Vol. 27, p. 46.

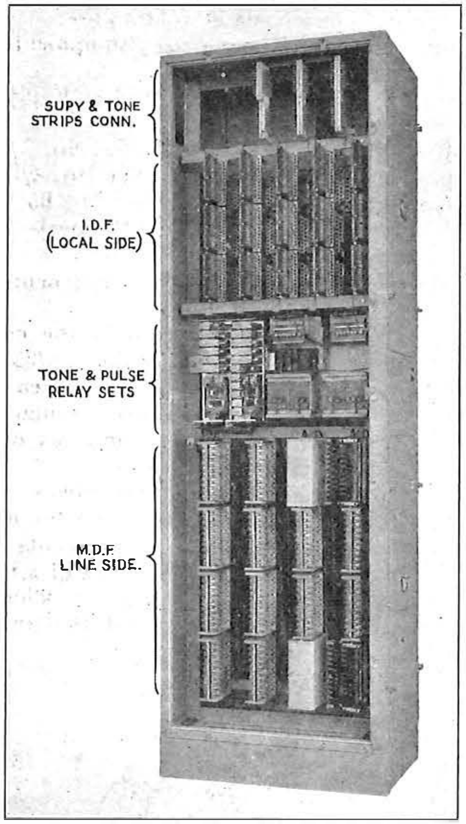


FIG. 5.—C UNIT. REAR VIEW.

containing the common apparatus, *i.e.*, ringing, tone, time pulse and meter pulse equipment.

The enclosed type of MDF for U.A.X's was first used in the U.A.X. No. 12 and a similar arrangement has been used. In addition, the IDF has also been accommodated in this unit, thus giving a combined M and IDF scheme which eliminates many of the disadvantages which occur when the IDF is mounted in the top of each unit.

An ultimate capacity for 12 protectors, heat coil and test and 16 fuse mountings is provided.

The alarm localizing and line testing equipment is fitted immediately above the protectors. The provision of the alarm localizing equipment is a novel feature and is designed to eliminate the following disadvantages of fault testing experienced in Unit Automatic Exchanges Nos. 5, 6 and 12 :—

(*a*) When the test number is dialled and the fault indicating tone is received, the maintenance officer on his arrival at the exchange has to remove the doors of each unit, and examine each fuse or piece of apparatus until the fault is located.

(*b*) To localize a fault on a common service, *i.e.*, tone, etc., it is often necessary to disconnect the lead on each miscellaneous strip connexion to locate the unit on which the fault exists.

(*c*) It is necessary for the officer to dial the test number before leaving the exchange to ascertain that no faults of an urgent nature exist.

In the U.A.X. No. 13, however, a visual fault localizing arrangement is provided for fuse alarm, PG alarm and release alarm. The fault indicating lamps are suitably designated and mounted directly behind a Rhodoid " window " fitted in the upper front door of this unit, and are visible when the door is in position.

In order to localize the fault to any particular unit, a press-button mounted on the left hand side and external to the " C " unit, is depressed. This lights the lamp on the faulty circuit, which indicates both the type of fault, and on which unit it exists. It is only necessary, therefore, to remove the doors of the unit on which the fault is localized, and at the same time the maintenance officer knows on which group of apparatus the fault exists.

The maintenance officer need only depress the press-button and inspect the lamp group before leaving the exchange to ascertain if any faults of an urgent nature exist. The arrangement of the lamps is shown in Fig. 6.

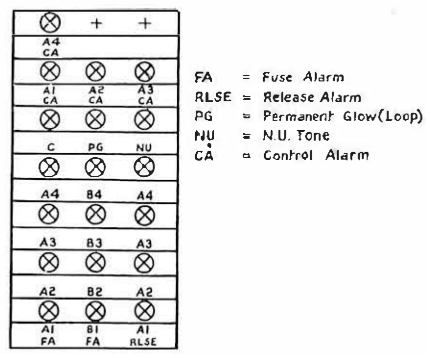


FIG. 6.—FAULT INDICATING LAMPS.

For the common services a group of " U " links is provided on a basis of one link per common service per unit, and two links per A unit for PG alarm. The links are fitted adjacent to the lamp group. A fault can, therefore, be localized to a particular unit by removal of " U " links.

Another novel feature incorporated in the U.A.X. No. 13 is the method of application of number unobtainable tone to faulty or T.O.S. lines. In previous types of U.A.X's, the N.U. tone is applied to these lines on the final selector multiple strips connexion by means of wire straps, which necessitate soldering. In the U.A.X. No. 13, however, the N.U. tone is applied to faulty or T.O.S. lines on the Protector H.C. and T No. 40B by means of plugs and cords. The application of tone is therefore simplified and obviates the necessity for soldering, with a consequent saving in time.

The IDF is mounted at the top of the unit immediately above the testing equipment, the multiple and local sides being at the front and rear of the unit respectively. Capacity for fourteen 6 × 20 and fifteen 8 × 25 strips connexion is provided on the multiple and local sides respectively. The strips connexion are mounted in 5 vertical rows of 3 on both the multiple and local sides, and are arranged as far as possible to give a straight jumpering scheme. In addition, the strips connexion (2 × 9) on which the alarms, tone, etc., are terminated, are mounted at the top of the local side.

Two 6-way fuse panels, one for positive and one for negative battery supply, are fitted at the rear of the unit. The positive battery is fed to the junction equipment in each B unit, and to the routine test jacks in the A units.

A distribution point for the main negative battery consisting of two copper busbars, one for the supply and one for the return, is fitted at the top left hand side of the unit. Ten cable lugs, two per unit and two for the main supply, are fitted to each busbar and the battery supply and return is distributed to each unit from this point.

The construction of the bottom of the cabinet of this unit is similar to that of the Auxiliary Unit in the U.A.X. No. 12. The unit has six doors, fitted one at the top and one at the bottom at the front, rear, and left hand side (viewed from the front). In addition, the front and rear door stiles are removable. The top doors give access to the IDF, alarm localizing, line testing equipment, and relay sets, and the bottom front and rear doors cover the protectors and fuse mountings. The top left hand side door gives access to the 1st vertical of the multiple and local sides of the IDF and the common battery and earth distribution busbars, the bottom door serving the 1st vertical of the protectors and fuse mountings.

There are two entrances in this unit for the main cable run, one at the top right hand side for the run to the A units, and one at the top front for the run to the B units. Both of these entrances are covered by a hardwood cover prior to installation. The cables between this unit and the 1st B unit are accommodated in a sealed cable trough of sheet steel cavity construction. To facilitate cabling, a removable door is fitted in the trough.

Mounted on the cabinet above the bottom left hand door, but external to the unit, is a combined telephone mounting bracket and writing desk.

Unit Auto No. 13A. (Figs. **7** and **8**).

This unit accommodates the subscribers' line relays, meters, allotters, control relay sets, line finders, group selectors and final selectors.

The unit framework has been designed on the lines of the main exchange racks, *i.e.*, single sided, the apparatus being mounted at the front, the strips connexion, wiring and cabling being at the rear.

There are seven shelves which are labelled A-G inclusive, from the bottom shelf upwards.

Provision is made on the shelves to mount the following apparatus :—

Shelf A. Subscribers' Line Circuits, Linefinder Overflow and Group Start Relays, and Allotters.
Shelf B. 3 Linefinders and 2 Control Relay sets.
Shelf C. 5 Linefinders.

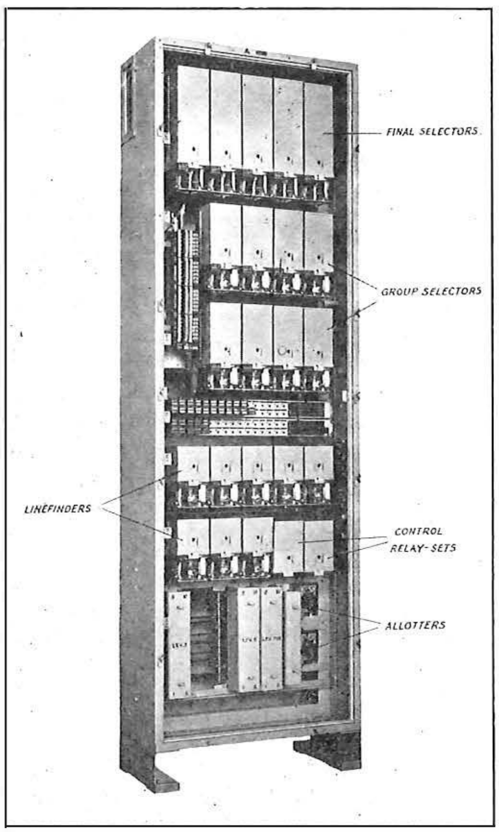


Fig. 7.—A Unit. Front View.

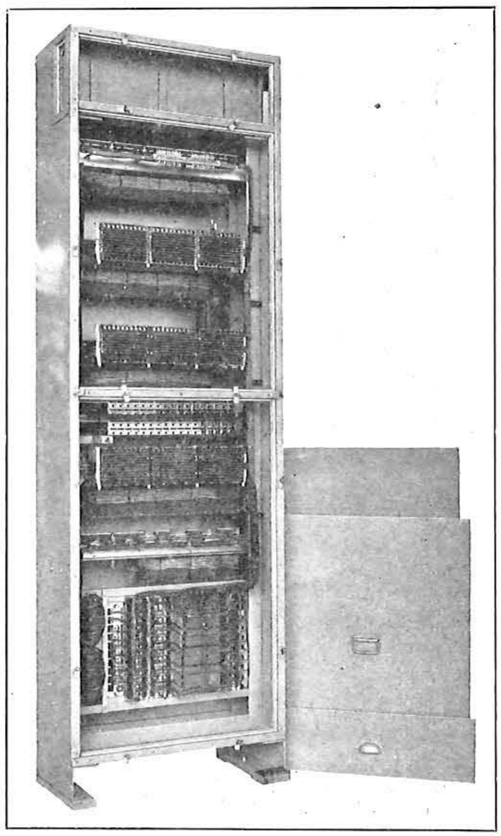


Fig. 8.—A Unit. Rear View.

Shelf D. Subscribers' Meters, Traffic Meters, and Meter Test Jacks.

Shelves E & F. 4 Group Selectors on each.

Shelf G. 5 Final Selectors.

Fuse panels are mounted on the left hand vertical, and the miscellaneous apparatus, routine test keys, lamps, etc., are mounted on the right hand vertical. Battery jacks are provided three per unit mounted two at the front and one at the rear.

The cable run is a separate sealed compartment accommodated in the top rear of the unit, the entrance for cables being through two holes provided at the bottom of the run, one at each end of the unit. When the cables are in position the holes are sealed with compound No. 5. A hole is provided in each side of the unit at the top to give a clear cable run throughout the suite when the units are in position.

Each unit is fitted with five doors, one at the top and one at the bottom at the front, giving access to the apparatus, one at the top rear giving access to the cable run and two lower doors at the rear screening the strips connexion, rack wiring and cabling. The front and rear doors stiles are removable.

Unit Auto No. 13B. (Fig. 9).

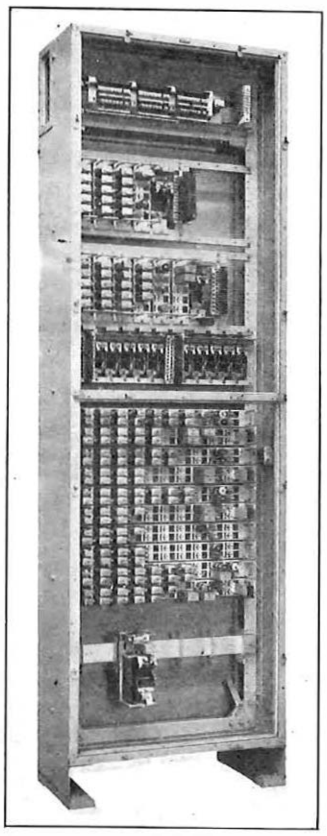


Fig. 9.—B Unit.

This unit accommodates the junction equipment and, when required, the common multi-metering relay sets.

The construction of the cabinet is identical with that of unit A, having the same type of sealed cable run and the same number of doors.

In the U.A.X. No. 12 the multi-metering and junction circuits are provided in the form of jacked-in relay sets. In the case of the U.A.X. No. 13, however, a more economic and flexible arrangement has been employed by strip mounting the junction circuit apparatus, the complete item being known as " Junction Terminating Sets and Auxiliary Sets." These consist of one or more standard flanged type mounting plates on which the apparatus is mounted, and the local wiring is terminated on a strip connexion also fitted on the plate. When the amount of apparatus involved necessitates the use of more than one of the flanged type mountings, the two or more plates required are bolted together to form one complete assembly. Test jacks are fitted for maintenance purposes, and one of the covers, which are provided on the basis of one per mounting plate, has an aperture to give access to the test jack assembly.

The terminating and auxiliary sets are wired so that a minimum of plate to plate wiring is involved, and protection has been provided where it is necessary for groups of wires to cross the edges of the plates, by the insertion of fabric covered rubber cord. This is kept in position by the cover locating lugs on the sides of the mounting plates. The standard plate wiring scheme has also been employed, *i.e.*, point to point wiring, using " cotopa " wire with loose ties. A view of a typical junction terminating set is given in Fig. 10. The rack uprights are universally drilled

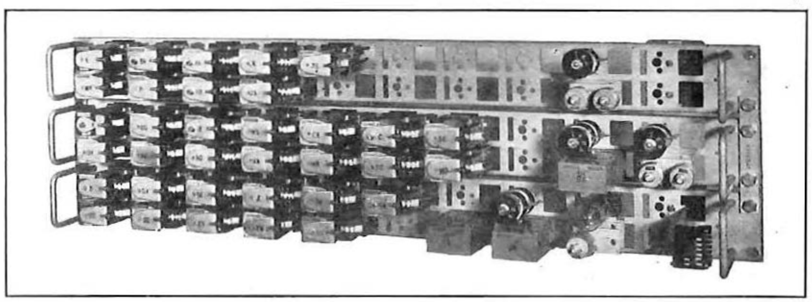


Fig. 10.—Typical Junction Terminating Equipment.

and the junction terminating and auxiliary sets are bolted to the uprights as required, the direction of growth being in an upward direction as on standard main exchange racks. The junction terminating and auxiliary sets are not supplied with the unit, but are ordered and fitted as required.

The unit when received on site will consist of cabinet, framework, fuse mountings, fuse alarm relay, strips connexion and battery jacks only. The fuse mountings, fuse alarm relay and strips connexion are mounted at the top front of the unit framework, and the battery jacks are mounted two at front and one at rear.

An ultimate capacity for three 6-way fuse mountings has been provided, but only two are equipped initially, the third being added when required.

When common multi-metering relay sets are required, they are provided on the basis of one for every B unit installed, but for convenience of mounting they are mounted on the 1st B unit of the suite. These relay sets are similar in construction to those utilized for the U.A.X. No. 12. Accommodation is provided by a rolled steel channel section which can be fitted in this unit, near the bottom, using existing drillings in the uprights.

Cabling and Wiring.

In U.A.X's No. 12, as a precaution against low insulation faults due to dampness, enamelled braided cable is used (Cable E & FP), which experience shows has the following disadvantages :—

A large overall diameter.

Limited range in number of conductors.

Braiding too loose.

Difficulty in soldering due to the enamel and untinned conductors.

Insulation not beeswaxed.

A new type of cable, similar to that used in a tropical climate has been introduced for U.A.X. No. 13. This cable, which is called " Cable Switchboard Enamelled," has the same braiding, overall diameter and range of conductors as the switchboard cable used in main exchanges. The conductors are tinned and enamelled, and the cable core is beeswaxed.

As a further precaution against low insulation faults, the conductors in all the wiring forms internal to the units, with the exception of the selector multiple banks, are enamelled. The conductors in the MDF and IDF Jumpers are also enamelled.

Typical cabling arrangements are shown in Fig. **11**.

The protector side of the MDF is cabled to the IDF multiple before the unit leaves the factory. The IDF ends of the cables are terminated on strips connexion, but at the MDF end six cables only (120 circuits) are terminated on the six Protectors H.C. and Test provided. The skinners of the remaining six cables (– ve and + ve conductors) are passed through the associated holes in the fanning strips, and held taut by being wrapped round a length of wire, which is stretched vertically down the MDF verticals and secured to the protector mounting details. The P conductor is terminated on the associated spring of the Jack Test No. **4**.

Power Plant.

The power plant equipment is similar to that of the U.A.X. No. 12 except that a larger type of cell is used for the battery.

A battery of 39 cells Leclanché D.S.6 provides the positive battery supply.

Building and Site.

The building is of the Post Office Standard Type " B " and incorporates cavity walls to guard against temperature variation.

The internal dimensions are as follows :—

Width	10′ 6″
Length	19′ 0″
Clear height	8′ 11″

Under exceptional circumstances, an extended " A " Type building can be utilized which has a width of 7′ 7″ with a 15′ 6″ extension, making an overall length of 29′ 6″.

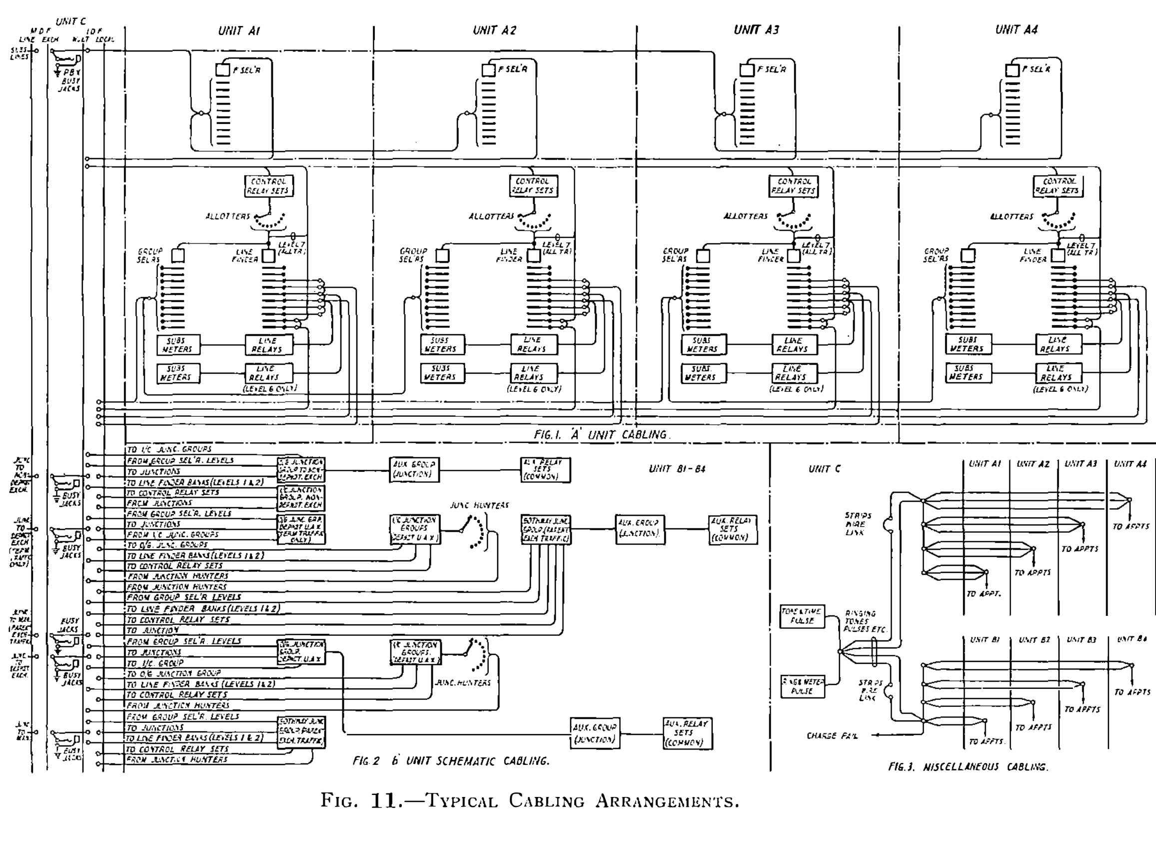


FIG. **11**.—TYPICAL CABLING ARRANGEMENTS.

Three classes of buildings are available—brick, stone and the " flooded area " type. The latter is of brick construction with the floor raised to cater for a flood line two feet above ground level.

Fig. **12** shows the exchange lay-out using the " B " Type building.

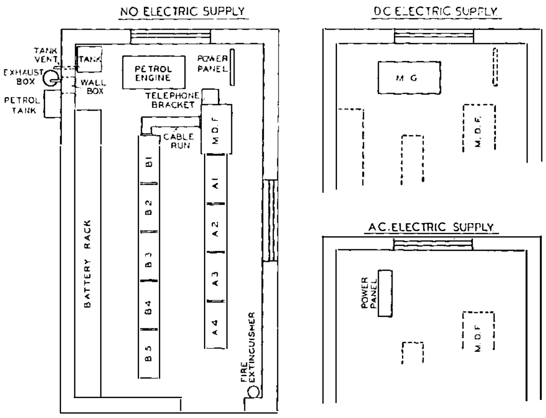


FIG. 12.—LAY-OUT USING B TYPE BUILDING.

Fig. **13** shows the exchange lay-out using the extended " A " Type building.

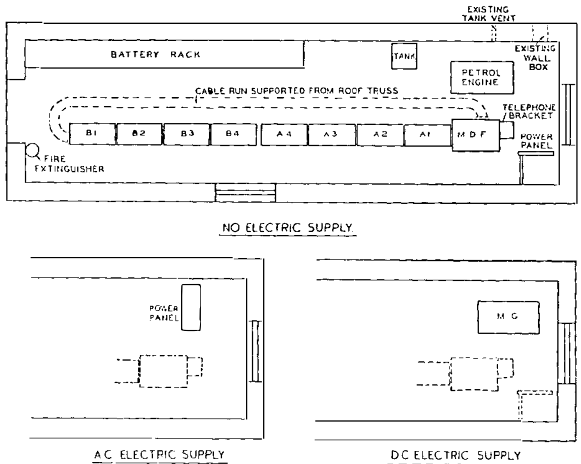


FIG. 13.—LAY-OUT USING EXTENDED A TYPE BUILDING.

A typical site has a width of 20′ with a depth of 60′ behind the building line. This length caters for an " A " Type building (as used for the U.A.X. No. 12) and a " B " Type building, being placed end to end, and also provides sufficient space for the provision of soakaways, a call office, a footpath to the door and clearance for the pole or underground lead in.

CIRCUIT NOTES.

It is not proposed to describe the circuits in detail, but to deal with the main differences between these and the U.A.X. No. 12 circuits.

Subscribers' Line Circuit.

This circuit is similar to the U.A.X. No. 12 circuit except that some re-arrangement has been necessitated owing to the use of a two-motion line finder. Additional contacts on relay L are required for level marking, and the arrangement by which when the line finder switches, relay P is operated, followed by the subsequent operation of K, has obviated the need for a slow acting relay L. Relay L is, therefore, not provided with a 5.5 ohm short circuited winding. Additional contacts of relays K and P are used to provide for PG localization.

Line Finder and Allotter.

As the circuit principles of a two-motion line finder are now well known, full circuit details are not given, but Fig. **14** shows in schematic form the novel features of the U.A.X. No. 13 line finder.

Coin Box Lines. Ten of the subscribers' circuits on each unit can be used for either ordinary or coin box lines. These ten lines are multiplied on both levels **7** and 8 of the line finder and the method of obtaining the coin box discrimination is to connect the level marking contact of relay L of coin box lines to level 8, and the level marking contact of ordinary lines to level **7**. Normal post springs are arranged on the line finder to close only on the 8th level and this enables a battery signal to be passed forward to the first selector when the call is from a coin box user. This signal can be used in the first selector to bar dialling out routes on certain levels, or on other levels it can be passed on to the junction relay equipment. In the junction relay equipment it is used, when " 0 " is dialled, to set up the appropriate junction signalling conditions so that the coin box lamp is lit on the manual board or, on an auto call, it effects barring of all calls over unit fee and, in certain cases (*e.g.*, phonograms) it bars unit fee calls. It is also used to bar coin box users access to manual boards other than that obtained by dialling " 0."

The Pre-dial Path. Another feature of the line finder circuit is the pre-dial path. The allotter circuit which is normally connected to a pre-selected line finder and first selector, provides a path for impulsing as shown schematically in Fig. **14**. When, however, the line finder finds the junction equipment the impulsing is received by the switch over the normal circuit and the allotter is released. It will be noted that the chances of calls being lost is still further reduced by arranging the junction equipments so that they have a choice of two allotters. Further, the connexion of the junctions to levels 1 and 2 of the line finders ensures that should a junction and local call originate simultaneously, the junction call will take precedence.

The 100 Outlet Group Selector.

As stated previously the U.A.X. No. 13 embodies the new standard 2000 type selector, and therefore its circuits will as far as possible follow the circuit principles being developed for new standard exchanges, details of which are given in another article in this issue.

The main features of the circuit are given in Fig. **15** which shows the vertical marking bank connexions, the battery testing relay that cuts the rotary drive circuit, and the time pulse release circuit.

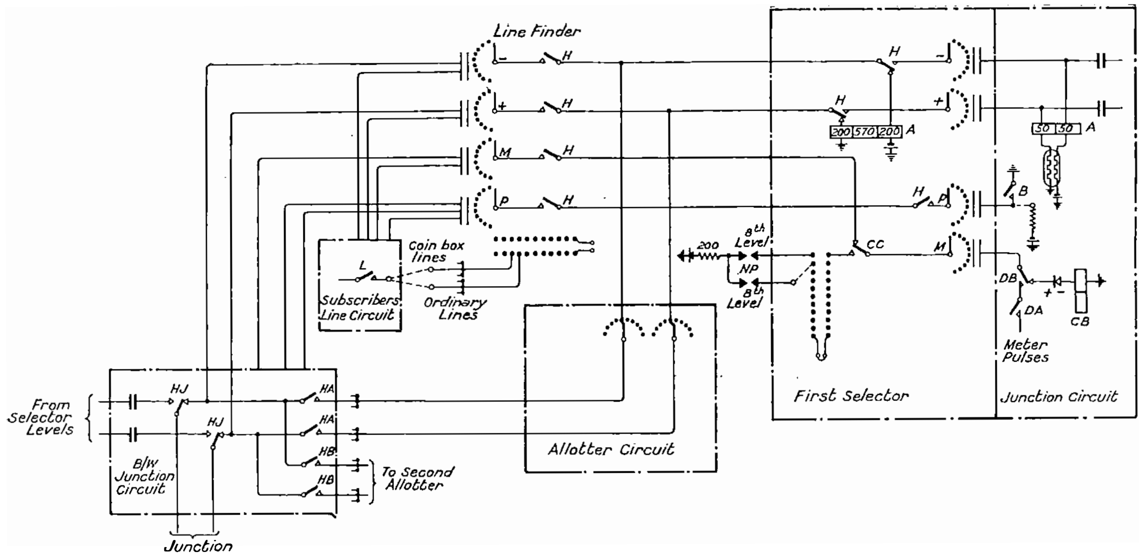


FIG. 14.—LINE FINDER SCHEMATIC DIAGRAM.

The Vertical Marking Bank. The cross connexions of this are used primarily for the purpose of applying N.U. tone on spare levels and for giving N.U. tone to coin box users attempting to dial a barred route. Under these conditions relay CC is held operated and a contact of CC applies N.U. tone to the line. Typical cross-connexions of the vertical marking bank are shown in Fig. **15**, the levels being allocated as follows :—

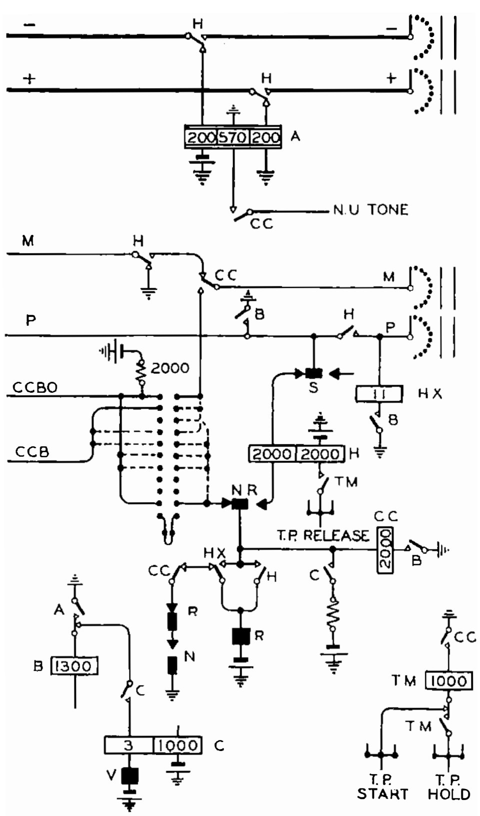


FIG. 15.—GROUP SELECTOR, CIRCUIT ELEMENTS.

Level 1 spare.
,, 2 } to final selectors.
,, 3 }
,, 4 } spare.
,, 5 }
,, 6 route to auto exchange barred to coin box users.
,, 7 route to auto exchange permitted to coin box users.
,, 8 route to manual exchange barred to coin box users.
,, 9 route to parent auto exchange.
,, 0 route to parent manual exchange.

The Testing and Drive Cutting Circuit. After the switch has been stepped to the required level relays C and CC release and a contact of CC completes the rotary drive circuit. The switch now self drives round the bank until relay HX operates to the testing battery in a disengaged circuit ahead. The operation of HX cuts the drive circuit and operates relay H in series with the R magnet, and contacts of H switch through the negative, positive, M and P wires.

The Time Pulse Release Circuit. This circuit is provided so that the selector cannot be unduly held under P.G. or N.U. tone conditions, release occurring after a period of approximately 1 to 5 minutes. The initial pulse from the common equipment operates relay TM and the release pulse operates relay H on its second winding thus effecting the release of the selector by releasing relays A, B, etc.

The 100 Outlet Final Selector (2-10 P.B.X.).

It will be noted, on referring to Fig. **16**, that this selector contains the transmission bridge and that use is made of a ballast resistance on the called subscriber's side of the bridge. The transmission advantages gained by the use of ballast resistances are fully described in the July, 1933, issue of this Journal.

Among the special features of this circuit is the

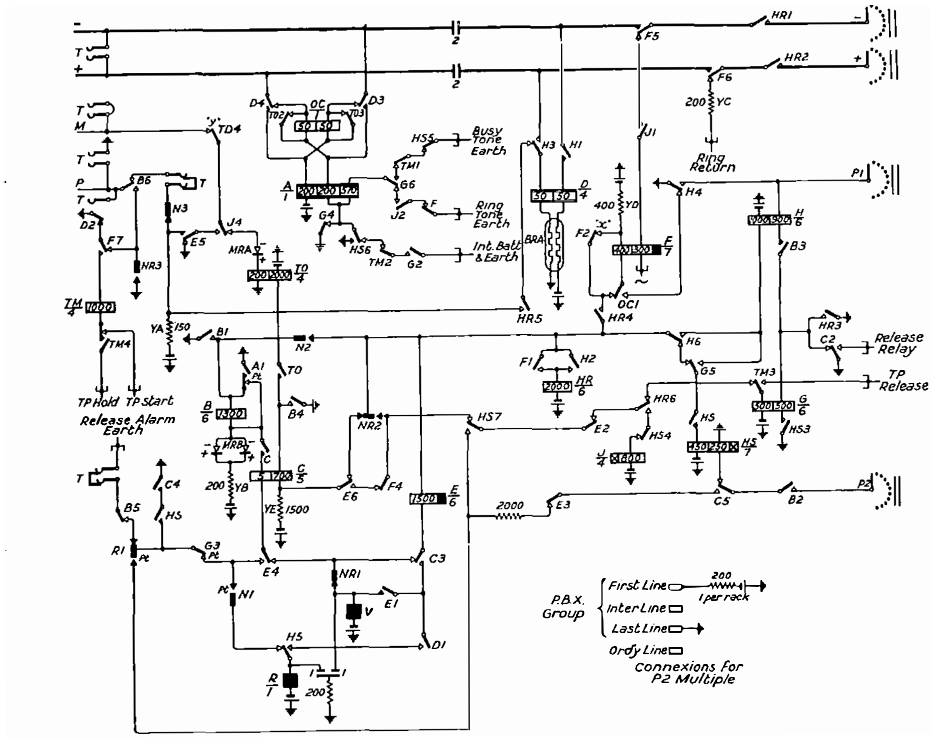


FIG. 16.—2-10 P.B.X. FINAL SELECTOR CIRCUIT.

trunk offering facility which is obtained by the operation of relay OC. This relay is so connected that the normal loop current fed *via* relay A does not operate the relay, but the earthing of the loop at the calling exchange causes an out-of-balance in the current in the two OC windings so that relay OC operates. As a precaution against the possible mis-operation of this relay by a faulty subscriber's line, relay OC is normally short-circuited by contacts TO 2 and 3, arrangements being made so that relay TO only operates on calls from the parent exchange. The parent exchange incoming junction equipment is arranged to pass forward a positive signalling current over the M wire which operates relay TO *via* the metal rectifier MRA, this metal rectifier being used to prevent relay TO operating to a negative battery.

On this " 2000 " type of selector P.B.X. marking is achieved by use of one of the normal multiple banks and not by means of an additional P.B.X. arc as is used on the U.A.X. No. 12 equipment. The necessary marking of the first and last lines of a P.B.X. group is shown in Fig. **16.** The first line in a group is marked by a 200 ohm battery and the last line by an earth while the intermediate lines are left unmarked. Ordinary single lines are also left unmarked.

This circuit is provided with forced release conditions so that the selector cannot be unduly held under CSH conditions, release occurring after a period of approximately one to five minutes.

Junction Relay Equipment.

Whereas in the U.A.X. No. 12 only one type of relay set is used on all types of junction routes, it has been found more economical on the U.A.X. No. 13 equipment to introduce the following types :

(1) A bothway equipment (AT 3943) to be used to parent manual and auto-manual exchanges and on routes to manual non-parent exchanges.

(2) An outgoing equipment (AT 3949) to non-dependent U.A.X's or auto exchanges together with an incoming equipment (AT 3946) which can be combined with the outgoing equipment for bothway working.

(3) An outgoing equipment (AT 3947) to a dependent U.A.X. and an outgoing equipment (AT 3948) to a dependent U.A.X. at which all traffic terminates. These two equipments may be combined with an incoming equipment (AT 3945) to form bothway circuits.

In addition there is the multi-metering equipment (AT 3950) with its associated common equipment (AT 3944) which is used on any of the above routes when working to an auto exchange at which all traffic does not terminate, and a route restricting equipment (AT 3951) for use on routes to auto exchanges at which all traffic terminates.

The relay equipment used on the route to the parent exchange is the most complicated and Fig. **17** gives the circuit in a simplified form, showing the most important features which are briefly as follows :

Combined use of one Group of Junctions for " 9 " and " 0 " Calls. This facility was provided on the U.A.X. No. 12 equipment and is given in a similar manner on this equipment by the operation of relays WS, WA and WR etc. on " 0 " level calls.

The Unbarring Signal. This signal is a positive battery passed forward *via* the line finder and 1st selector over the M wire which causes relay DS to operate in the multi-metering equipment. This multi-metering equipment is similar to that used on the U.A.X. No. 12 equipment, but is provided with additional discriminating leads, two of which are shown in the diagram as " barred manual " and " barred auto " respectively.

When access to a manual exchange is barred to U.A.X. No. 13 subscribers but is allowed to operators or subscribers on other auto exchanges, the discriminating contact on the MM switch is connected to the " barred manual " contact instead of to the spare code tag. On a call originated by a local subscriber relay DS is normal and therefore relay EF operates and the circuit functions as for a spare code. On an incoming junction call, however, relay DS is operated and therefore relay MC operates in place of

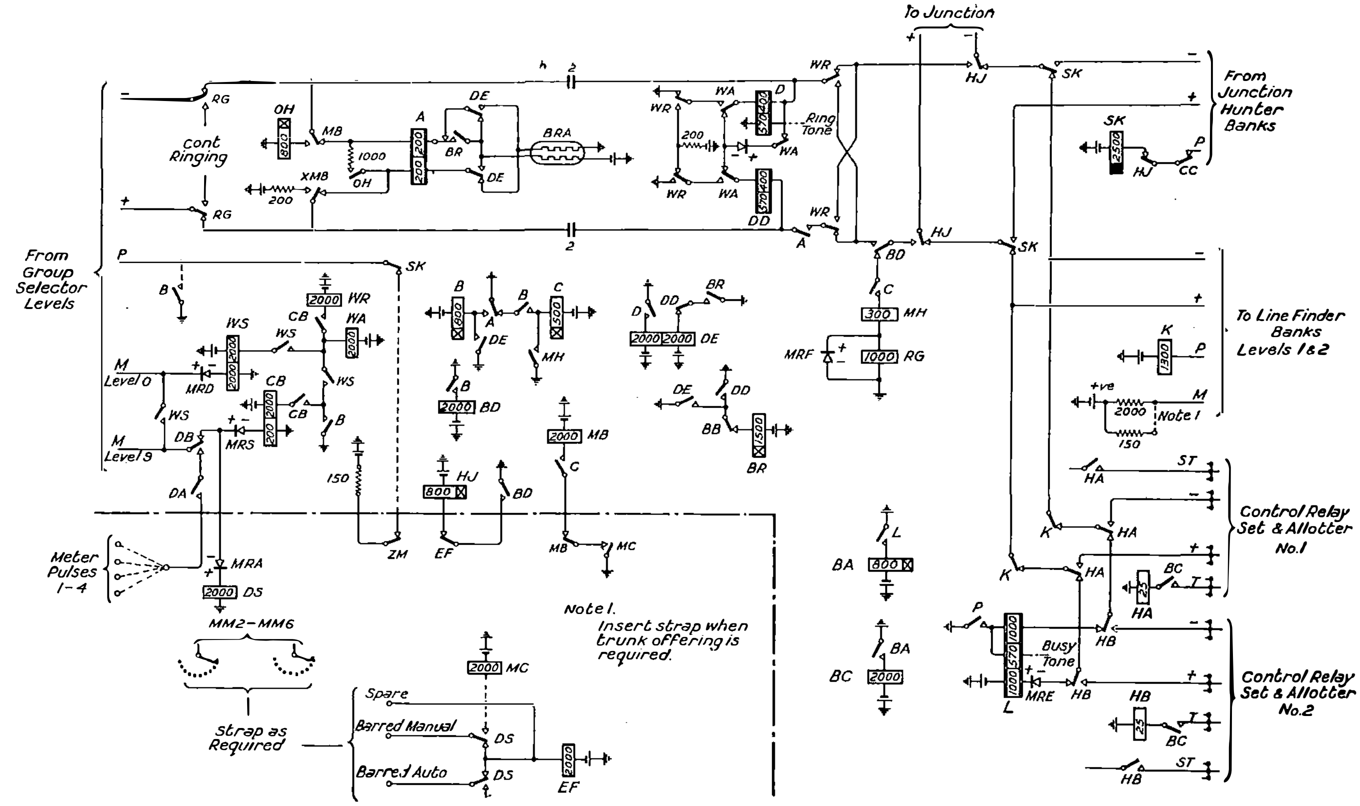


FIG. 17.—SCHEMATIC DIAGRAM OF B/W JUNCTION RELAY EQUIPMENT TO PARENT AUTO EXCHANGE.

relay EF and a contact of MC provides the operating circuit for the MB relay, the functions of which are described under manual hold.

A discriminating lead is provided for giving operators or subscribers on other auto exchanges access to auto exchanges which are barred to local subscribers. The unbarring of an incoming junction call is effected by the disconnexion of this "barred auto" lead from relay EF by the operation of relay DS.

Manual Hold. As the U.A.X. No. 13 can be used as a tandem exchange, it is necessary to provide for the relaying back of manual hold to U.A.X's that dial to manual boards *via* this tandem exchange. If the subscriber attempts to release the connexion relays A, B and BD release in turn and C operates connecting the MH relay to the positive line. Relay MH operates to battery returned over the positive line and a contact of MH holds relay C. Relay MB is operated by a contact of C and contacts of MB disconnect relay A and connect relay OH to the negative line and send back a manual hold battery over the positive line. When the subscriber re-lifts his receiver the junction is re-looped at the originating exchange and relay OH is operated. A contact of OH re-operates A which in turn re-operates relays B and BD and releases relays MH, C and MB.

Junction Hunter. In the Section on tandem working it was shown schematically in Fig. **2** how a hunter switch is required to give access to the parent junction when an **0** level call is originated at a dependent exchange, and the connexions of this hunter switch are shown at the top right hand of Fig. **17**. When the junction is free the relay set and junction can be seized by the searching hunter and relay SK operated. Contacts of SK switch through the lines and also engage the private incoming from the group selector level. When the junction is engaged contacts of either relay CC or HJ engage the hunter private.

Incoming Calls : the Pre-dial Path. On an incoming call relay L is operated which in turn operates relays BA and BC, contacts of BC applying relays HA and HB to the test wires of the two allotter control circuits. If both allotters are free, relay HA switches in preference to HB and completes the start circuit and at the same time switches through the lines. Relays ST, LK and VR in the control set then operate and so complete the pre-dial path. When the line finder finds the calling junction relay K is operated and the pre-dial path is broken down.

Ringing Tone and Time Pulse Equipment.

This equipment is very similar to that used on the U.A.X. No. 12, but the larger size of the U.A.X. No. 13 has necessitated the provision of two ringing feeds for odd and even final selectors and of NU tone circuits for each of the four units. Other differences exist owing to the introduction of balanced tones on the U.A.X. No. 13 equipment.

Conclusion.

In conclusion, the authors desire to thank Messrs. Automatic Electric Company, Ltd., for the photographs and to thank various members of the Engineer-in-Chief's Office staff who supplied information useful in the compiling of this article.

The Carrier System No. 3

N. W. LEWIS, Ph.D. (Eng.), A.M.I.E.E.

Details of a three channel carrier telephone system for open wire lines, and the necessary line characteristics are briefly given, and the place of the system in the trunk network of the British Post Office is discussed.

Introduction.

CARRIER System No. 3 is now the official designation of the three channel carrier telephone equipment intended for use with open wire lines, and designed and manufactured by Messrs. Standard Telephones and Cables, Ltd. In Fig. 1 is shown a general view of a set of terminal equipment, complete with the exception of power plant. The purpose of this article is to describe briefly the principles of the system and to indicate its place in the trunk network of the country.

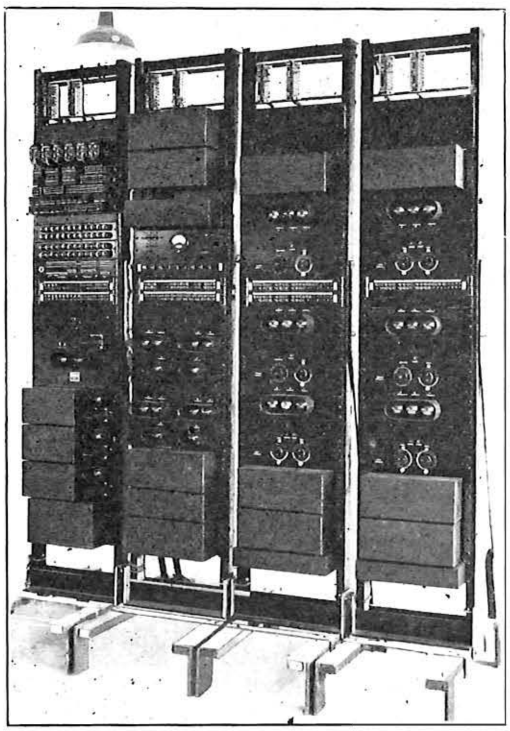


FIG. 1.—TERMINAL EQUIPMENT.

On an open wire line consisting of a suitable pair of wires, the system enables three two-way speech channels to be superimposed without appreciably affecting the physical, or voice channel. Each carrier channel is the equivalent of a 4-wire circuit, in that the *go* and *return* paths are virtually separate except at the terminations. Each may be lined up to an overall transmission equivalent of 3 db. although the voice channel possibly may have a much higher equivalent.

Signalling over the carrier channels is necessarily on a voice frequency basis, and the terminal equipment includes ringer units, which convert generator signals into voice frequency signals and *vice versa.* From an operating standpoint, therefore, the carrier channels may be worked on a generator signalling basis. Signalling over the voice channel is practically unaffected by the system and may be either of the D.C. or generator type.

Application.

In the more sparsely populated parts of Great Britain, particularly in Scotland and Wales, there are a number of trunk pole routes which are now approaching the limit of their wire carrying capacity, but which cannot yet economically be relieved by underground cables. Also, there are routes on which additional circuits are urgently required but on which it would be uneconomical to erect more wires because cable relief is expected in a comparatively short time.

The primary function of Carrier System No. 3 is to afford temporary relief on such routes and form an economical alternative to the two other methods of circuit provision, the underground cable with large idle plant loss in the early years, and open wires with wastage of the labour of erection after a short period of use.

The cost of the terminal equipment, however, is such that the use of a system on one route for several years is only justifiable on a few of the longest routes now remaining in the country. It is therefore clear that although carrier systems of this type may have a large field of permanent application on long open wire lines in other countries, they must be regarded in this country merely as temporary expedients for bridging an awkward gap.

It is intended that the system shall generally be installed in a temporary manner, and that as soon as the purpose of each has been fulfilled it shall be as rapidly as possible dismantled and re-installed on another route in need of relief. In order to facilitate these shifts, special attention has been given to the design of the equipment. For example, a height of 8′ 6″ has been decided upon for the apparatus racks, so that accommodation difficulties will not arise due to necessity for high-ceilinged rooms, and where two systems are to be installed initially at one place each system is being made complete in itself so that its future allocation may be unhampered.

Location.

Two systems have been in operation between Bristol and Plymouth since December, 1935, and a system of an earlier type has been worked between Belfast and Dublin in co-operation with the Irish Free State since the end of 1934.

Further systems are being installed during 1936 for service initially between the following places :—

Aberdeen-Kyle of Lochalsh.
Aberdeen-Wick.

Aberystwyth-Newtown.
Aberystwyth-Swansea.
Bangor-Holyhead.
Belfast-Dublin.
Belfast-Enniskillen.
Belfast-Omagh.
Birmingham-Machynlleth.
Birmingham-Newtown.
Campbeltown-Glasgow.
Cardiff-Llandrindod Wells.
Fort William-Glasgow.
Fort William-Inverness.
Fort William-Oban.
Glasgow-Oban.
Llandrindod Wells-Swansea.
London-Wisbech.
Nottingham-Spalding.
Nottingham-Wisbech.

Description.

As in most modern carrier systems the single side-band, suppressed-carrier method of transmission is employed, with different frequency bands for the *go* and *return* sides of each channel.

Three types of system are made, known by Messrs. Standard Telephones and Cables as CN4, CS 4, and CT 4 respectively. They are identical in general design and construction, and differ only in the frequencies of certain of their carriers and bands. In the following table are given the carrier frequencies of the two types, CS 4 and CT 4, that will be used by the Department.

System.	Channel.	Direction A to B.		Direction B to A.	
		Carrier.	Side-band.	Carrier.	Side-band.
		kc.p.s.		kc.p.s.	
CS 4	1	12.9	Upper	24.4	Lower
	2	9.4	,,	20.7	,,
	3	6.3	,,	28.5	,,
		kc.p.s.		kc.p.s.	
CT 4	1	12.9	Upper	23.7	Upper
	2	9.4	,,	19.8	,,
	3	6.3	,,	27.7	,,

Either type of system may be used alone, but one of each type is employed when two systems are required on one pole route.

The three bands allocated for transmission in the direction B to A on the CS 4 system are staggered in frequency with respect to the corresponding bands of the CT 4 system, for the reason given later under "Line Requirements."

It will be observed, taking the width of a side-band as roughly 3 kc.p.s., that transmission in the direction A to B requires approximately the band of frequencies from 6 to 16 kc.p.s., and in the direction B to A approximately 16 to 30 kc.p.s.

The following is a brief description of the operation of the system. A more complete explanation will be found in another article[1] in this Journal.

A block schematic diagram of the system is given in Fig. 2. Speech from the exchange on carrier

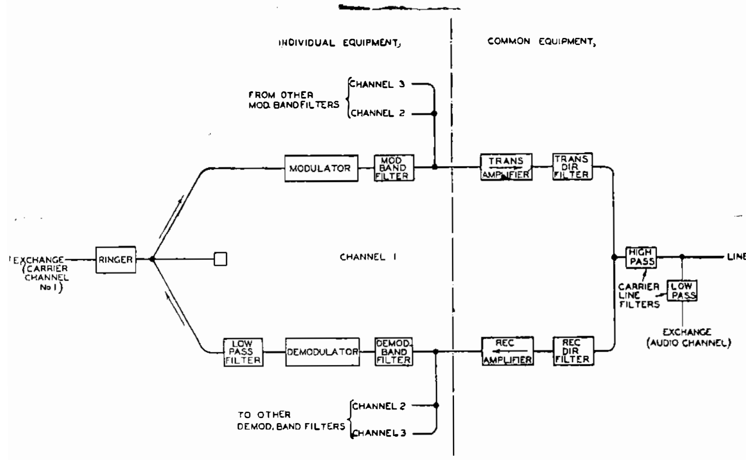


FIG. 2.—SCHEMATIC DIAGRAM OF SYSTEM.

channel 1 passes through the ringer and differential transformer to the modulator, which is of the Carson type employing a push-pull arrangement of two valves as a modulating element and a third valve as an oscillator for generating the appropriate carrier frequency. The output from the modulator contains the two main side-bands together with other products of the process of modulation. The associated modulator band filter rejects, however, all except the side-band required, which passes to the common transmitting amplifier. This is a two-stage push-pull amplifier employing six valves, each half of the output stage having two valves in parallel in order to obtain sufficient power-handling capacity to amplify simultaneously the side-bands from the three channels.

The transmitting and receiving directional filters form a complementary pair for separating the frequency bands allocated to the two directions of transmission, and have a common cut-off frequency of about 16 kc.p.s. At the A terminal the transmitting and receiving filters are of low-pass and high-pass types respectively; at the B terminal they are the reverse.

The carrier line filters also form a complementary pair and serve to separate the six carrier bands from the voice band. The common cut-off frequency is approximately 5.5 kc.p.s., so that the band-width of the voice channel is sufficient to allow of music transmission in an emergency.

The output from the transmitting amplifier passes through the transmitting directional filter to the line, being rejected by both the receiving directional filter and the carrier line low-pass filter. In the other direction, the carrier bands received from the distant terminal pass through the receiving directional filter to the common receiving amplifier, which in design is similar to the transmitting amplifier. The amplifier output is applied to the three demodulator band filters in parallel. The side-band of channel 1 is selected by the filter shown in the diagram and passes to the demodulator, which is a three valve

[1] "Carrier Telephony II." G. J. S. Little.

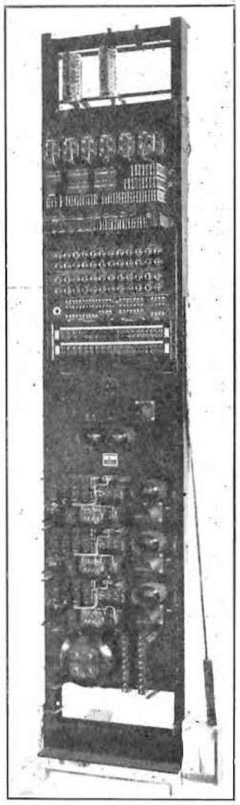


FIG. 3.—APPARATUS BAY.

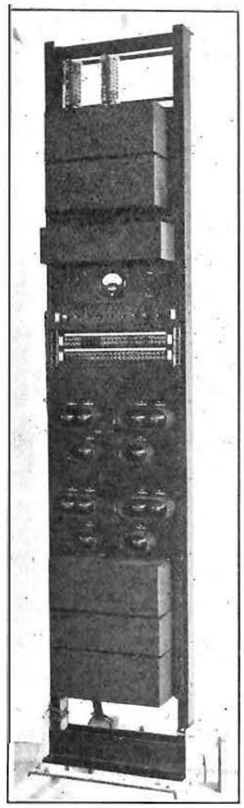


FIG. 5.—1ST CHANNEL BAY.

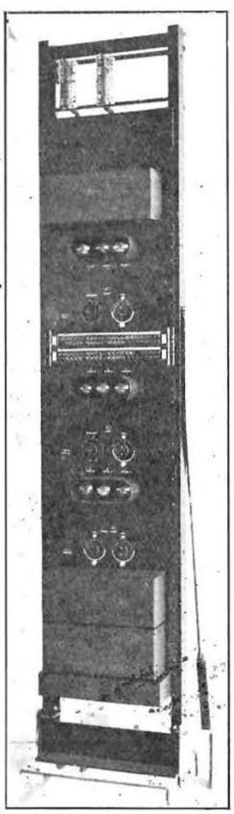


FIG. 4.—AMPLIFIER BAY.

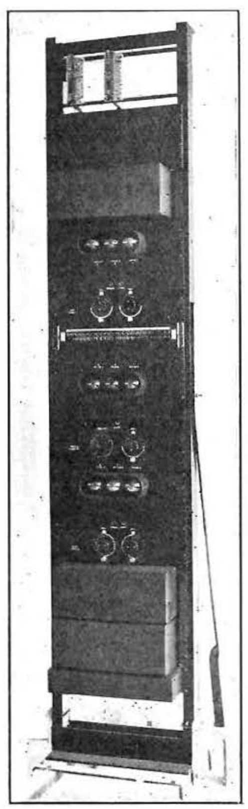


FIG. 6.—2ND CHANNEL BAY.

device very similar to the modulator. When the appropriate carrier frequency is re-introduced by the oscillator valve, the demodulator output includes among other products of demodulation the voice frequency band corresponding to the speech from the distant terminal. This band is allowed by the low-pass filter to pass on through the differential transformer and ringer to the exchange.

For signalling over carrier channels it is essential to employ frequencies in the speech range, so that the signals may pass through the various stages of modulation, demodulation, and filtration in the same way as speech. The ringer unit is similar in principle to the 500/20 c.p.s. system used on repeatered circuits. The 17 c.p.s. ringing signal from the exchange is intercepted by the unit, which sends into the channel a voice frequency signal consisting of a 1000 c.p.s. tone interrupted at 17 c.p.s. The tone is supplied by a common two-valve oscillator and interrupted by means of a vibrating relay. In the other direction, a 1000/17 c.p.s. signal received from the channel causes, through the medium of a valve rectifier, a 17 c.p.s. signal to be sent to the exchange. The frequency of 1000 c.p.s. was chosen in order that advantage could be taken of the staggering of the carrier frequencies to reduce ringing crosstalk between two systems working on the same pole route.

The apparatus is assembled on panels of the standard 19″ width mounted on bays 8′ 6″ in height. The complete terminal equipment consists of a rack of four bays, the layout of each of which is shown in Figs. **3**, **4**, **5**, and **6** respectively.

The equipment requires the repeater station type of power supply, *viz.*, 24-volt. for the filaments and 130-volt. for the anode circuits. For offices in which only D.C. supply mains are available the power plant will consist of ordinary double battery charge-discharge arrangements, but where A.C. mains are available single batteries floated across special rectifiers will be provided.

Line Requirements.

The main requirements concerning lines used for carrier working may be summed up under two heads, attenuation and crosstalk. Although the former is always the primary consideration, the problem of inter-system crosstalk usually presents greater difficulty.

The Carrier System No. 3 will provide channels of 3 db. transmission equivalent given a line having a maximum attenuation of the order of 50 db., and average conditions of noise induction.

The attenuation of open wire lines increases considerably with frequency. For example, the attenuation of a 150 lb. copper circuit, normally taken as 0.077 db. per mile at 800 c.p.s., may be of the order of 0.2 db. per mile at 30 kc.p.s. under wet weather conditions.

A further difficulty is introduced by the short lengths of underground cable now more commonly used for carrying open wire routes through towns. These lengths greatly increase the attenuation of the circuits at carrier frequencies, not only on account of the inherent high attenuation constant of the cable, but because its low characteristic impedance at these frequencies gives rise to a heavy reflection loss at each junction with the open wire line. For example, the total loss introduced by a length of 1 mile of cable may be of the order of 9 db. at 30 kc.p.s. This figure may, however, be reduced by as much as 6 db. by the insertion of impedance-matching transformers at each end of the cable.

As a rather extreme instance of the rise of attenuation with frequency may be cited a Bristol-Plymouth circuit that had an attenuation characteristic rising from about 9 db. at 800 c.p.s. to over 70 db. at 30 kc.p.s. By diverting the circuit from a continuously loaded to an unloaded length of cable at Plymouth, and installing impedance-matching transformers there, and on other lengths of cable at Exeter, Taunton, and Bristol, the maximum attenuation was reduced to a little less than 40 db.

The problem of crosstalk arises when two systems are superimposed on the same pole route. In such a case, the systems are arranged to transmit their upper frequency bands in the same direction, and their lower bands in the other direction. The *near end* crosstalk between the systems need not therefore be considered, and the problem is reduced to one of *far end* crosstalk only.

Crosstalk is generally more severe at the higher frequencies. In order to alleviate the difficulty, the CS 4 and CT 4 systems have their upper bands, *i.e.*, those used in the direction B to A, staggered in frequency in the manner indicated by the table given earlier. This method has two advantages; one is that the carrier frequencies corresponding to the high-energy portions of the speech bands of one system fall outside or between the speech bands of the other system. The second advantage is that any crosstalk which cannot be eliminated is at least rendered unintelligible. The net result of the staggering is that crosstalk of the order of 10 db. greater in magnitude may be tolerated for a given degree of disturbance.

For the purpose for which the systems are intended, the maximum single-frequency far end crosstalk over the lower bands should be of the order of **55** db., so that over the upper bands the corresponding crosstalk may be as low as 45 db. These figures are not, however, easy to obtain on long routes not built or modified for carrier working. In general, it is found that the best results are given by two lines as widely as possible separated on the pole, with perhaps one or more special transpositions inserted in one of the lines.

Conclusion.

Although the Department has had comparatively little experience with the Carrier System No. 3 under normal maintenance conditions, there seems no doubt that without undue expenditure on the maintenance of equipment or lines, the system is quite reliable and free from trouble. It is confidently anticipated that the systems now being put into service will prove to be valuable additions to the trunk network for many years to come.

The photographs in this article are reproduced by courtesy of Messrs. Standard Telephones and Cables, Ltd., to whom thanks are also due for much of the data given.

Carrier Telephony II

G. J. S. LITTLE, B.Sc., A.M.I.E.E.

In this second article of the series dealing with Carrier Telephony, the author explains the methods used to effect modulation of the carrier, and illustrates the principle of multi-channel working by reference to a three channel aerial system.

Modulation of the Carrier.

THE relation between a modulated wave and its component frequencies (carrier and sidebands) has been discussed and the methods used to effect modulation in present day carrier systems will now be considered.

The circuit, shown diagrammatically in Fig. 1, illustrates grid modulation. An alternating voltage

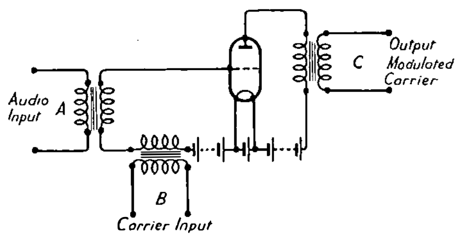


FIG. 1.—GRID MODULATION.

of speech frequency is applied to the grid of a valve through the input transformer A in series with the carrier voltage of constant frequency applied through the transformer B. The grid bias voltage is much greater than would be provided if the valve were to be used as an amplifier, with the result that the output of carrier at C in the absence of audio voltage is small.

The comparatively slowly varying speech voltage, which is added to the carrier voltage, can be regarded as causing a variation in the effective grid bias voltage. Thus the speech voltage during the negative half-waves increases the grid bias, causing the output of carrier to be reduced and during the positive half-waves the output of carrier is increased as the normal value of grid bias for an amplifier is approached. The output of carrier current from the modulator varies in sympathy with the instantaneous speech voltage. This system of modulation gives an output current consisting of carrier and both sidebands and unwanted components of speech frequency together with harmonics of the carrier and sideband frequencies.

In the more recent developments of multi-channel carrier telephony, single sideband working is almost always employed and an extension of the circuit of Fig. 1 is used to eliminate the carrier frequency from the output of the modulator. This is shown in Fig. 2 in which the circuit is arranged with a second valve as in a push-pull amplifier, but with the carrier voltage still applied in series with the grid bias voltage. The grid bias and carrier voltages are applied simultaneously, affecting equally the grids of both valves. The anode currents of the two valves, however, flow in opposite senses through the windings of the output transformer. As long as speech voltage is not applied to the input transformer the variations in anode current of the two valves cancel out and no carrier current appears at the output terminals. This assumes that the two valves are identical, although in the practical case the carrier is not completely suppressed.

Speech voltage applied at the input transformer acts on the grids of the two valves in opposite senses so that, for a half-wave of speech frequency of a given polarity, the negative bias of one valve is increased (thus reducing the amplitude of carrier frequency current in its anode circuit) while the reverse applies to the other valve. The net result is that for successive half-waves of speech the output of first one valve and then of the other overpowers that of its fellow. When the circuit of Fig. 2 is used the output consists of the two sidebands and speech frequency together

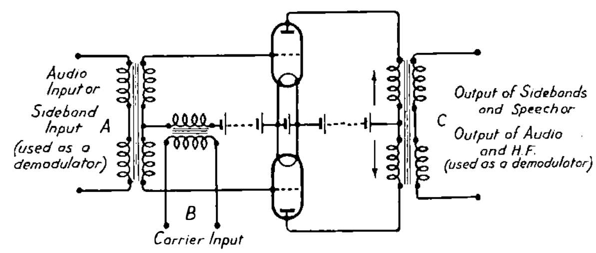


FIG. 2.—CARSON MODULATOR.

with unwanted modulation products. The carrier frequency not being present the selection, by means of filters, of the sideband to be transmitted is simplified.

The circuit of Fig. 2 was invented by J. R. Carson and is usually referred to as the Carson modulator. It is equally suitable as a demodulator where a single sideband is transmitted. When working as a modulator, let the speech frequency applied at A be f_a and the carrier frequency applied at B be f_b. The output at C consists of upper sideband frequency $f_b + f_a$ and lower sideband $f_b - f_a$. When used as a demodulator the incoming sideband, $f_b - f_a$ say, is introduced at A and the carrier frequency f_b, as before, at B. The resulting frequencies at the output are $f_b - (f_b - f_a)$ and $f_b + (f_b - f_a)$, that is f_a and $2f_b - f_a$. The original speech frequency f_a is separated from the unwanted high frequency component $2f_b - f_a$ by a low-pass filter.

The form of a wave consisting of the two sidebands without the carrier is shown at (b) in Fig. 3. The envelope of the curve (b) represented by the broken line corresponds exactly to the shape of the speech wave (a). When the carrier frequency is added to the incoming (lower) sideband at the receiving end the resulting wave at (*d*) is similar in character to the full modulated wave in which both sidebands as well as the carrier are present. The intervals at which the wave crosses the zero line, however, are not equal, but it is hardly practicable to show this feature in the diagram.

The transmission of a single frequency or even of speech by a modulated wave can be fairly readily visualized because the shape of the speech wave is preserved in the envelope of the modulated wave. In single sideband transmission when more than one audio frequency are present the matter is somewhat complicated. The complex wave used as an illustration in the first article (Fig. 3) has been taken to represent the audio wave in Fig. 3 in the present

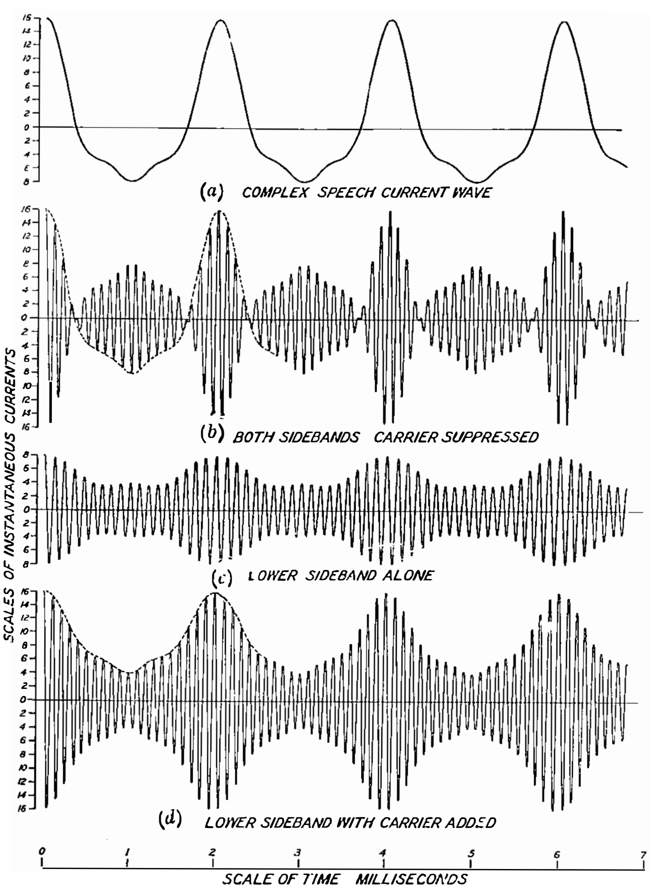


FIG. 3.—COMPLEX WAVE—SINGLE SIDEBAND TRANSMISSION.

article. There is no relationship apparent between the audio wave and the envelope of the single sideband wave. The general character of the single sideband wave might perhaps be considered as resulting from the interference effects of a number of waves differing only slightly in their frequencies. As mentioned in the case of curve (*d*) the intercepts on the zero line of curve (*b*) are not strictly equal.

During the last few years cuprous oxide rectifiers have been increasingly used instead of valves for modulation. A circuit which has been used for modulation and demodulation in the Post Office Voice Frequency single channel carrier system designed for underground cables[1] is shown in Fig. 4. Its mode of action is practically the same as that of the Carson

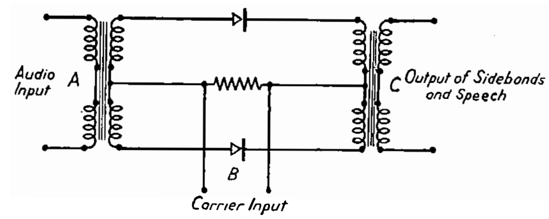


FIG. 4.—RECTIFIER MODULATOR—CARRIER SUPPRESSED.

Modulator (Fig. 2). When there is no audio input or the instantaneous audio voltage is nil, any carrier current which may be flowing is without effect in the output winding at C, as the currents flow differentially in the other winding of the transformer. Audio voltages applied at A act in opposite senses on the two rectifiers with the result that carrier frequency voltage appears in the winding C at the output. As with the Carson modulator the carrier is suppressed and the output consists of the two sidebands together with an audio frequency component. When the carrier is suppressed, there is no output except when there is audio frequency input.

The circuit which has been described is typical of a number of arrangements which have been used. The use of cuprous oxide rectifiers in place of valves has been an important factor in cheapening the cost of carrier equipment and extending its field of application. This type of modulator can be designed to work satisfactorily up to 100 kilocycles per second, but at higher frequencies the capacity of the rectifier elements can be a serious difficulty.

A brief outline has now been given showing how the voice frequency currents normally used in a telephone conversation can be changed in frequency to enable ranges of frequency other than the natural range of the voice to be used for the transmission of speech. Where conditions are suitable a pair of open wires for example may have an effective frequency range extending up to 30 kilocycles per second. This is many times the width of the band necessary for normal telephone speech and suitably designed electrical filters can be used to split up the range of frequencies available into a number of independent channels each of which can be used for the transmission of speech. The function of filters in such a case is twofold.

(*a*) The currents of the several conversations have to be combined together at one end of the pair that is to be used for carrier transmission and separated out again at the other end in order that each conversation may be led to its appropriate equipment. This must be accomplished without serious reflection losses.

(*b*) The above requirement (*a*) can be satisfac-

[1] Carrier System No. 2. See E.I. Transmission Carrier A1009.

torily met without directing the whole of the power of each conversation into its appropriate channel. To prevent interference due to currents from neighbouring bands, the filter of each channel at the receiving end needs to attenuate heavily the frequencies appropriate to other channels. At the sending end, filters are required to ensure that the currents of each channel lie wholly within the appropriate frequency band.

The two functions (*a*) and (*b*) are normally performed by the same filters, but this is not necessarily so.

When the available frequency range has been split up into bands, each band becomes analagous to a pair of wires in a cable or on a pole route. The bands, together with the appropriate modulators and demodulators can be connected, by means of hybrid transformers, to form the equivalents of two-wire and four-wire circuits with, if necessary, intermediate repeaters. There is, however, one important respect in which a pair carrying a number of carrier transmissions differs from an equal number of pairs in a cable. Each of the cable pairs must be provided with an individual amplifier at each amplifying point, but with carrier working a single amplifier suitably designed can be used to amplify a whole group of carrier transmissions simultaneously. This is a fundamental advantage of carrier transmission and carries with it the economic justification of the extensions in the field of application of carrier transmission which are taking place.

Multi-channel Carrier System.

In the earlier phases of its development carrier telephone equipment was used almost exclusively to obtain extra circuits on open wire lines. Fig. **5** illustrates in a purely diagrammatic form the arrangement of equipment at one end of a system which provides three telephone channels, in addition to the normal speech circuit, over a single pair of wires. The arrangement is typical of systems which were designed and have been installed very widely by the Bell System in the U.S.A. The field of use for carrier equipment on overhead lines in this country has not been so great, owing to the shorter distances involved and the replacement of overhead routes by underground cable. Similar systems have, however, been manufactured by Messrs. Standard Telephones & Cables from 1925 onwards for use in this country and abroad. These systems have been used by railway companies and more recently also by the Post Office, to cope with rapid expansion of traffic on certain routes. This development is dealt with in another article in the present issue.[2]

The way in which the frequency band from 0 to 30 kc.p.s. is utilized by the CT4 system of Messrs. Standard Telephones & Cables (Carrier System No. 3) is indicated in Fig. **6**. This system is typical of a three-channel system such as is shown in Fig. **5**.

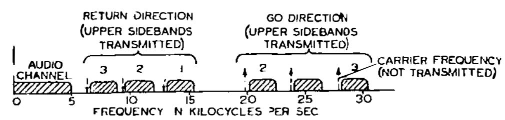


Fig. **6**.—Carrier Frequencies and Transmitted Sidebands—Three Channel System.

A band of frequencies extending from 6 to 16 kc.p.s. provides three channels to transmit speech in one direction and a band extending from 20 to 30 kc.p.s. for speech in the other direction. Regarding each individual band as equivalent to a pair of wires, the arrangement used provides three four-wire circuits. The differential transformers that are required as in ordinary four-wire voice repeater circuits are indicated on the right of Fig. **5**.

Considering channel 1, speech from the subscriber passes *via* the switchboard and the differential transformer to the modulator M1. Here the audio frequencies modulate the 23.7 kc.p.s. carrier supplied from a valve oscillator. The modulator, being of the type shown in Fig. **2**, delivers to the transmitting band filter TBF1 the two sidebands without the carrier. The band filter is designed to attenuate heavily the lower sideband and other unwanted products of modulation, including speech frequencies, and to pass the upper sideband (approx. 24 to 26.3 kc.p.s.) to the transmitting amplifier without causing losses from reflections due to the coupling together of the three band-pass filters in parallel. The transmitting amplifier amplifies at the same time the side-band currents of channels 1, 2 and 3 outgoing from the terminal. From the output of the transmitting amplifier the currents pass

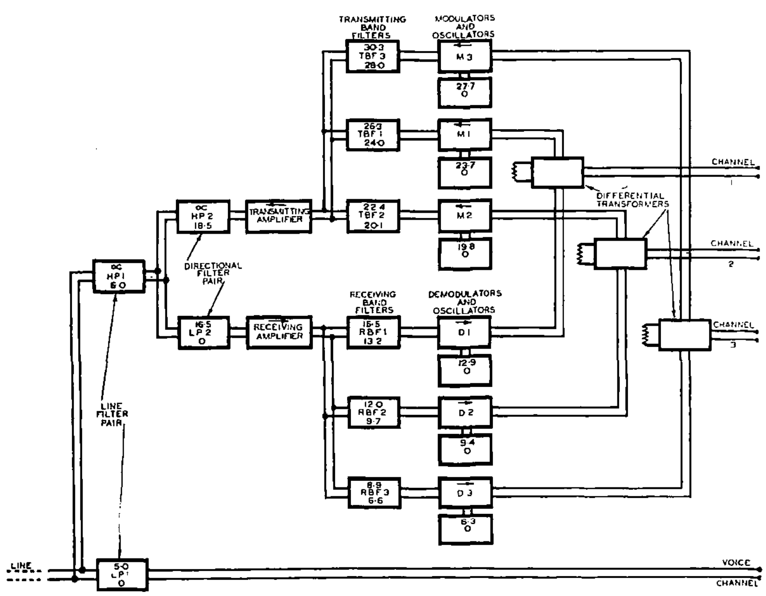


Fig. **5**.—Block Schematic of Three Channel (Grouped) Carrier System.

[2] "The Carrier System No. 3." N. W. Lewis, Ph.D. (Eng.), A.M.I.E.E.

through the high-pass filter HP1 to line, towards the other terminal of the system.

Speech from the subscriber at the other end, who is speaking over channel 1, arrives over the line in the form of sideband currents within the range of frequencies 13.2 to 15.5 kc.p.s. The high pass filter of the line filter pair HP1 serves to direct the currents towards the directional filter pair and away from the switchboard jack of the voice channel which is connected to the far side of LP1. The sideband currents of channel 1 are within the range of frequencies passed by the low-pass filter LP2 of the directional pair, and accordingly they are directed towards the receiving amplifier. This amplifies the incoming sideband currents of all three channels which are delivered to the receiving band-pass filters which direct the currents towards their appropriate demodulators where the conversion from sideband to the original speech frequencies takes place.

Approximate limits of the frequencies which are freely passed by the individual filters are shown, in kilocycles per second, within the rectangles which represent the filters in Fig. **5**. The functions of the various pieces of apparatus are summarized below :—

- Line Filter Pair (LP1 and HP1)—To separate audio and carrier currents incoming from the line and to combine audio and carrier currents outgoing to line.
- Directional Filter Pair (LP2 and HP2)—To discriminate between currents in the two ranges of frequency which are used for the two directions of transmission.
- Transmitting Amplifier—To amplify the currents of all three channels outgoing towards the other terminal.
- Receiving Amplifier—To amplify the currents of all three channels received from the distant terminal.
- Transmitting Band Filters (TBF1, etc.)—To eliminate the unwanted sideband and speech frequency components from the modulator. To assemble together the outgoing currents of the three channels at the input to the common amplifier.
- Receiving Band Filters (RBF1, etc.)—To direct the received currents to the appropriate demodulators.
- Modulators (M1, etc.)—By the interaction of the speech currents and the appropriate carrier frequency to produce the sideband currents.
- Demodulators (D1, etc.)—By the interaction of the received sideband currents and the carrier frequency to convert sideband currents to the original speech currents. The demodulators shown in Fig. **5** should be understood to include the low pass filters necessary to eliminate the unwanted high frequencies which accompany speech in the output of the demodulators proper.
- Differential Transformers—To couple together the audio transmitting and receiving sides of the channels as is required for four-wire repeater circuits.

Fig. **5** shows the apparatus at one terminal. The arrangement at the other end of the circuit would be the same except that the carrier frequencies supplied to modulators and demodulators are interchanged. The transmitting and receiving band filters, often referred to as channel filters, have also to be interchanged.

From Fig. **6** it will be seen that there are gaps between the bands of frequencies transmitted, so that the whole available range of frequencies is not actually used for the transmission of speech. The gaps are required to enable the action of the filters to change from transmitting freely, in the pass range, to heavy attenuation in the frequency range used by the neighbouring channels. Up to a point the gaps between the channels can be reduced by using filters with more sections, but as in practice the change from the pass band to the attenuating band is more or less gradual, the addition of more sections tends towards less efficient transmission of the frequencies at the upper and lower edges of the transmitted band. The spacing of the transmission bands is a compromise between quality of transmission, (frequency response), cost of filters and the number of channels in a given frequency range. The larger gap at 15 kilocycles is accounted for by the greater differences in transmission levels that occur between channels transmitted in opposite directions, requiring heavier filter attenuations. The gaps between bands transmitting in the same direction are greater in the upper block of channels as in general with a given quality of inductance coils the *percentage* gap necessary remains roughly constant if equal performance is required.

The transmission equivalents per mile of overhead lines composed of various gauges of wire are shown in Fig. **7**. The maximum useful overall amplification of a carrier system such as has been described may

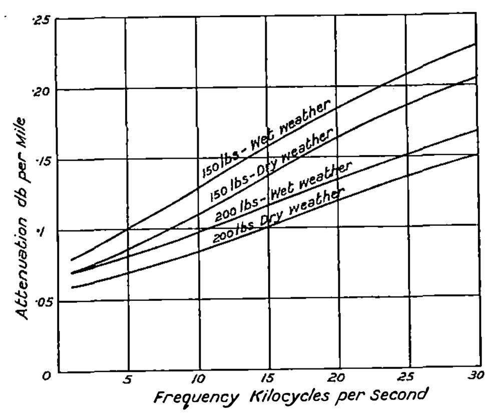


FIG. **7**.—ATTENUATION OF OPEN WIRE LINES AT CARRIER FREQUENCIES.

be taken as being about 50 db. This is sufficient to give satisfactory working over about 250 miles of 150 lbs. line. Any underground sections, with their higher losses, will naturally reduce this figure. Where larger distances have to be dealt with a carrier repeater is installed, and each repeater would increase the range by 150 miles. The arrangement of the filters required is indicated in Fig. **8**. The amplifiers would be of the same design as the transmitting and receiving amplifiers in the terminal equipments. In all such amplifiers three conversa-

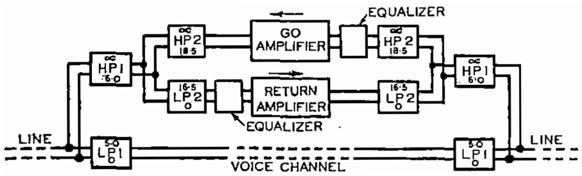


FIG. 8.—CARRIER REPEATER.

tions are amplified together and special care is necessary to avoid interference between the conversations. If the amplifiers were perfect, in the sense that any input voltage irrespective of its actual magnitude were reproduced at the output, always magnified in exactly the same ratio, one conversation would not affect the other two in any way during the process of amplification. In actual fact no valve exactly obeys the principle implicit in simple A.C. theory, namely, that any change in voltage in a particular circuit always causes corresponding changes in current which are in strict proportion to the voltage changes. The effect of curvature of valve characteristics is that in passing through an amplifier a single frequency current generates harmonics. If currents of more than one frequency are amplified together the output currents contain other additional frequencies equal to the sum and difference between the frequencies of the currents being amplified. In fact, amplifiers act to some degree as modulators as well as amplifiers. Frequencies generated as described will in general cause noise on one or more channels which may be noticeable during silent periods during conversation or, in an extreme case, might reduce the intelligibility of speech. In such a system as has been described the effects mentioned are reduced to unimportant proportions by connecting the valves in push-pull and providing for large power handling capacity in the output stage.

The system that has been discussed uses separate groups of frequencies for " go " and " return " directions and is usually referred to as a " grouped system." The similarity to four-wire repeater circuits has been suggested. In one of the two early carrier systems developed by the Bell System in the U.S.A. the same frequency bands were used for both directions of transmission. Differential transformers were employed, as in a two-wire repeater, and balancing networks were provided which simulated the line impedances up to the highest frequency transmitted. This method of working employs the same basic principles as a duplex or two-wire repeater circuit and has the same disadvantages. Duplex carrier circuits are in practice now confined to special systems providing circuits over non-loaded submarine cables where the extremely smooth impedance curves make accurate balances possible and the high cost of submarine cable links compared with land cable may make the greater complication of equipment worth while. A block schematic of a system which might make use of the same bands of frequency as those of the return direction of the system of Fig. **5** is given in Fig. **9**. In the diagram the common transmitting and receiving amplifiers have been omitted as in a duplex system if it were used on an overhead route, the overall gain might be less owing to the difficulty of maintaining accurate line balances. The same oscillator would feed both modulator and demodulator, and the high pass filter, with an impedance to represent the low pass filter, would have to appear in the carrier balance in addition to the line balance.

Apart from the use of cuprous oxide rectifiers as modulating elements all the features of carrier systems which have been described were incorporated in one or other of the two systems which were put into commercial operation in U.S.A. about 1918. The development of amplifiers of the negative feedback type has made possible a striking increase in the number of carrier transmissions which can receive simultaneously amplification and the greatly increased gain that has become practicable has led to the use of separate conductor pairs for the two directions of transmission to avoid the limitations of cross-talk and the expense of filter equipment at intermediate amplifying points. Apart from these points, however, the early carrier installations incor-

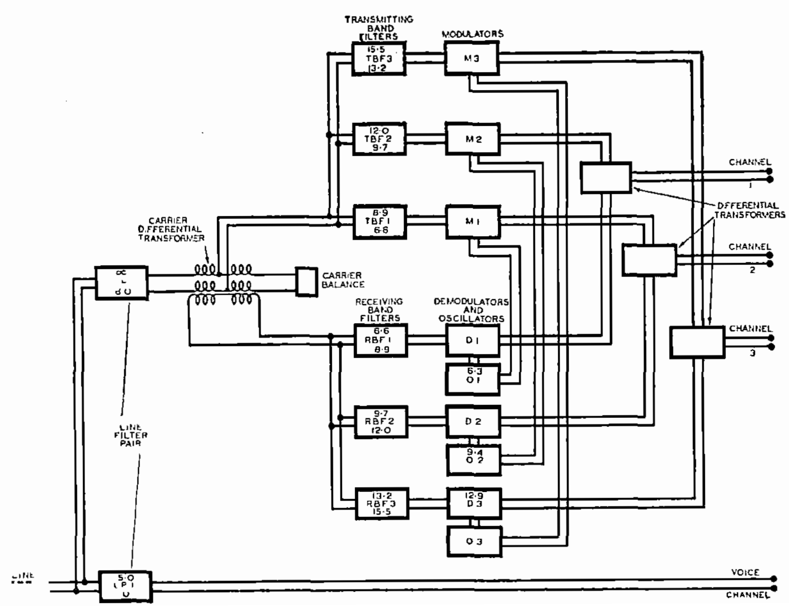


FIG. 9.—BLOCK SCHEMATIC OF THREE CHANNEL DUPLEX SYSTEM.

porated the essential general underlying principles of operation upon which the latest developments depend.

Notes and Comments

Back Numbers

THE sales of the Journal continue to expand and over 12,000 copies have been printed of this Part. One result of this increase in circulation is that enquiries are often received for past issues of the Journal containing articles referred to in a current number. Of the last two volumes copies of Parts 2, 3 and 4 of Vol. 27 and the whole of Vol. 28 have been sold out, and the Managing Editor would like to hear from any readers who have spare copies which they do not wish to keep.

It is thought that there may be some members of the Department about to retire who may wish to dispose of a complete set. If these and new readers who wish to obtain a complete set will communicate with the Managing Editor, they will be put in touch with one another.

Birthday Honours List

We offer our congratulations to all members of the Post Office staff who are included in the King's Birthday Honours List, and particularly to Capt. A. Hudson, Chief Motor Transport Officer of the Engineering Department, who receives the Order of the British Empire.

Fire Refined Copper

In the April, 1936, issue of this Journal the following statement was made :—

" Fire refined copper from two sources is now considered to be quite suitable for use as annealed wires and merits consideration for use in hard-drawn wires."

As far as British Copper Refineries fire refined copper is concerned, the British Insulated Cables, Ltd., point out that during the last three years they have processed over 3,000 tons of this copper into various sizes of hard-drawn wire for telegraph and telephone purposes in accordance with British Standard Specification No. 174/1927. Every coil of this wire has been inspected by their customers' representatives before despatch and not a single rejection has been experienced throughout.

In addition to the above, many thousands of tons of the same copper have been supplied to B.S.S. 125/1930 and other specifications in the form of hard-drawn wire for use as Transmission Line Conductors and to B.S.S. 123/1933 for Trolley Wires, and always with entirely successful results.

Book Review

" Foundations of Technical Electricity." E. Mallett, D.Sc., M.I.E.E., A.M.I.C.E., F.Inst.P., and T. B. Vinycomb, M.C., M.A., F.Inst.P. 188 pp. 92 ill. Pitman. 5/-.

Considerable discussion has taken place in recent years regarding the correct method of teaching " Magnetism and Electricity " and the authors have been strong advocates not only of commencing with current electricity, but of treating alternating currents concurrently with direct currents. Their new book is a complete vindication of this method of approach for, having assimulated in easy steps the opening chapter on Electric Currents, the reader finds himself taking ωC's in his stride and even the *j* operator loses its terrors so easily is it introduced.

In the second chapter which deals with Electrostatics, it is pleasing to find the condenser occupying its rightful place and glass and ebonite rods relegated to the background.

The next two chapters deal with electro-magnetics under the heading of " The Motor Effect " and " The Generator Effect." In the former magnetic fields are introduced not by means of bar magnets, but by considering the magnetic effect of a current. Flux equations, forces on currents in magnetic fields and the magnetization of iron follow in logical order leading to the application of these effects in measuring instruments, telephone relays and receivers, etc.

The chapter on the Generator effect is equally important and deals with magnetic induction and the generation of E.M.F's by the rotation of a conductor in a magnetic field. Inductance is introduced in the same easy way as capacitance and methods of dealing with inductance and resistance in series and in parallel given.

The last chapter is headed Chemical Action and Electric Currents and deals mainly with primary and secondary cells.

The book concludes with a most interesting Appendix on Units in which the relationship between Practical, Electromagnetic and Electrostatic (C.G.S.) Units is lucidly derived and explained.

The book is most rightly called the " Foundations of Technical Electricity." Upon its information the student will be able to build a structure of greater knowledge without misconception and without the necessity of unlearning wrong ideas. For the C. and G's new examinations in technical electricity this will be a most valuable text-book. There are no teachers of " Magnetism and Electricity " or, as it is better called, " Technical Electricity," who would not find benefit from a perusal of this book.

J.R.

District Notes

North Eastern Region

BRADFORD ELECTRIC SUPPLY FAILURE.

The Telephone Area inaugurated at Bradford on December 16th, 1935, had to face its first emergency when the electric supply failed at 6.18 p.m. on Monday, the 24th February, 1936. Five exchanges, (including Bradford, a C.B. No. 1 exchange with some 8000 lines) were affected, but by the aid of emergency gas lighting and candles the operating staff were able to deal successfully with a large increase in traffic during the early hours of the failure.

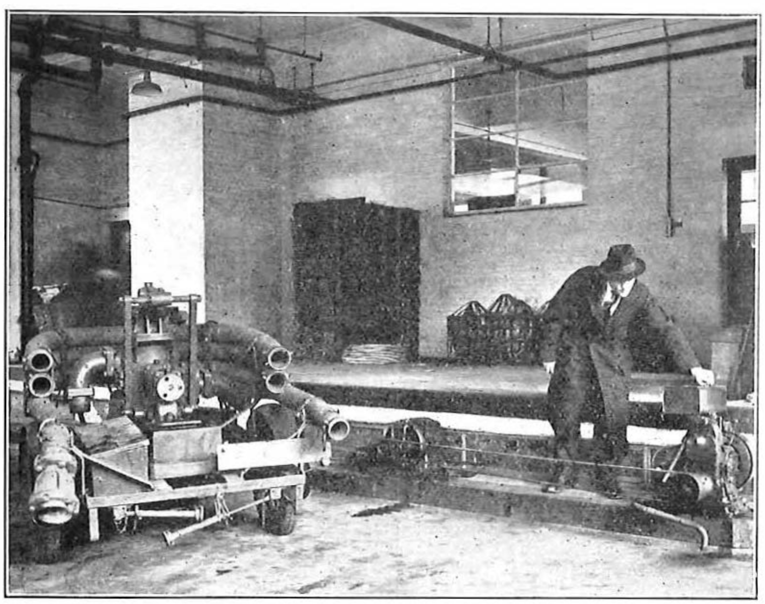
Although no information was obtainable regarding the nature of the breakdown, it was learned that seven fire engines had answered a call to the Corporation's Power Station, and following a visit to the scene of the fire it was realized that emergency measures would be necessary. Battery conditions at the five affected exchanges were ascertained and at 9.0 p.m. a request was made for the emergency charging equipment to be supplied from Leeds.

At 10.30 a.m. on Tuesday morning the Beardmore-Diesel 100 H.P. transportable charging equipment was charging the Bradford exchange batteries. Charging normally commences at 8.30 a.m. and the fact that a delay of only two hours occurred was due to the energies of both the Bradford and Leeds staffs, and to the ready assistance given by the L.M.S. Railway.

During Tuesday and Wednesday a transportable Coventry Simplex 8 K.W. charging set was kept busy at the smaller exchanges.

At the Post Office five teleprinters were stopped and the traffic had to be handled by telephone, keys and sounders until noon on Tuesday when the teleprinter service was restored. This was possible by the use of the 110 volt race meeting equipment normally held at Leeds, comprising teleprinters, batteries, and a 1200 watt Stuart petrol-electric charging equipment.

Fifty thousand letters were stamped by hand, and by the light of candles, at the Bradford Sorting Office on Monday evening and every effort was made to supply power to a stamping machine for Tuesday evening's collections. With the assistance of a local Electrical Contractor, (Messrs. Collinson Bros.) a further petrol-electric set was brought into use at 6.30 p.m. A 230 volt 6 amp. D.C. generator having a speed of 1000 R.P.M. was available and as no other petrol engine could be obtained, that from a Trailer Motor Pump was dismantled and fitted with a pulley and a belt drive to the generator. The photograph shows this set, which proved most successful and which ran for some 36 hours until the power was restored on Friday morning.



TEMPORARY CHARGING SET.

Although the Post Office was able to maintain its services, other services in the City were completely disorganized. Some of the larger factories were not able to commence work until the following Monday, with the result that several thousands of operatives were out of work for nearly a week. Widespread apprehension has been caused by the breakdown, and it is to be hoped that the Electricity Commissioners' Report will enable such a complete failure to be avoided elsewhere.

AN UNUSUAL CABLING OPERATION.

Although the laying of a sub-aqueous cable is no uncommon occurrence, it may be of interest to describe the difficulties encountered in the excavation of a 6 ft. trench in which to lay such a cable across the River Trent between Althorpe and Burringham. The river crossing is part of the Doncaster-Scunthorpe main 60 pr/20 cable, the total width being 385 yards, of which 245 yards are under water at high tide.

The contract to dredge a channel across the river was let to a dredging firm, who anticipated completion of the whole job within a fortnight. Operations commenced on 13th November last, the method adopted consisting of drawing a scoop to and fro by a steam tractor on either bank, scraping a trench across the river and allowing the mud to be eroded by the river currents.

The end of the first day's work saw the 3″ steel hawser snapped in mid-stream and the scoop stuck about 20 yards from the Burringham bank. It took three days, followed by an obliging tide to loosen the grip, and allow the scoop to be drawn out. The width of this scoop was 9 ft. so a smaller 5 ft. scoop was substituted and a fresh start made.

Numerous obstructions were encountered in the shape of wreckage and, on one occasion, a millstone five feet in diameter was brought to the side by the dredge.

After six weeks' dredging it was decided to ask the River Conservancy Board to make the first test. Many were the astonished faces when only a 2 ft. trench could be found in the muddy Burringham side of the river, and none at all in the navigation channel, which extends for 90 yards from the Althorpe side.

Prongs were then fitted to the cutting edge of the larger scoop with side prongs projecting outwards at 45 degrees. The whole apparatus was weighted to prevent overturning and brought into use. Another month elapsed before it was confidently felt that a good trench then existed. This time the test was made with an Echo Sounder Apparatus, and again no trench could be found for the greater part of the crossing.

Owing to abnormal flood conditions existing, it was agreed on 3rd February to suspend work for a few weeks, a fresh start being made on 30th March. Careful analysis of tests which were now made revealed that either a dense mobile bed of silt was immediately filling in the trench behind the scoop, or that the strong currents at each high tide were turning back the excavated mud into the trench. So far it had only been possible to test at high tide as more than half the river is unnavigable at low water for anything except a rowing boat. Arrangements were eventually made to have the Conservancy Board's tester there continuously and to test at the first favourable moment from such a boat.

At 8 p.m. on 12th May a test was made at dead low water, and, for the first time, a satisfactory trench for the greater part was proved. Taking the chance that another day's continuous dredging would complete the task, rapid arrangements were made to bring back the Cable Contractors staff—who had long since given up waiting and gone to Scotland.

At 8.30 p.m. the following day, 13th May, owing to the difficulty in holding a rowing boat in the fast flowing channel, soundings were taken in this portion of the river from a hired tug and from the rowing boat in the other parts. Darkness was now coming on, and it was a relief to all concerned when the sounding rod was seen to sink to the correct depth, and at 8.50 p.m. the Conservancy Board's representative passed the trench as satisfactory. The ideal conditions then present had never before existed during the operations, no wind, no current, and an abnormally low tide. In spite of the gathering darkness it was decided to proceed with the cabling and such activity as then ensued had probably never before been witnessed in these regions. The scoop was drawn out of the river, the cable end attached by a shackle to the hawser, and in 11 mins. the whole length pulled across. So ended six months' effort.

An unusual feature of the cable was the thimble termination at the pulling end. This termination had been prepared in the factory and was made up on the armouring only and finished off similarly to a stay-wire. This ensured that the pulling load was taken by the armouring, and that no stresses were put on the lead sheathing of the cable. At 50 ft. intervals along the cable 2 ft. " Stocking Grips " had been inserted in the factory under the outer hessian covering and then taped over so that by cutting the tape the eye could be bared and would have been accessible for pulling purposes had it been necessary to pick up the cable.

The cabling arrangements were in the hands of The United Telephone Cables, Ltd., Prescot, the Contractors for the whole of the cable between Doncaster and Scunthorpe. The smallest detail of the requirements at the river bank necessary, when the word " go " was received, had been thought of, and arranged for, and it is a matter of congratulation to the representatives of the firm who had the matter in hand that the final work of laying the cable was carried out without a hitch.

Scottish Region

REGIONAL RE-ORGANIZATION.

The Scottish Regional Headquarters were formally established on the 9th of March, 1936. Satisfactory progress has been made in setting up the Engineering Branch at Headquarters, and the complement of the Chief Regional Engineer's Office is practically completed. An Organization Chart for the Branch has been drawn up and each member of the Chief Regional Engineer's staff is now aware of his duties and responsibilites.

A Regional reception and dance were held in Edinburgh on the 6th March as a medium for bringing members of the Regional Organization together and very cordial relations have been established between the various Headquarters Branches which will ensure smooth working and successful co-operation.

Considerable new work is being undertaken in the Region at the present time. The conversion of the Glasgow Telephone Area to automatic working in 1940 has necessitated a detailed study of the problem of meeting telephone developments until such time as the automatic transfer can be effected, including abnormal extension to existing equipment at a number of exchanges and advanced provision of a number of small automatic exchanges to afford relief to existing manual exchanges.

MAIN CABLE EXTENSIONS.

A new main cable from Dumfries to Stranraer is being provided which will afford connexion *via* the recently completed London-Liverpool-Glasgow cable between Northern Ireland and England. Two new cables to provide for carrier working between Edinbugh, Dundee and Aberdeen are in hand. The main cable northwards has been extended from Inverness to Dingwall, the distance from Edinburgh to Dingwall being 242 miles, making a continuous underground route from London of 640 miles.

3-CHANNEL CARRIER EQUIPMENT.

3-Chanel carrier equipment is being provided to afford relief to outlying centres, Wick, Kyle of Lochalsh, Oban, Fort William and Campbeltown, and it is anticipated that the additional channels to Glasgow, Edinburgh, Aberdeen and Inverness will be available for the current summer traffic.

RADIO LINKS.

Sites have been acquired at Ardrossan and Arran and the erection of huts has begun. It is hoped that a considerable increase of traffic will be handled on the six ultra short wave radio links during the holiday season in the Isle of Arran. The six-channel link between Ballygomartin (Northern Ireland) and Port Patrick Radio Stations has also been augmented by nine additioal channels.

REGIONAL SCHOOL.

A Regional Training School was opened in January, suitable temporary accommodation having been rented from the Edinburgh Borough Education Authority at the Leith Academy Annexe. Classes have already been held in Fitting, Jointing, and Plumbing, Overhead and Subscribers' Apparatus Maintenance. Additional courses, including Youths' Training courses A. and B., will be included in the near future.

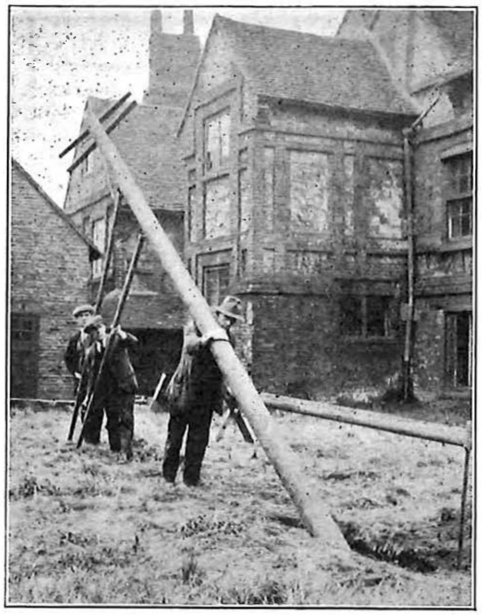
South Midland District

INTENSIVE TRAINING OF WORKMEN.

To meet the pressing need for increase in number and skill of various classes of Workmen, Training Courses in Overhead Work, Switchboard Fitting and Cable Jointing were established at convenient centres in the South Midland District last autumn and have been conducted throughout the winter months.

Favourable conditions for demonstration and tuition in the latest methods of Overhead Construction existed at Guildford owing to the acquisition of extensive gardens and premises in readiness for a new Telephone Exchange, Sorting Office, etc., and a few notes regarding the Training Course organized under the guidance of Mr. Lock—the Sectional Engineer, Guildford—may be of general interest.

The syllabus covered up to date standard practice in overhead line construction and included a series of lectures followed by demonstrations and practical training in the field, as illustrated by the accompanying photograph.



GUILDFORD TRAINING SCHOOL.

In addition an Advanced Course, suitable for potential Foremen, was included, in which particular attention was given to Unit Construction Costs, Unit Maintenance Costs, Stores matters, Transport, Accidents on Duty and Precautions against Accidents, Discipline, etc. Lectures on these subjects were given by the Assistant Engineer and members of the Clerical Staff and keen interest and an improved outlook were evoked.

Selected Workmen from all Sections of the District have received training during the nine Sessions, each Session being of 3 weeks duration. 112 men from the four Sections passed through the course of training and remarkable results as regards speed and quality of work were achieved. An excellent spirit was also fostered among the trainees and the scope and quality of the training earned the popular local description of " Workmen's College."

North Midland District

RETIREMENT OF MR. D. S. ARUNDEL, A.M.I.E.E.

The retirement of Mr. D. S. Arundel, who has spent almost the whole of his official career in the North Midland District, has left a very definite sense of loss amongst his associates of all ranks.

Mr. Arundel entered the Engineering Department in 1900 as a Junior Clerk, having transferred from the rank of S.C. & T. After 12 years in the Nottingham Section he took a large part in the N.T. Co. inventory prior to the transfer to the Post Office.

In 1922 he took charge of the development of the main underground system in the District and was responsible for the construction of the London-Manchester cable, one of the first long distance loaded cables laid. Under his supervision the main underground in the District developed from 150 route miles to nearly 1,100 route miles, at the present time the greatest mileage of main underground in any District.

Mr. Arundel was deeply interested in and closely associated with the Works Unit and other Committees. He was also largely responsible for the first steps which led to the mechanization of certain aspects of the clerical and accounting work in the Superintending Engineers' offices.

The high regard held for " Dan " by his confreres of all grades in the District was due to personal qualities which endeared him to all with whom he was associated. Justice coupled with sympathy and human understanding led to an appreciation of staff problems which brought out the best in those who worked with him.

Mr. Arundel was a keen pedestrian and cyclist, and his hobbies included field science, geology and archæology. He was also an authority on old churches.

His services to the Department received official appreciation and recognition during his last year of office by the award of King George's Silver Jubilee Medal.

The best wishes of his colleagues for an old friend go with him in his retirement.

ANNUAL DINNER.

The Annual Dinner of the North Midland District was held at the Welbeck Hotel, Nottingham, on March 3rd, 1936.

The Superintending Engineer, Mr. A. Wright, M.I.E.E., occupied the chair, and the guest of honour was the Engineer-in-Chief, Colonel A. G. Lee.

The meeting was of a very representative character, and included members of the staff of all Sections with their ladies. The Engineering Department welcomed as guests the Assistant Surveyor, Mr. O. J. Miles, the District Manager, Mr. T. A. Beck, and the Head Postmaster of Nottingham, Mr. A. E. Squirrell.

Speeches were made by the Chairman, the Engineer-in-Chief, the District Manager and the Head Postmaster of Nottingham dealing with developments in the Engineering Department in general, and of the North Midland District in particular.

An excellent programme of music was provided by members of the staff, and their friends, and was thoroughly enjoyed by the assembly.

South Western District

PRESENTATION TO MR. V. G. PENDRY.

A notable event took place at Penzance on March 23rd, 1936, when on behalf of His Majesty the King, the Lord Lieutenant of Cornwall (Col. E. H. W. Bolitho) presented the Medal of the British Empire, Civil Division, to Mr. V. G. Pendry, S.W.II, Plymouth Secton. The ceremony was held in the Council Chamber in the presence of a large number of prominent citizens, the Mayor of Penzance (Ald. Robt. Thomas) presiding.

Prior to the presentation Mr. P. Thornton Wood, Superintending Engineer, described the services rendered by Mr. Pendry in connexion with the repair of the telegraph cable connecting St. Mary's in the Scilly Isles with the mainland at Porthcurno, Cornwall, which broke down in December, 1935. The Commander H.M.T.S. Alert had decided that it would be necessary to lay a new shore end and Mr. Pendry formed a landing party of five men of the Plymouth Section together with five local labourers engaged at St. Mary's.

The cable had to be hauled in from below water mark to the cable hut, over rocks and up the face of a cliff for a distance of about 100 yards. On the evening of the 19th December it was temporarily secured in position and was permanently fixed by Mr. Pendry and the local labourers on the following days by clamping and cementing into the cliff face and rocks.

The heavy seas running made it impracticable to use ladders and the work on the cliff face had to be done from a Bosun's chair. High winds, heavy seas, and frequent rainstorms made the conditions extremely difficult and unpleasant for the men engaged, who were wet through for the greater part of each day.

In making the presentation the Lord Lieutenant congratulated Mr. Pendry who, he said, had been awarded the Medal for "conspicuous energy, initiative and devotion to duty."

Mr. Pendry terminated a suitable response by saying that he would rather do the work all over again than continue his speech.

OPENING OF BATH SORTING OFFICE.

On May 22nd, the District was honoured by a visit from the Director General who, in company with the Mayor and other officials, performed the opening ceremony of the new Bath Sorting Office.

The office which has been built on the most modern lines possesses certain features not found elsewhere. One uncommon feature is that the roof of the centre portion measuring 100 feet by 100 feet is entirely without pillar supports so obviating all floor obstructions. The heating is carried out by means of a series of panels fitted in the ceiling which warm the room by radiation and do away with any obstruction caused by radiators at floor level.

In view of the structural features of the building it was decided to provide a flood lighting system for the centre portion of the office. Gas discharge lamps were used for the purpose. This type of lamp gives approximately three times the amount of light for the same current consumption, compared with the filament type of lamp. The light obtained is bluish green owing to a deficiency of red rays and in order to overcome this disadvantage a certain number of filament type flood lights were interspersed to supply the deficiency. The resultant effect gives an almost true colour rendering with an intense sharpness of vision which enables fine details to be seen very rapidly without eyestrain.

OPENING OF CHIPPENHAM NEW AUTOMATIC EXCHANGE.

The transfer of Chippenham exchange from magneto working to automatic was successfully accomplished on the 4th April, 1936, some 500 subscribers and 50 junctions being concerned. The installation was carried out by Messrs. Standard Telephones and Cables, Limited.

The official opening took place on the 6th April, 1936, when the Hon. Lady Cooper, accompanied by prominent residents of the area, visited the exchange. The opening was preceded by a film display and followed by a social gathering. During the proceedings Lady Cooper made appreciative remarks about the new installation and referred to her occasional impatience with the original magneto system which was explained as mostly due to her inappreciation of the complications of the system.

One of the most interested of the visitors was the first telephone subscriber in Chippenham.

The exchange is housed in a completely new building which also makes provision for accommodation for the Inspector and Sales Representative in the Chippenham Area and the site provides combined Postal and Engineering Transport facilities including a M.T. workshop. There is no doubt that the telephone service in Chippenham will be greatly improved by the new apparatus and plant provided.

SAFETY FIRST AWARDS IN THE BRISTOL SECTION.

Bristol Section is proud to be able to record the following awards to engineering members of the staff under the National Safety First Association scheme:—7 bars to silver medals, 5 silver medals, 71 diplomas, during the year 1935/36.

Many of these were presented by the Director General on the occasion of his recent visit to Bristol, some at the opening of the new Bath S.S.O. on the 21st May and others at combined Postal and Engineering presentations at Bristol H.P.O. on Friday, 22nd May, 1936. Sir Donald Banks expressed his appreciation of the difficult conditions under which Post Office drivers often worked and congratulated the drivers before him on their excellent record.

North Wales District

BIRMINGHAM REGIONAL TRAINING SCHOOL.

The Birmingham Regional Training School, on lines similar to those obtaining at the Central School, Dollis Hill, London, was established on April 23rd last.

The School is temporarily functioning in premises at 32, Lancaster Street, Birmingham, pending permanent accommodation being obtained by the Office of Works Department. Although in temporary premises, the School is giving Courses in Overhead Wiring; Plumbing and Jointing; Subscribers' Fitting including U.A.X. and House Telephone System, to men from the North Midland, South Wales and North Wales Districts.

Since the opening a total of 246 students have been trained in these subjects and by the end of September it is hoped that the figure will have reached approximately 550, excluding any Y-in-T, who will have completed a 5 weeks' Course at the Central School, and are due for additional training in Overhead Construction and Plumbing and Jointing.

Although the accommodation is not all that could be desired, the students all appear to be perfectly content and every effort is made by the staff to ensure that their period of training is made as congenial as possible.

The School Staff would like to take this opportunity of conveying their appreciation for the help received from the Engineer-in-Chief's Training School, Dollis Hill, which has been of considerable assistance during the initial stages at the Birmingham School.

RETIREMENT OF MR. R. P. COLLINS.

Mr. R. P. Collins, Chief Inspector at Birmingham, who retired from the service on 29th February, 1936, was well known to large numbers of the staff of all ranks.

He joined the Engineering Department at the C.T.O. in April, 1891, resigning in October, 1893, to join the Royal Engineers, in which Corps he served for nearly 26 years, attaining the rank of Sergeant Major. After 5 years he was transferred to the "K Company" and was employed on Post Office duties, and completed his army career on Active Service in France. On discharge in August, 1919, he took up duty with the P.O.E.D. at Waterford and was transferred to Birmingham in October the same year.

He was a teacher of the City and Guilds Institute in Telegraphy and Telephony while a Sapper in the Royal Engineers and was also a Lecturer in the Technical College at Exeter, Waterford and Birmingham.

He was for 9 years on the Council of the Institution of Post Office Electrical Engineers, and was a member of the Committee which set up the constitution of the Junior Section of the Institution.

He was also prominent in sport, being Chairman of the Engineering Department Cricket Club and Vice-Chairman of the Birmingham Post Office Swimming Club in which capacities he is being retained. Having plenty of time now for practice he is hopeful of reducing his golf handicap and carrying off the " Faulkner " Cup recently presented by the Superintending Engineer for competition among the staff.

At a smoking concert on March 25th, 1936, under the Chairmanship of the Superintending Engineer, Mr. Faulkner, a large number of the staff, including ladies from the Trunk Exchange and representatives of the Traffic Department, met to bid farewell to Mr. Collins. The presence of Mrs. Collins and Miss Collins was greatly appreciated.

Gifts of a radiogram from the Engineering Department, a pewter tea service from the Telegraph Branch, a clock and ash tray from the Trunk Supervisors, and an illuminated address from the Swimming Club were indicative of his popularity.

It is interesting to note that the Telegraph Staff arranged a separate smoker at which presentations were made. This rather unique event demonstrated the happy relations which he fostered between the separate branches of the Service. He leaves the Service in good health and with the best wishes of his colleagues for a long and happy retirement.

Messrs. Price, Hughes, Thomas and Nock, Inspectors at Birmingham, and Mr. Taylor, Inspector at Stoke, have also retired recently and to them all we wish good health and happiness for many years to come.

REMOVAL OF BIRMINGHAM SECTION OFFICES.

Leap Year Day, February 29th, was moving day for the Section Office staff at Birmingham. 42, Paradise Street, which has housed the Section Offices since 1916, was vacated in favour of the new quarters at Telephone House, Newhall Street. The number of staff concerned in the removal was approximately 180, and included the Internal, External, and Power Engineers and their staffs; the External staff included the Installation Group from Lancaster Street.

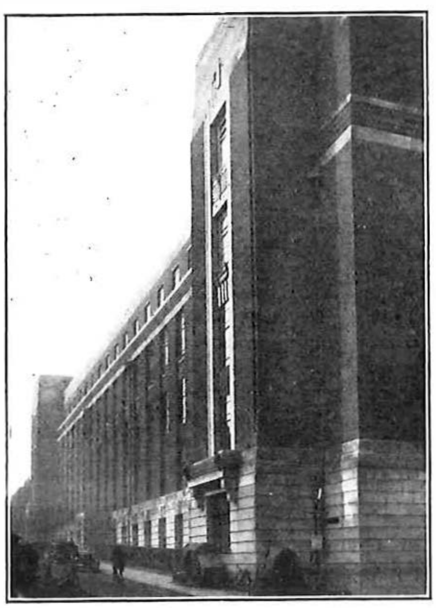


Photo by *Birmingham Mail.*

TELEPHONE HOUSE, BIRMINGHAM.

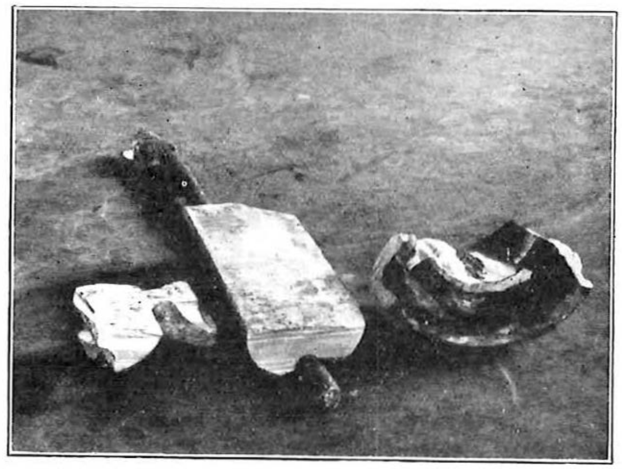
A local contractor was engaged to carry out the actual removal, and a generous supply of packing cases suitable for papers was made. To facilitate the work of the contractor, each officer or group was given a Code Letter and Number with which to label cases and parcels, this Code and Number corresponding with the floor, room and table allocated to that particular Officer or Group. The scheme worked very satisfactorily and avoided many enquiries and delays which the labelling of packages by name would have occasioned.

Difficulties naturally arose in locating personnel during the first few days in the new surroundings, but these were soon overcome and normal conditions again prevailed.

AN UNUSUAL FORMATION OF SEDIMENT IN DUCTS.

An unusual case of sediment in ducts was discovered when a cable was being drawn out at Boat Bridge on the Walsall-Lichfield Road in the North Wales District.

At this point a three-way duct line is carried over the usual type of humped back canal bridge in steel pipes. On breaking down it was found that a hard sediment had formed in the first four ducts leading from the end of the steel pipes down the remaining gradient of the bridge to the normal road level. This sediment, as will be seen from the centre specimen in the photograph, about half



SEDIMENT TAKEN FROM DUCT.

filled the duct, and completely encased the cable, preventing it being drawn out.

The sediment is of a peculiar nature, unlike anything met with in the District before, and it would be interesting to know if other Districts have experienced similar types. It consists of alternate layers of a flint like blue grey rock, about the hardness of a three to one sand and cement mixture that has been allowed to set for three days, interleaved with layers of a soft chalk like deposit. The layers can be clearly seen in the illustration.

The steel pipes, and the ducts at road level, were clear, the sediment being found only in the four ducts rising from road level to the commencement of the steel pipes. The greatest depth of deposit occurred in the highest of these four ducts adjacent to the steel pipes, the lowest duct being almost clear.

The most surprising feature of this case, apart from the hardness of the deposit, is the way in which it accumulated most in the highest duct leaving the ducts at the lower level of the road quite clear, and while no prizes can be offered for the solution, an explanation that would account for this peculiar phenomenon would be very welcome.

The Institution of Post Office Electrical Engineers

RETIRED MEMBERS.

The following members, who have retired from the Service, have elected to retain their membership of the Institution :—

A. W. Field, 14 Oak Drive, Bramhall, Cheshire.
E. Hopper, 14 Cromwell Road, Penwartham, Preston.
F. McClarence, 72 Drury Road, Harrow, Middlesex.
A. F. C. Reid, 9 Cross Street, Southport, Lancs.

CORRESPONDING MEMBERS.

Applications for corresponding membership of the Institution have been approved by the Council in respect of the undermentioned :—

R. B. Jones, C.T.O. Radio House, Cairo.
D. D. C. Knuckey, P.M.G's Dept., 219 Castlereagh Street, Sydney, Australia.
W. Stubbs, Posts & Telegraphs, Kuala Lumpur, Malaya.

RECENT ADDITIONS TO THE INSTITUTION LIBRARY.

New Books.

Engineering economics :
1130 Book II. Works organization and management.—T. H. Burnham. (1935, Brit.).
1190 Die castings : their design, composition, application, specification, testing and finishing.—H. Chase. (1934, Amer.).
1191 Plastic molding : an introduction to the materials, equipment and methods used in the fabrication of plastic products.—L. F. Rahm. (1933, Amer.).
1192 Finishing metal products.—H. R. Simonds. (1935, Amer.).
1193 Introduction to the study of physical metallurgy.—W. Rosenhain, revd. J. L. Haughton. (1935, Brit.).
1194 Human factor in industry.—E. P. Cathcart. (1928, Brit.).
1195 Elements of electrical engineering : a text-book of principles and practice.—A. L. Cook. (1935, Amer.).
1196 Mechanical and electrical equipment for buildings.—C. M. Gay and C. de Van Fawcett. (1935, Amer.).
1197 Mercury-arc current converters : an introduction to the theory of vapour-arc discharge devices and to the study of rectification phenomena.—H. Rissik. (1935, Brit.).
1198 Industrial drawing and geometry : an introduction to various branches of technical drawing.—H. J. Spooner. (1933, Brit.).
1199 Practical building construction : handbook for students preparing for the examinations of the Science and Art Dept., the Royal Institute of British Architects, the Surveyors Institution, etc.—J. P. Allen. (1930, Brit.).
1200 Architectural practice and procedure : a manual for practitioners and students.—H. H. Turner. (1931, Brit.).
1201 Principles of electric welding, metallic arc process.—R. C. Stockton. (1933, Brit.).
1202 Electric arc welding practice : a handbook for welding engineers and welders.—H. I. Lewenz. (1936, Brit.).

Gauges and fine measurements :
1203 Vol. I. Standards of length, measuring machines, comparators.—F. H. Rolt. Ed. by Sir R. T. Glazebrook. (1929, Brit.).
1204 Vol. II. Limit gauges, measuring instruments, general methods of measurement.—F. H. Rolt. Ed. by Sir R. T. Glazebrook. (1929, Brit.).
1205 Punches, dies and tools for manufacturing in presses.—J. V. Woodworth. (1930, Amer.).
1206 Practice of lubrication : an engineering treatise on the origin, nature and testing of lubricants, their selection, application and use.—T. C. Thomas. (1926, Amer.).
1207 Inorganic chemistry : a text-book for colleges and schools.—E. J. Holmyard. (1935, Brit.).
1208 Supervision of building work and the duties of a clerk of works.—J. Leaning, revd. H. J. Leaning. (1928, Brit.).
1209 Thermionic emission.—T. J. Jones. (1936, Brit.).
1210 Electron diffraction.—R. Beeching. (1936, Brit.).
1211 High speed diesel engines : with special references to automobile and aircraft types—an elementary text-book for engineers, students and operators.—A. W. Judge. (1935, Brit.).
1212 Elementary treatise on differential equations and their applications.—H. T. H. Piaggio. (1933, Brit.).
1213 Superheterodyne receiver : its development, theory and modern practice.—A. T. Witts. (1936, Brit.).
1214 Intermediate engineering drawing including a course in plane and solid geometry and an introduction to design.—A. C. Parkinson. (1936, Brit.).
1215 Special steels : a concise treatise on the constitution, manufacture, working, heat treatment and applications of alloy steels for students, operators and users of special steels—chiefly founded on the researches regarding alloy steels of Sir Robt. Hadfield.—T. H. Burnham. (1933, Brit.).
1216 Steel treating practice.—R. H. Sherry. (1929, Amer.).
1217 Steel and its heat treatment.—D. K. Bullens. (1935, Amer.).
1218 New acoustics : a survey of modern development in acoustical engineering. — N. W. McLachlan. (1936, Brit.).
1219 Empire development and proposals for the establishment of an Empire Development Board.—Sir Robt. Hadfield. (1935, Brit.).
1220 A fugue in cycles and bels.—J. Mills. (1935, Amer.).

Communication networks :
1221 Vol. I. Classical theory of lumped constant networks.—E. A. Guillemin. (1931, Amer.).
1222 Vol. II. Classical theory of long lines, filters and related networks. — E. A. Guillemin. (1935, Amer.).
1223 An examination of examinations : being a summary of investigations on the comparison of marks allotted to examination scripts by independent examiners and boards of examiners together with a section on a *viva voce* examination.—Sir P. Hertog and E. C. Rhodes. (1936, Brit.).
1224 Quantum theory of radiation.—W. Heitler. (1936, Brit.).
1225 Electro-plating : a survey of modern practice including nickel, zinc, cadmium and chromium.—S. Field and A. D. Weill. (1935, Brit.).
1226 Design problems of heating and ventilation.—A. T. Henly. (1936, Brit.).

Junior Section Notes

Aldershot Centre

The Fourth Annual General Meeting of the Aldershot Junior Section was held on April 28th, at 7.30 p.m.

At the opening of the proceedings a cordial message was read from the Superintending Engineer, Mr. Cornfoot, M.I.E.E., appreciating the excellent work done by the Centre despite difficulties and assuring them of the interest and help of the Senior Section.

The Secretary, Mr. Permain, reported on the work of the Aldershot Centre during the past session. A satisfactory programme had been carried through and an interesting visit paid to Faraday House. An outdoor event arranged for Whit-Monday had had to be abandoned at considerable pecuniary loss, but despite this the financial position was now sound.

The retiring officers were thanked for their services and the following officers were elected for the ensuing session :—

Chairman—Mr. S. Allen.
Hon. Secretary and Librarian—Mr. L. E. Permain.
Hon. Treasurer—Mr. F. J. Holden.
Committee—Messrs. Anger, Bray, Hallett, Payne, Ralf and Sylvester.
Auditors—Messrs. G. W. Allen and D. Coffey.

The ordinary business concluded, Mr. Bell, Hon. Secretary of the South Midland Centre, who was present, addressed the meeting. He paid tribute to the excellent work done by the Aldershot Section and particularly the enthusiasm and efficiency of its officers. He stressed the worth-whileness of the I.P.O.E.E. to all grades, especially at the present time, when the developments of technique and the increasing complexity of the work demanded not merely a high standard of technical competence but also the ability to keep pace with the advances continually being made in the science and practice of communication engineering.

There was thus a real need for such organizations as Junior Centres, not merely to enable members to keep in touch with progress in the various branches of the work, but also to afford an outlet for individual expression of ideas and to maintain a spirit of co-operaton between the various sections of the staff.

Gloucester Centre

The fourth session of the Gloucester Branch terminated on May 23rd with the Annual General Meeting which was held at the Spread Eagle Hotel in Gloucester. The Chairman, Mr. F. W. Gill, presided, and business included the election of officers for the ensuing year, and adoption of the year's working by the Secretary, Mr. R. A. Kibby, and Treasurer, Mr. S. B. Foote.

The Secretary stated that seven papers had been read during the session, viz. :—

(1) " U.C.C. Statistics," by Mr. H. W. Gifford.
(2) " Safety First," by Mr. A. J. Hodgson.
(3) " Units Amplifying," by Mr. T. Middleton.
(4) " The Metal Rectifier and its uses in Telephony," by Mr. R. C. Bossom.
(5) " P.A.B.X's," by Mr. A. G. Horton.
(6) " Fault Control," by Mr. F. Keen.
(7) " The U.A.X. No. 12 System," by Mr. H. E. Huckfield.

Of these, two had been selected for submission under the Parent Institution's Award Scheme.

An innovation was the reading of two of the papers at Worcester at which meetings we were pleased to record remarkably good attendances. This was no doubt in some measure attributable to the recent announcement that travelling expenses up to 1/- would be defrayed by the Department.

We take this opportunity of expressing our appreciation of this gesture, which has undoubtedly assisted those of our members who are stationed in the more remote parts of this extensive section.

The Treasurer's report was unanimously adopted, and indicated a good balance in hand, due in the main to a large increase in the membership this session. Our members now number sixty.

In declining his nomination to the chair for the forthcoming session, Mr. Gill stated that it was his wish, and be believed that of the Parent Institution, that the Branch should conduct their affairs independently of officers of the supervising grades. He had enjoyed every moment of the two years he had spent with the Branch as its Chairman, but he thought it best at this stage to be allowed to withdraw his nomination in favour of a Junior Section member.

Mr. A. J. Hodgson, who has been Vice-Chairman for the past two years, was elected Chairman for the coming session, and Mr. Gill was unanimously elected an Honorary Life Member of the Branch.

Other officers elected were as follows :—

Vice-Chairman—Mr. G. A. Rutland.
Secretary—Mr. R. A. Kibby.
Treasurer—Mr. S. B. Foot.
Committee—Messrs. F. E. Huckfield, S. Alder, D. G. Bartlett, and J. S. Cox.

The meeting was followed by a dinner at the hotel. Mr. F. W. Gill, occupied the chair, and our guests included the Sectional Engineer, Mr. T. A. Taylor, and many other representatives of the supervising grades. The Toasts included " The Gloucester Branch," " The Parent Institution " and " Our Visitors." Speeches were interspersed with an excellent musical programme by local artistes. The evening was unanimously acclaimed " an undoubted success." There was an attendance of nearly one hundred, and a number of new members were enrolled following an appeal by the Chairman for 100% support of the Branch by the staff eligible.

Manchester Centre

Another very successful session was brought to a close on April 20th, when the reports presented at the Annual General Meeting showed the Centre to be in a flourishing condition.

The election of officers for the forthcoming session resulted as follows :—

Chairman—Mr. R. Kibble.
Vice-Chairman—Mr. J. A. Barrass.
Hon. Secretary—Mr. R. S. I. Ogden.
Hon. Treasurer—Mr. R. R. Gaythorpe.
Hon. Assistant Secretary—Mr. A. R. Powell.
Committee—Messrs. Hodson, Potts, Pratt, Watson, and Whitehead.

It was agreed to reduce the annual subscription for Youths-in-Training and Labourers to 1/-, and it is hoped that increased membership will result.

A further Essay Competition will be held on the same lines as last session. The closing date will be 30th September, 1936, and three prizes of £1 1s. 0d. each and a Certificate of Merit will again be offered. Essays should be in the hands of the Local Secretary on or before the above date.

Book Reviews

" Advanced Laboratory Practice in Electricity and Magnetism." E. M. Terry, Ph.D., and H. B. Wahlin. 318 pp. 175 ill. McGraw Hill. 18/-.

This book, originally published in 1922 by Dr. Terry, has been revised by Dr. Wahlin and now appears in its third edition. It is stated to be based on the third year electrical engineering course at the Wisconsin University, U.S.A., where Dr. Terry is the late professor and Dr. Wahlin the present professor of Physics.

The course differs considerably from those in British universities for, although the student is expected to have a moderate knowledge of the calculus and complex algebra, his electrical knowledge is assumed to be very scanty since the course commences with lectures and experiments on units, galvanometers and simple bridge measurements. Despite this, before the year is completed, the student is performing experiments on transients, the measurement of electronic charge, photometry and the modulation of high frequency currents.

Naturally with such a large field to cover much is omitted and from the engineer's viewpoint much of value. Little is mentioned of the practical applications of the various effects and phenomena. Generators and motors perhaps have no place in a text-book on Electricity and Magnetism, but it is a little surprising to find no mention of the Carson Modulator, for example, in the chapter on modulators.

As the title indicates, the authors believe in illustrating their lectures with practical work and 52 experiments are included. They cover a most interesting range and the course would undoubtedly prove of great interest and value to the student who wishes to acquire a general knowledge of electrical properties, but is not planning to earn his living as an electrical engineer.

H.L.

" Les Installations Télégraphiques." J. Jacob, 1936. Dunod 92, rue Bonaparte (VI), Paris. 542 pp. 384 ill.

This text-book has been written for student engineers taking the course corresponding to its title at the Ecole Superieure des Postes et Télégraphes.

The treatment is elementary and non-mathematical and conforms with the telegraph definitions and standards laid down by the C.C.I.T.

In addition to chapters on relays, power and the more historic types of apparatus, submarine telegraphy, phototelegraphy, teleprinters, sub-audio and super audio systems, voice frequency systems, subscriber telegraphy and radio are all given some space in a book covering a very wide field.

In spite of the complete modernization of telegraphs in the British Isles and the standardization of teleprinters and voice frequency methods, this book should be of use to British students of telegraphy generally, and of particular value to those who wish to improve their knowledge of the technical French on the subject.

L.H.H.

" Radio Receiving and Television Tubes." J. A. Moyer, S.B., A.M., and J. F. Wostrel. Third edition. 635 pp. 487 ill. McGraw-Hill. 24/-.

The scope of this volume is rather more than might be imagined from a glance at its shortened title for it includes applications of vacuum tubes for distant control of industrial processes and precision measurements.

The authors state in their introduction that information that is no longer of general usefulness to designers has been omitted, but include much matter, particularly in Chapter 3, which might well have been consigned to a handbook or remembered by a designer. Throughout the book there appears to be some confusion between cycles and cycles per second; in one place kilocycles are converted into cycles per second. Confusion will also be caused by such statements as that on p. 421 that " the amount of power then is equal to the decibel value *times* the level value "; the level value being the reference datum, actually specified in watts or milliwatts in the text. Again on p. 440 it is stated that a signal voltage has *several* sidebands whereas, as stated a little later in the same paragraph, it has two.

In spite of the prominence given to television in the title only some 30 out of 635 pages are given to television tubes. More space than this is given to the industrial application section. Presumably the title given to Fig. 485 is not meant to be taken too seriously!

The book contains much matter of interest to those studying vacuum tubes and their applications.

A.H.M.

" Measurements in Radio Engineering." F. E. Terman, Sc.D. 400 pp. 210 ill. McGraw Hill. 24/-.

This is a companion volume to the author's book " Radio Engineering," and deals comprehensively with measuring methods and apparatus.

It gathers together information on measuring techniques and equipment and thereby will be of value to the radio engineer whilst for the student it presents in an organized and systematic form, a complete picture of the laboratory methods and measuring equipment ordinarily used in radio and allied fields.

Emphasis has been placed upon detailed laboratory experiments suitable for use in university courses devoted to radio and students taking such a course will find this volume of great use and value.

J.R.

" The Mechanical Properties of Tin-base Alloys." By D. J. Macnaughtan and B. P. Haigh. International Tin Research and Development Council.

To meet modern requirements, there is considerable opportunity for the improvement of such tin-base alloys as pewters, solders and bearing metals. This publication reviews some of the investigations, completed and in progress, which are being carried out on these materials on behalf of the Council.

As is the case with lead and its alloys, the rate of straining in the tensile test and the time of loading in the hardness test have a profound effect on the results obtained. A special technique is being developed for the measurement of these properties and details of this are given.

Tin-base bearing metals and solders are liable on occasions to fail in " fatigue," and some fatigue results on alloys used in the former application are given. The phenomenon of " creep " in tin alloys, especially with regard to solders is being investigated.

The paper concludes with a summary of some mechanical properties obtained on alloys of tin, which up to the present have not been in commercial use.

This publication gives an excellent idea as to the amount of work now being done to improve the properties of many tin-base alloys, which play so important a part in engineering practice.

E.V.W.

Staff Changes

PROMOTIONS.

Name.	From.	To.	Date.
Davis, H. G. ...	Power Engr., Scot. Region	Regional Engr., Scot. Region	1-5-36
Ireland, W.	Exec. Engr., Scot. East ...	Efficiency Engr., Scot. Region	4-3-36
Williams, L. E.	Asst. Engr., E.-in-C.O. ...	Power Engr., Scot. Region	1-6-36
Meek, L.	Asst. Engr., London	Actg. Exec. Engr., E.-in-C.O.	1-6-36
Casemore, G. ...	Asst. Engr., S. Eastern	Actg. Exec. Engr., S. Eastern	1-7-36
Whittaker, A. W.	Chief Insp., London	Asst. Engr., London	3-4-36
Riley, C.	Chief Insp., E.-in-C.O.	Asst. Engr., E.-in-C.O.	3-4-36
Winch, B.	Chief Insp., E.-in-C.O.	Asst. Engr., E.-in-C.O.	3-4-36
Coote, F.	Chief Insp., Scot. East	Asst. Engr., Scot. Region...	31-12-35
Mills, A. D.	Chief Insp., E.-in-C.O.	Asst. Engr., Scot. Region...	1-5-36
Jackson, A. G.	Insp., S. Lancs.	Chief Insp., S. Lancs.	23-2-36
Blower, W. M.	Insp., N. Wales	Chief Insp., N. Wales	1-8-35
Cleary, H.	Insp., S. Lancs.	Chief Insp., N.E. Region...	10-5-36
Davies, R. C....	Insp., S. Lancs.	Chief Insp., S. Lancs.	6-2-36
Naylor, W. H. G.	Insp., E.-in-C.O.	Chief Insp., E.-in-C.O.	26-2-36
Cattle, F.	Insp., E.-in-C.O.	Chief Insp., Test Sec., London	1-6-36
Brown, A. H.	Insp., N. Midland ...	Chief Insp., N. Midland ...	18-3-36
Wells, H. G.	Insp., London	Chief Insp., London	11-2-36
Knee, H.	Insp., S. Western ...	Chief Insp., S. Western	22-3-36
Curling, T. N.	Insp., London	Chief Insp., London	1-6-36
Matthews, R. F.	Insp., London	Chief Insp., London	14-4-36
Rudeforth, S.	Insp., E.-in-C.O.	Chief Insp., E.-in-C.O.	12-1-36
Hey, H. E.	Insp., N.E. Region...	Chief Insp., N.E. Region...	15-3-36
Barrett, H.	Insp., London	Chief Insp., London	1-6-36
Waters, H. S.	Insp., E.-in-C.O.	Chief Insp., E.-in-C.O.	25-4-36
Brock, W. P.	Insp., London	Chief Insp., Eastern	3-6-36
Pettitt, V. R.	Insp., London	Chief Insp., E.-in-C.O.	24-5-36
Birch, S.	Insp., E.-in-C.O.	Chief Insp., E.-in-C.O.	31-5-36
Joyce, R. M. ...	Insp., E.-in-C.O.	Chief Insp., E.-in-C.O.	15-1-36
Collett, W. A.	Insp., E.-in-C.O.	Chief Insp., E.-in-C.O.	19-4-36
Corkett, H.	Insp., E.-in-C.O.	Chief Insp., E.-in-C.O.	4-2-36
Jeynes, E. H....	Insp., E.-in-C.O.	Chief Insp., E.-in-C.O.	22-3-36
Ovenall, E. W.	Insp., N. Wales	Chief Insp., N. Wales	1-3-36
Whittingham, L.	Insp., N. Wales	Chief Insp., N. Wales	24-5-36
Rance, A. W....	Insp., Eastern	Chief Insp., Eastern	3-5-36
Haliburton, F. C.	Insp., E.-in-C.O.	Chief Insp., E.-in-C.O.	14-4-36
Thomas, C. F.	Insp., E.-in-C.O.	Chief Insp., E.-in-C.O.	24-5-36
Markby, E. J.	Insp., London	Chief Insp., London	24-5-36
Pyrah, F.	Insp., E.-in-C.O.	Chief Insp., E.-in-C.O.	1-6-35
Hudson, H.	Insp., N.E. Region...	Chief Insp., N.E. Region...	1-2-36
Proudfoot, G.	Insp., Scot. Region	Chief Insp., Scot. Region...	22-9-35
England, A. G.	Insp., Scot. Region	Chief Insp., Scot. Region...	30-4-36
Bucknall, F. R. B. ...	Insp., Scot. Region	Chief Insp., Scot. Region...	1-5-36
Doughty, R. S.	Insp., Scot. Region	Chief Insp., Scot. Region...	6-2-36
Townsend, S. B.	A.T.O., N. Midland	Reg. M.T.O., N.E. Region	1-4-36
Wood, E. W. ...	A.T.O., S. Western	Reg. M.T.O., Scot. Region	1-4-36
Huxley, R. T.	Tech. Asst., London	M.T.O., Cl. III., E.-in-C.O.	17-5-36
Finney, C. W.	Tech. Asst., London	M.T.O., Cl. III., E.-in-C.O.	1-4-36
Williams, S. A.	Mech.-in-Chge, Gde. I., S. Wales	Tech. Asst., N. Wales	1-4-36
Turner, C. W.	S.W.I., S. Eastern...	Insp., S. Eastern ...	9-2-36
Padgham, F. S.	S.W.I., S. Midland...	Insp., S. Midland ...	8-3-36
Pratchett, C. ...	S.W.I., S. Midland...	Insp., S. Midland ...	28-3-36
Maslin, A. E. W.	S.W.I., S. Midland...	Insp., S. Midland ...	27-3-36
Fable, F. P. ...	S.W.I., S. Midland...	Insp., S. Midland ...	8-3-36
Plant, F.	S.W.I., S. Lancs. ...	Insp., S. Lancs.	18-1-36
Roberts, W. E. C. ...	S.W.I., S. Western...	Insp., S. Western ...	28-3-36
Brooks, C. W.	S.W.I., Eastern	Insp., Eastern ...	3-5-36
Kilvert, F. R.	S.W.I., S. Lancs. ...	Insp., S. Lancs.	19-2-36
Cleary, C. L. ...	S.W.I., N. Western	Insp., N. Western ...	4-4-36
Anderson, S. D.	S.W.I., S. Wales ...	Insp., S. Wales	To be fixed later.
Brewer, F.	S.W.I., S. Wales ...	Insp., S. Wales	,,
Chapman, C. J. W. ...	S.W.I., S. Wales ...	Insp., S. Wales	,,
Collins, G. A.	S.W.I., S. Wales ...	Insp., S. Wales	,,
Ellis, R.	S.W.I., S. Wales ...	Insp., S. Wales	,,
Aggett, E. H....	S.W.I., S. Western...	Insp., S. Western ...	4-2-36
Parker, A. S....	S.W.I., N. Wales ...	Insp., N. Wales	1-5-36
Owen, G. I. ...	S.W.I., N. Wales ...	Insp., N. Wales	17-5-36
Bowers, R.	S.W.I., N. Wales ...	Insp., N. Wales	17-5-36
Reeve, L. J. A.	S.W.I., N. Wales ...	Insp., N. Wales	9-10-35
Painter, C. H.	S.W.I., N. Wales ...	Insp., N. Wales	1-2-36
Oliver, W.	S.W.I., N. Ireland	Insp., N. Ireland ...	8-10-35
Mullard, R.	S.W.I., Test Section, B'ham	Insp., Test Section, B'ham	To be fixed later.
Snow, H. F. ...	S.W.I., Test Section, London	Insp., Test Section, London	,,
Andrewartha, C. J. ...	S.W.I., Test Section, B'ham	Insp., Test Section, B'ham	,,

PROMOTIONS—continued.

Name.	From.	To.	Date.
Davies, H. V. G.	S.W.I., S. Western...	Insp., S. Western	22-12-35
Wildig, A.	S.W.I., N. Wales	Insp., N. Wales	1-4-36
Davies, N. S.	S.W.I., S. Wales	Insp., S. Wales	To be fixed later.
Wall, C. G.	S.W.I., S. Wales	Insp., S. Wales	,,
Leech, W. H....	2nd Offir, H.M.T.S. " Monarch "	Chf. Offir., H.M.T.S. "Monarch "	1-4-36
Paines, H. V....	3rd Offir., H.M.T.S. " Monarch "	2nd Offir., H.M.T.S. " Monarch "	1-4-36
Troops, A. E....	4th Offir., H.M.T.S. " Monarch "	3rd Offir., H.M.T.S. " Monarch "	1-4-36

TRANSFERS.

Name.	Rank.	From.	To.	Date.
Morgan, J.	Regl. Engr.	Scot. Region ...	A.S.E., S. Western...	1-5-36
Pitcairn, A. C.	Asst. Engr.	London	E.-in-C.O.	14-3-36
Anderson, E. W.	Asst. Engr.	S. Western	E.-in-C.O.	29-3-36
Wood, A. E.	Asst. Engr.	London	E.-in-C.O.	1-4-36
Harrison, G. B. W.	Asst. Engr.	Eastern	E.-in-C.O.	23-3-36
Hayes, H. C. S.	Asst. Engr.	S. Lancs.	E.-in-C.O.	5-4-36
Swift, A. E.	Asst. Engr.	E.-in-C.O.	S. Eastern	5-4-36
Beach, W. R.	Asst. Engr.	S. Eastern	E.-in-C.O.	26-4-36
Pate, H. S.	Asst. Engr.	E.-in-C.O.	S. Eastern	10-5-36
Alderson, A. H.	Asst. Engr.	N.E. Region ...	E.-in-C.O.	26-4-36
Knowers, A. D. V.	Asst. Engr.	E.-in-C.O.	Eastern	20-5-36
Towers, R.	Asst. Engr.	Baldock Radio ...	London	24-5-36
Shepherd, J.	Proby. Asst. Engr....	Baldock Radio ...	S. Western	22-3-36
Seaman, E. C. H.	Proby. Asst. Engr....	Eastern	E.-in-C.O.	22-3-36
Taylor, F. J. D.	Proby. Asst. Engr....	S. Wales	E.-in-C.O.	10-4-36
Fairweather, A.	Proby. Asst. Engr....	London	E.-in-C.O.	12-4-36
Trott, L. J.	Proby. Asst. Engr....	S. Western	S. Wales	20-4-36
Luckhurst, J. E.	Chief Insp.	Cupar Radio ...	Baldock Radio ...	17-5-36
Haliburton, F. C.	Insp.	N. Midland	E.-in-C.O.	14-4-36
Ball, F. T.	A.T.O.	Scot. Region ...	N. Midland	17-5-36
West, P. S.	Tech. Assistant ...	N. Wales	London	13-4-36
Palser, F. D.	M.T.O., Cl. III. ...	E.-in-C.O.	London	1-4-36
Collman, E. L.	M.T.O., Cl. III. ...	London	S. Western	1-4-36
Leech, W. H....	Chief Officer ...	H.M.T.S. " Alert "	H.M.T.S. "Monarch"	26-3-36
Jago, D. V.	2nd Officer	H.M.T.S. "Monarch"	H.M.T.S. " Alert "	26-3-36
Jones, C. W.	Insp.	E.-in-C.O.	N. Western	17-5-36
Horner, F. H.	Insp.	E.-in-C.O.	N.E. Region ...	24-5-36

RETIREMENTS.

Name.	Rank.	District.	Date.
Rattue, A.	Asst. Suptg. Engr.	S. Western	30-4-36
Bell, J. H.	Asst. Suptg. Engr.	London	31-5-36
Balchin, G.	Exec. Engr.	S. Eastern	30-4-36
Watson-Weatherburn, S. W. ...	Exec. Engr.	N. Midland	31-5-36
Preston, E. L.	Exec. Engr.	S. Wales	30-4-36
Brentini, J.	Asst. Engr.	E.-in-C.O.	27-5-36
Pooley, R. E....	Asst. Engr.	Test Sec., London	31-5-36
Neal, W. A.	Asst. Engr.	London	31-5-36
Hyde, J.	Chief Insp.	N.E. Region	30-4-36
Leete, J. T.	Chief Insp.	London	31-5-36
Clothier, W.	M.T.O., Cl. III.	E.-in-C.O.	16-5-36
Hawes, J.	Insp.	London	31-3-36
Rogers, H.	Insp.	London	31-3-36
Reid, A. F. C.	Insp.	N. Western	1-5-36
Taylor, W. E.	Insp.	N. Wales	31-3-36
Perkins, C. L.	Insp.	S. Midland	5-5-36
Lygo, E.	Insp.	S. Lancs.	31-3-36
Yewen, W. A....	Insp.	London	7-4-36
Thomas, A. C.	Insp.	N. Wales	10-4-36
Hayward, W. J.	Insp.	London	30-4-36
Hughes, J. H.	Insp.	N. Wales	30-4-36
Price, E. F.	Insp.	N. Wales	30-4-36
Martin, C. J.	Insp.	Eastern	2-5-36
Lodge, A. A.	Insp.	London	8-6-36
Thompson, H.	Insp.	Eastern	3-5-36
Blackpool, F. W.	Insp.	London	31-5-36
Ross, C.	Insp.	London	31-5-36
Roberts, F. R.	Chief Officer	H.M.T.S. " Monarch "	31-3-36

DEATHS.

Name.	Rank.	District.	Date.
Saunders, F. J.	Exec. Engr.	London	5-5-36
Bromley, F. G.	Insp.	Test Section, London	24-3-36

APPOINTMENTS.

Name.	From.	To.	Date.
Ince, W. C.	S.W.II., Test Section, London ...	Proby. Insp., E.-in-C.O.	1-5-36
Warner, H. F.	S.W.II., London	Proby. Insp., E.-in-C.O.	1-5-36
Chaplin, H. T.	S.W.II., London	Proby. Insp., E.-in-C.O.	1-5-36
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Weaver, E. W.	Proby. Insp., London	Insp., London	1-6-36
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Bullock, C.	H.C.O.	N. Midland	22-4-36
Thomas, F.	Clerk, 2nd Class	E.-in-C.O.	30-4-36
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Mackrill, A. H.	H.C.O.	Eastern	30-6-36

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Goodway, T. C.	C.O., E.-in-C.O.	Actg. Exec. Officer, E.-in-C.O. ...	11-2-36
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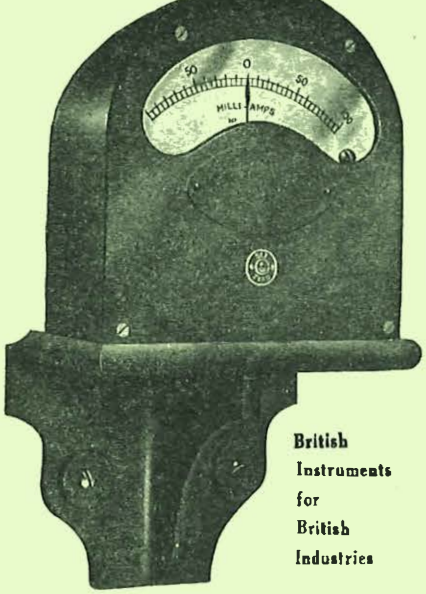

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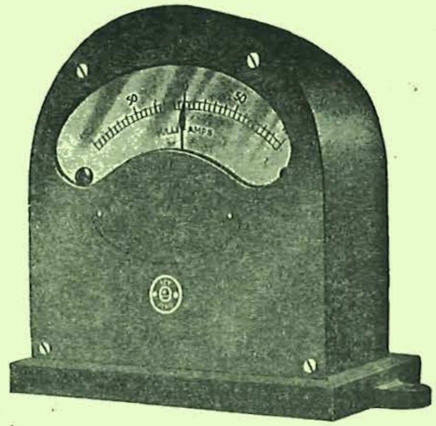

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