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Replacement of London Toll Exchanges

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This article describes the new London Toll A and B exchanges and shows how a large proportion of the Toll circuits have been converted to automatic switching.

The First London Toll Exchange.

IN 1921 it became necessary to relieve the London Trunk exchange, and it was decided to open a new exchange called Toll to deal with traffic between London and the nearer provincial exchanges. This exchange was designed to work on a no-delay basis as distinct from delay working then in force on trunk circuits. The service was very popular with subscribers and the traffic grew to such an extent (approximately 20 per cent. per annum) that by 1925 available accommodation was rapidly becoming exhausted. Consideration was therefore given to the best means of relieving the position and it was decided to open a second Toll exchange to deal with outgoing traffic from London, the existing exchange being used for traffic incoming to London. In December, 1927, this second Toll exchange, designated Toll A, was opened, and the first exchange was renamed Toll B.

Since the introduction of demand working on trunks the difference between trunk and toll working is not so marked, but differences exist in that Toll continues to deal with the shorter distance circuits and the operating procedure is different. Toll circuits are also provided on a more liberal basis than trunk circuits.

FIG. 1.—LONDON TOLL AREA SHOWING GROUP CENTRES.

Area Served by London Toll Exchanges.

The area covered by the original London Toll exchanges has been extended as more routes were brought into the no-delay service. At the present time the area extends over the counties of Kent, Surrey, Sussex, Middlesex, Hertford, Essex, Bedford, and part of Hampshire, Berkshire, Bucks and Suffolk, and includes 36 out of the 48 group centres in the London zone (Fig. **1**). The Toll exchanges are directly connected to all the group centres in this area and also to a large number of minor exchanges to or from which routes are justified by the volume of traffic. Traffic to or from exchanges which are not directly connected circulates in accordance with scheduled routing instructions, via intermediate routing centres.

As mentioned previously, Toll A deals with traffic outgoing from London to exchanges in the toll area and Toll B with incoming traffic to London from these exchanges. In this connection the boundary of "London" is a circle of 10 miles radius round Oxford Circus. Besides traffic to and from London there is also traffic between exchanges in the toll area. This is passed through Toll A. Brighton to Ipswich, Wallington to Canterbury, etc., are typical examples.

This traffic compared with that outgoing from London is small.

It must be explained that Toll A and B are purely switching centres, the Toll A or B operator normally taking no part in the control of a call. The operating procedure for a call, circulating via either of the toll exchanges, places the control of the call, i.e. timing, etc., in the hands of an operator at the local exchange. Access to this local operator is obtained on automatic exchanges in the London director network by dialling TOL. It will be seen later, however, that in the new Toll A exchange provision has been made for the control to be exercised by the Toll A operator if it becomes necessary to work routes on a delay basis.

Reason for Replacement of Toll A and B.

The main aims of the replacement were to put as much as was practicable of the traffic on an automatic basis so reducing the operating staff employed in the centre of London and to house the exchanges in strongly protected accommodation. Although replacement of the Toll exchanges at the present time is essentially a war measure, plans were already in hand before the war which provided for an automatic toll equipment, and the design of the new Toll A exchange has been arranged so that it will fit into the ultimate scheme after the war.

Toll A Replacement

Old Toll A Manual Exchange.

The old Toll A manual exchange was a 50 V equipment operated on a straightforward junction basis (S.F.J.). An operator at a local exchange, on receiving a demand for a call to an exchange inside the toll area, consulted her routing booklet to ascertain whether she could obtain direct connection through Toll A to the required exchange, or whether she should ask Toll for an intermediate routing centre. She then selected a junction to Toll A and, on receipt of a three-pip signal from the S.F.J. position, passed the demand to the Toll A operator who connected the plug-ended incoming junction to an outgoing circuit in the multiple and was then finished with that particular call. The local operator passed her demand when the distant operator answered.

Outline of new Scheme.

As previously stated, the main object in replacing Toll A was to convert as many as possible of the toll lines to work on an automatic basis. As will be seen from the operating procedure described above for old Toll A, the Toll operator merely performed a switching operation. Plans were made, therefore, to install automatic switching equipment to replace the Toll A operators. It was decided to work the incoming lines to this equipment loop dialling and the outgoing lines from the levels on a C.B. signalling basis to the distant manual boards. As only C.B. signalling circuits had at that stage been developed for signalling from automatic levels, it was decided that lines requiring differential, or generator signalling, together with any incoming lines unsuitable for loop dialling, would be terminated on an associated sleeve control manual board. This manual board was also to be capable of controlling traffic for "delay working" under cable breakdown conditions.

To determine the suitability of the existing lines for automatic working, impulsing and signalling limits were determined. An analysis was then made of the signalling paths of all incoming and outgoing Toll A lines to ascertain whether there was a complete metallic loop and whether the loop resistance fell within the limits determined. As it was desired to switch as much traffic as possible automatically, the limits were set as high as was considered consistent with satisfactory operation. As a result of these investigations it was found that 95 per cent. of the lines could be worked on the automatic plant, leaving only 5 per cent. to work on the manual board.

Toll A Automatic Exchange.

The automatic switching equipment provided at Toll A consists of three ranks of group selectors, the 2nd and 3rd selector levels carrying the routes to distant exchanges. The number of levels provided for outgoing routes is 226, of which 189 are in use for routes to the Toll area and nine are used for special services. The equipment is of the 2,000 type and the main items are as follows :—

Switching equipment.

1st Selectors	(200 outlet)	3,294
2nd ,,	(,,)	3,183
3rd ,,	(,,)	1,319

Relay sets.

Dialling out to C.B. exchanges	1,920
,, ,, C.B.S. ,,	240
,, ,, Sleeve Control exchanges	600
Assistance type	600

Incoming circuits are worked loop dialling and terminate on 1st selectors. C.B. signalling is employed on all outgoing routes from the automatic equipment and all these lines terminate on distant manual boards. Each outgoing circuit from Toll A is equipped with a suitable relay set, the main functions of which are (1) to hold the selector train, (2) to transmit a calling signal, (3) to relay supervisory signals to the calling operator, and (4) on lines to C.B.S. and Sleeve Control exchanges to guard the level outlet against re-seizure until the plug is removed from the answering jack. On circuits to C.B. exchanges a "follow on" call is permitted to seize an outlet although a plug may still be in the answering jack. Under these conditions the operator receives a recall signal.

The operating procedure under the automatic conditions is as follows :

A subscriber desiring a Toll call passes his demand to the local manual board operator. If he is a subscriber connected to an automatic exchange in the London Director area he would dial "TOL" to reach the local auto-manual board. The operator then consults a routing booklet to determine the routing and the code to be dialled into the automatic Toll A to reach the desired exchange. This code will consist of two or three numerical digits. Having dialled the appropriate code the local manual operator passes her demand when the distant operator answers, an d so the connection is completed under the control of the local originating operator. Fig. 2 illustrates the routing of a call from a London subscriber via automatic Toll A to a subscriber connected to an exchange in the Toll area.

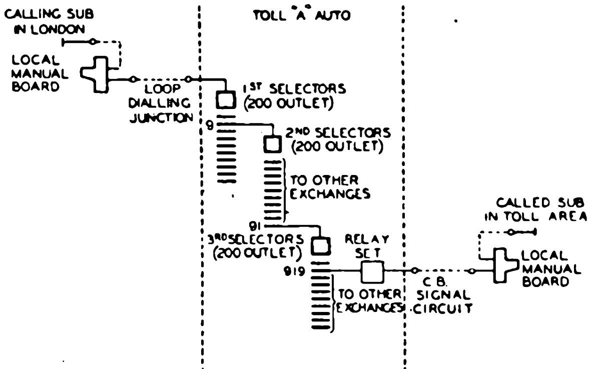

Fig. 2.—Routing of a Call via Automatic Toll A.

Outstation Equipment.

Changes of outstation equipment which had to be made to meet the automatic conditions were as follows:

On circuits outgoing to automatic Toll A, loop dialling equipment had to be provided or augmented. Relay sets of a type recently designed were installed at C.B. and C.B.S.2 exchanges; at C.B.S.1 exchanges the terminal apparatus was changed. At some manual exchanges it was also necessary to fit dials. At most sleeve control auto-manual exchanges additional loop dialling relay sets had to be fitted.

On circuits incoming from Toll A the only new equipments required were jack-ended terminations at C.B. exchanges to cater for follow on calls; S.F.J. and sleeve control terminations required no change, and at C.B.S.1 and 2 exchanges modifications only were involved.

At a large number of out-stations it was found possible to work the new terminations, under the old manual conditions, prior to the transfer. This greatly simplified the change-over arrangements.

Toll A Manual Exchange.

As stated earlier, it was not found possible to work all lines on the automatic plant and some are, therefore, accommodated on a new manual board which is of standard sleeve control type. Incoming lines not suitable for dialling work with the normal manual signalling methods and terminate in the answering multiple. Calls received over these circuits are extended by the Toll A operator dialling over 1st selector circuits into automatic Toll A or over direct signalling circuits in the outgoing multiple. Outgoing routes requiring differential or generator signalling and, therefore, unsuitable for working from the levels of the automatic plant, are connected to this manual board multiple. Levels on the automatic plant have, however, been allocated for each of these outgoing routes, but the outlets from these levels are trunked to the manual board via assistance type relay sets.

The allocation of a separate level to each route of this type will enable these routes to be worked direct from the automatic levels, when suitable equipment becomes available, without any disturbance of the codes to be dialled. It also enables a uniform and more efficient method to be applied in dealing with these routes under "delay" conditions. This method of manual board interception has also been applied to routes on which a proportion of the outgoing lines of a route are unsuitable for C.B. signalling. Early choice contacts carry the suitable lines direct and the unsuitable lines are reached over the later contacts of the level via the manual board. This arrangement enables the majority of the traffic to be switched automatically, overflow traffic at peak periods only being routed via the manual board.

Delay Working.

All the manual positions are not in use for dealing with manually worked routes; some are held in reserve for delay working. To deal with a particular outgoing route connected to the automatic plant should this route become overloaded by reason of cable breakdowns or shortage of lines, it is necessary to obtain control of the route at the central point, i.e. Toll A manual board. The reasons for this are as follows:—

(1) So that urgent calls may be given prompt attention.
(2) So that other calls may be dealt with in rotation.

Several schemes were considered whereby this control for delay working could be accomplished, but eventually it was decided that a scheme which enables any route to be taken from the selector levels and patched to a common pool of manual board multiple circuits would best meet the required conditions.

Perhaps the arrangements made can best be illustrated by an example. Assume that the Ipswich route is "in delay." A City subscriber dials "TOL" and the local auto-manual board operator accepts the call for Ipswich.

Assuming that she is not already aware that the Ipswich route is "in delay," she plugs into a free Toll A circuit and dials the Ipswich code. She is answered by a Toll operator who quotes the delay on the Ipswich route. The City auto-manual board operator then clears this connection and advises the subscriber accordingly. If he desires to book the call, she dials a code to reach a record position and books the call with a Toll A booking operator. The ticket prepared is passed to the delay operator who has control of the Ipswich route. The City subscriber is subsequently rung back by the Toll A delay operator when the call matures. The equipment to effect the above arrangement is as follows:—

In the outgoing multiple over the delay positions is a group of multiple jacks which are wired via C.B. signalling relay sets to jacks on a patching frame (Fig. 3) in the test room. These will be referred to as pool multiple circuits. One such circuit is shown on the left of Fig. 4. Every outgoing line connected to the automatic selector levels is wired via a line patching circuit with a jack on the patching frame. It is thus possible by means of a double-ended cord to connect a pool multiple circuit to any outgoing line.

When the external lines are taken away from a level of the automatic plant for delay control it is necessary to divert calls for this level to an operator in Toll A who will advise the amount of delay on the route. A few outlets from each level, therefore, are wired via switching contacts which enables each of these outlets to be diverted to a level patching circuit as shown in Fig. **5**. These level circuits are also equipped with jacks on the patching frame, and by means of a double-ended cord a level outlet may be patched to any one of a group of jacks carrying circuits from the patching frame to the delay quote positions. The remaining outlets from the level are busied.

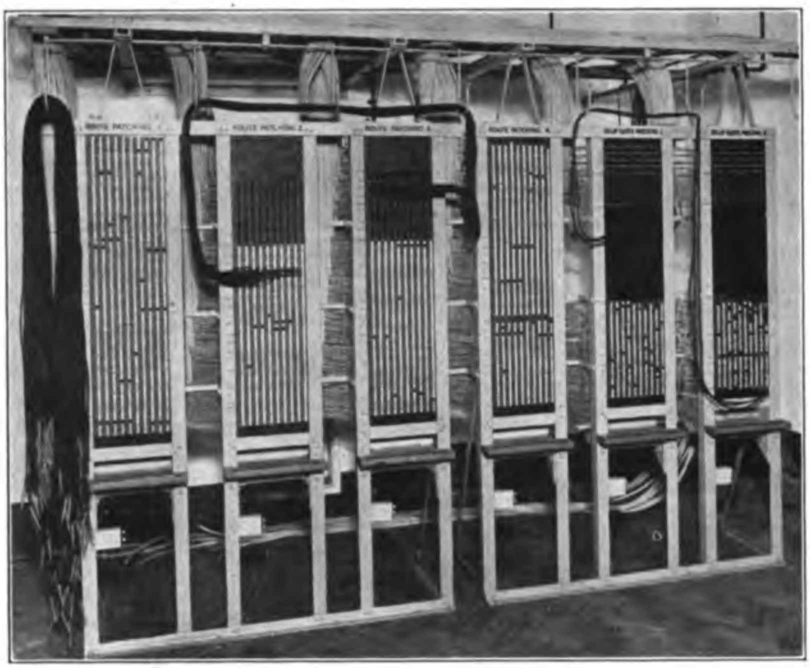

Fig. 3.—Patching Frame.

To return to the Ipswich example again. When the Toll A supervisor decides to put the Ipswich route in delay, she first labels the pool multiple circuits selected to carry the Ipswich lines with the Ipswich code. Labels are also placed against the delay quote circuits on which calls for Ipswich will arrive from the automatic plant. The next step is to request the engineers to patch the sixteen pool multiple circuits to the sixteen Ipswich lines and the level outlets to the delay quote positions. When this has been carried out the supervisor operates the delay key associated with the Ipswich route. The operation of the delay key operates the SW relays (Fig. **5**) associated with level outputs 1–3 (if free) causing them to be switched through to their level patching circuits and thence to the delay quote circuits to which they have been patched. The delay key also causes the operation of the BY relays (Fig. **4**) associated with the remaining outlets 4–16. Earth is then applied to the P wire of each of these outlets at contacts BY2. It will be seen from Fig. **5** that had one of the first three outlets been engaged, when the delay key was operated, the K relay of that particular outlet would have been operated by the normal earth on the P wire from the level relay set. The operation of K relay prevents the operation of the SW relay at contact K3, so preventing any interference with this engaged outlet. When the outlet is free, K relay releases and SW relay then operates, switching the outlet through. Similarly, had one of the outlets 4–16 been engaged when the delay key was operated (Fig. **4**) the relay BY would have been prevented from operating at contact K1. Should a call now arrive on the Ipswich level it is extended via SW2 and 3 operated and patching jacks to the delay quote circuit.

The delay quote operator answers by operating a non-locking key associated with this circuit, and gives the delay on the Ipswich route. The photograph (Fig. **6**) shows a call being answered on the delay quote positions.

As stated previously, the supervisor has requested that sixteen pool multiple circuits be patched to the sixteen Ipswich lines. The delay operators dealing with calls to Ipswich now have exclusive access to these lines. When a plug is inserted in one of the pool multiple circuits relay S operates (Fig. **4**), operating in turn relay CO via the double-ended patching cord. C.B. signalling is now applied to the

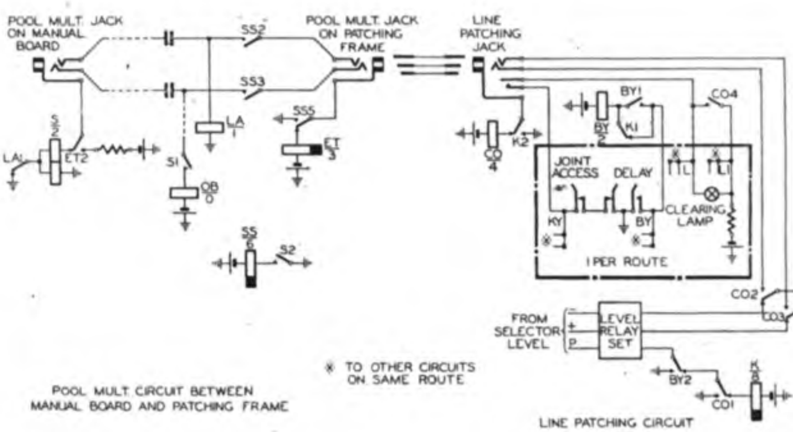

Fig. 4.—Schematic Diagram of Pool Multiple and Line Patching Circuits.

line via contacts SS2 and SS3 and the circuit then functions in the usual manner of a sleeve control manual junction.

When it is desired to resume normal working from the automatic plant, the delay key is restored and the lines, if free, immediately become available from the level again. Relays SW now release and at contacts SW2 and 3, outlets 1–3 are switched through to line. The restoration of the delay key also causes the BY relays (Fig. 4) associated with outlets 4-16 to restore, so removing the guarding earth from the P wires of each of these outlets. The patching cords have now to be removed from the Ipswich route, and this is done by the test room staff. A clearing lamp (Fig. 4) assists this operation by indicating that all the CO relays are normal.

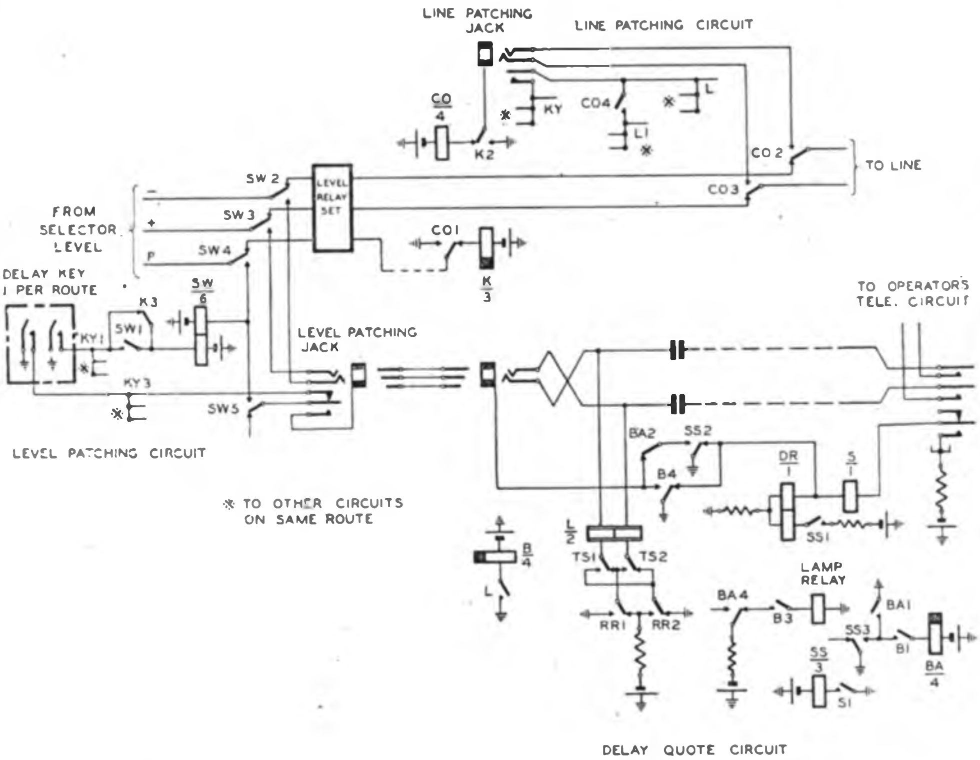

Fig. 5.—Schematic Diagram of Level Patching and Delay Quote Circuits.

It is proposed later to adapt the delay quote arrangements described above for mechanical delay announcing, which was described in last quarter's Journal.

Joint access to routes from the manual board and the level equipment is also possible, if desired, by use of the line patching jacks. A group of pool multiple circuits may be patched to a route it is desired to work on a joint access basis, but in this case the delay key is not operated. A joint access key, however, is operated to disconnect the route clearing lamp. Under these conditions, as will be seen from the diagram, access to lines from the level or from the manual board may be obtained as desired.

Another feature associated with the delay working is the "delay broadcast." This is reached from a level of the automatic plant. This service is used when a number of routes are in delay. Its function is to keep local exchange operators at the larger exchanges apprised of the delay on these routes, so reducing the number of ineffective calls made to Toll A. The broadcast is made by an operator at a multiphone board. Groups of local exchanges, twenty at a time, dial the delay broadcast level at fixed times in accordance with a prearranged programme.

Transfer of Toll A.

The transfer of the Toll A lines to the new automatic exchange and the opening of the new manual board took place successfully on November 14th, 1942.

Toll B Replacement

Old Method of Working.

As previously stated, Toll B deals with incoming traffic to London. On the old manual Toll B exchange incoming circuits were operated on an order wire or jack-ended basis. Outgoing junctions were available to every exchange inside the 10-mile circle. On receipt of a demand for connection to a London manual exchange subscriber, the Toll B operator passed the number over an order wire or signal junction to the operator at the required exchange. Calls to automatic exchanges were passed from Toll B to the local auto-manual board and were dealt with on either jack-ended or key-sender positions. The local London operator completed the connections by 4-digit dialling or key-sending. It will be seen that the originating operator required the assistance of both the Toll B and the objective exchange operator to obtain connection to a London subscriber.

Outline of New Scheme.

As stated above, old Toll B exchange had outgoing junctions to every exchange inside the 10-mile circle. The Trunk automatic exchange also has an outgoing network covering the same area, and as spare capacity was available it was decided that some of the incoming lines to Toll B should be converted to automatic working by accommodating them on this equipment, which would then be a combined Trunk/Toll B exchange. The remaining circuits were to be connected to a new sleeve control manual board with dialling facilities to enable calls to be routed direct into first numerical selectors at London automatic exchanges.

Conversion of Toll B Lines to Automatic Working.

An incoming line to the Trunk automatic equipment terminates on a 2VF relay set which works into a Trunk first code selector. This relay set, in addition to other facilities, provides the transmission bridge. To work Toll B circuits on a loop-dialling basis into this equipment it was necessary to replace the 2VF relay set with one capable of receiving and repeating loop impulses. There existed at Holborn Tandem exchange a surplus of auto-auto repeaters, and it was decided to transfer these to Trunk automatic exchange and thus make loop dialling possible. The number of Toll B routes which could be converted to automatic working was limited by two considerations :

(1) The margin of spare capacity on the Trunk automatic equipment.

(2) The maximum permissible resistance of the Toll circuits for loop dialling. The impulsing conditions are not exactly similar to any existing condition. After some consideration it was decided that the maximum limit which would give satisfactory working was 1,400 Ω.

An analysis was made to select the Toll B circuits with resistances below this limit. As a result of these investigations it was found possible to transfer approximately 620 circuits to the Trunk equipment.

To carry the additional traffic it was necessary to augment the outgoing junction groups from the Trunk exchange selector levels. When this had been completed the conversion of the selected routes was commenced. The change-over to the Trunk equipment was effected in a piecemeal manner, the first route being transferred on September 27th, 1941, and the last route on March 20th, 1942. Operators in the Toll area using these dialling routes for calls to London subscribers connected to automatic exchanges now dial seven digits to reach the required subscriber without the assistance of London operators.

The Trunk automatic exchange network gives access to the automatic exchanges in the 10-mile circle, but not to the manual exchanges. As 85 per cent. of the exchanges in the 10-mile circle are automatic, however, the majority of the traffic can be completed by direct dialling. To dispose of traffic to manual exchanges it was necessary to provide a route from a level of the automatic Trunk exchange to a new sleeve control manual board. This is reached by dialling the code " TLB." The Toll B operator then completes the call on a manual basis. Consideration is being given to the provision of dialling-out facilities to these manual exchanges. Automatic Trunk and Toll B exchange would then provide automatic access to the whole of the exchanges in the London 10-mile area.

Toll B New Manual Exchange.

A new Toll B manual exchange with 99 sleeve-control type positions was installed in a strongly protected building to accommodate the remainder of the incoming lines. Standard C.B. signalling is employed on the bulk of the routes, but differential or generator signalling had to be adopted on a few of the routes on which technical difficulties such as excessive line resistance, absence of a metallic signalling path, etc., prohibited C.B. signalling.

As in the old Toll B exchange, outgoing junctions were provided to every exchange in the 10-mile circle. Instead of terminating on the local auto-manual board or key-sender positions, junctions from Toll B now terminate on 1st numerical selectors. A call for a London subscriber originating at an exchange in the Toll area which works to the new manual Toll B, is passed to the Toll B operator as before. This operator completes the call by direct dialling and does not require the assistance of the objective exchange operator. On calls to manual exchanges in the London area the operating procedure remains unchanged. As mentioned previously, calls to these manual exchanges arriving over Toll B dialling routes are routed via the " TLB " level to the manual board for completion.

The transfer to the new exchange was simplified by the fact that practically all the outgoing junctions to every outstation were set up on spare line plant and equipment. With an outgoing network thus available it was possible to change over the incoming routes as and when convenient. The first batch of routes was transferred on April 25th, 1942, and the last batch on May 8th, 1942, after which date the old exchange was closed.

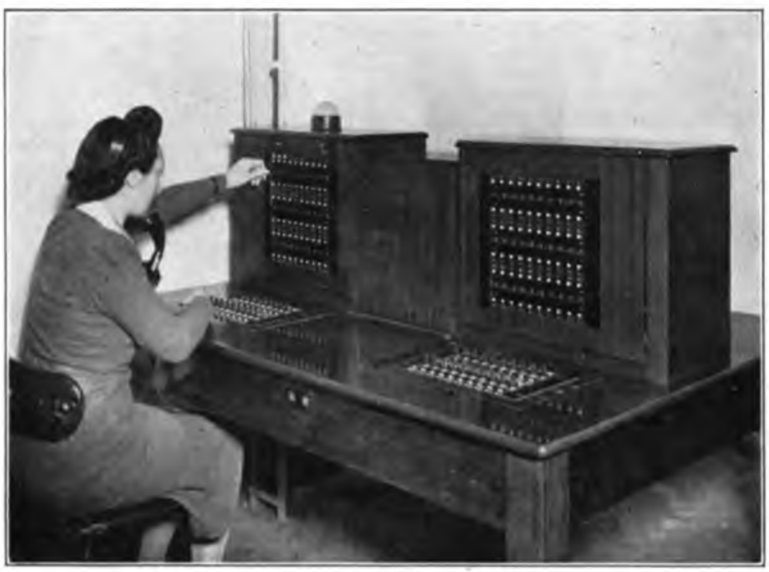

FIG. 6.—DELAY QUOTE POSITIONS.

Conclusion.

The work of replacing the London Toll exchanges was one of some magnitude and the transfer of so many long distance lines to automatic switching was of particular interest. The installation of the new equipment was carried out by Messrs. Standard Telephones & Cables, Ltd., to whom the authors are indebted for the photographs used in this article.

Calculation of Insertion Loss and Phase Change of 4-Terminal Reactance Networks

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U.D.C. 621.391

Concluding the article in the October, 1942, issue, the use of a special slide-rule as an alternative to the loss and phase charts is described, and attention is drawn to a method of correcting the results to allow for dissipation. The accuracy with which characteristics can be predicted is illustrated for four networks, including a tuned transformer and a crystal filter.

Principle of Slide-Rule.

The principle on which the the slide-rule is based will now be considered.

Referring to the skeleton loss charts shown in Fig. **4**, let any given values of X_x/R_t and X_y/R_t

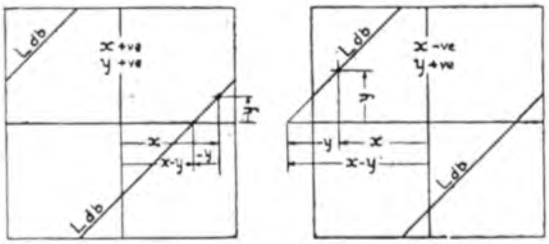

Fig. **4**.—Skeleton Loss Charts.

correspond to x and y units of length measured from the origin along the horizontal and vertical axes respectively. The point to which these values of X_x/R_t and X_y/R_t refer is fixed by a displacement x along the horizontal axis followed by a vertical displacement y. Consider the loss line on which this point falls. As all loss lines have a positive slope of 45° this particular line will cut the horizontal axis, both produced if necessary, x−y units of length from the origin. The converse holds ; the loss corresponding to the given values of X_x/R_t and X_y/R_t is that of the loss line crossing the horizontal axis at a distance x−y from the origin. The usual convention of signs must, of course, be applied in making the measurements.

From an inspection of the chart it will be seen that loss lines disappearing over the left-hand edge reappear on the right-hand side at the same height. In fact, if the chart were wrapped on a cylinder with the vertical edges coinciding, the lines would be continuous at the junction. This makes it unnecessary to produce lines when the length x−y measured from the origin along the horizontal axis extends beyond the edge of the chart. The extra distance may be measured from the opposite edge towards the origin, and the correct loss will be given by the loss line cutting the horizontal axis at this point.

As the scales on the X_x/R_t and X_y/R_t axes are the same, y as well as x may be determined from the former axis. If this is done, all operations will be restricted to the horizontal axis. The chart can therefore be replaced by a line with the X_x/R_t scale marked on one side and the corresponding values of loss for $X_y/R_t = 0$, i.e. the intersections of the loss lines, on the other. It can be seen from the chart that the loss scale will be symmetrical about the centre point and that the same values of loss will be obtained if displacements to the left of this point are substituted by equal displacements to the right. The difficulty of applying the convention of signs in this case can be avoided by remembering the following "rule of contraries": When X_x/R_t and X_y/R_t are of like sign take the positive difference, $|x - y|$; when x and y are of unlike signs take the positive sum, $|x| + |y|$. If $|x| + |y|$ extends beyond the right-hand end of the scale, the extra length can be measured back towards the origin. The other half of the scale is therefore quite unnecessary.

The process of determining $|x|$ and $|y|$ from the X/R scale and finding the loss corresponding to their sum or difference may be carried out on a suitably calibrated slide-rule. If the remaining halves of the X/R and L scales are engraved on a 20-in. rule they will be more than seven times the length of the scales on the chart, as reproduced in the previous article, and can be far more closely and accurately divided. Moreover, any errors in setting the slide-rule are likely to be far smaller than those involved in laying out and reading from the network of lines on the chart. The resulting gain in accuracy is considerable.

Use of Slide-Rule for Loss Calculations.

One form that the slide-rule may take is shown in Fig. **5**, the cursor being omitted to avoid obscuring the scales. For the present the bottom scale should be ignored. The rule may be used for loss calculations in the following way :

X_x/R_t and X_y/R_t of Like Sign. When X_x/R_t and X_y/R_t are of like sign, the sliding, X/R, scale should first be adjusted until its zero corresponds with the infinity mark on the top scale. Of the lengths $|x|$ and $|y|$, corresponding respectively to X_x/R_t and X_y/R_t, whichever is the larger should then be projected from the X/R to the L scale. Leaving the cursor in this position the X/R scale should be moved until the second, smaller, X/R value is covered by the cursor line. The zero on the X/R scale will then be opposite a point on the L scale $|x-y|$ to the right to the infinity mark. This point gives the insertion loss.

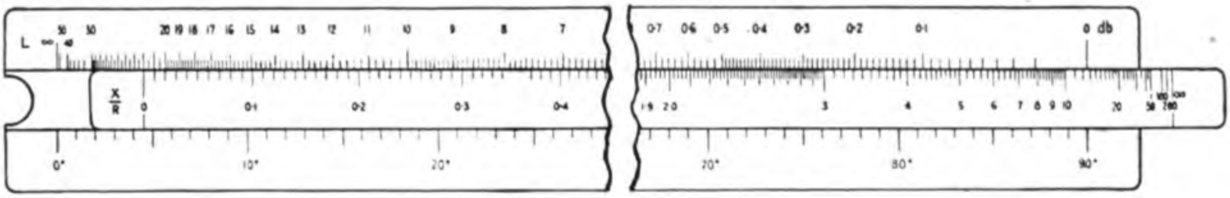

Fig. **5**.—Section of Slide Rule for Loss Calculations.

X_x/R_t and X_y/R_t of Unlike Signs. Two conditions are possible when X_x/R_t and X_y/R_t differ in sign; $|x| + |y|$ may be either less than or greater than the scale length l.

When $|x| + |y|$ is less than l, starting from the left-hand end of the L scale the two lengths should be added by successive projections from the X/R scale, using the cursor. The second setting of the cursor will give the insertion loss.

When $|x| + |y|$ is greater than l the procedure is different; it is necessary, in effect, to fold the extra length $|x| + |y| - l$ back along the L scale from the right-hand end. The final distance from the left-hand end is then $l - \left\{ |x| + |y| - l \right\}$, i.e. $2l - \left\{ |x| + |y| \right\}$. The distance may be determined, however, by adding two lengths, $l - |x|$ and $l - |y|$ in the following way. The sliding scale should be moved until the required X_x/R_t value is opposite the infinity mark on the L scale. On the cursor being set over the right-hand end of the sliding scale it will then mark off a distance $l - |x|$ on the top scale. The required X_y/R_t value should then be adjusted to come under the cursor by moving the sliding scale again. The right-hand end will then come opposite a point on the L scale $2l - \left\{ |x| + |y| \right\}$ from the infinity mark. This point will give the insertion loss.

Use of Slide-Rule for Phase Change Calculations.

Referring back to equation (10) the phase change ψ is given by:

$$\psi = \theta + \phi \pm (1 + 2n)\frac{\pi}{2}$$

The lengths $|x|$ and $|y|$ determined from X_x/R_t and X_y/R_t on the X/R scale are directly proportional to θ and ϕ respectively. If a third scale is provided for turning these lengths into angles it becomes possible to use the slide-rule for finding $\theta + \phi$ and hence ψ. This is the reason for the bottom scale.

X_x/R_t and X_y/R_t of Like Sign. When X_x/R_t and X_y/R_t are of like sign the angle corresponding to $|x| + |y|$ must be found.

If $|x| + |y|$ is less than the scale length, l, the two lengths should be added on the bottom scale, starting from the left-hand end, by successive projections from the X/R scale. The cursor setting for the second projection will give the absolute magnitude of $\theta + \phi$ on the bottom scale. The sign of the angle will be that common to the two X/R ratios.

If $|x| + |y|$ is longer than the scale, one component, say $|x|$, should be projected with the cursor on to the bottom scale, starting from the left-hand end. The right-hand end of the X/R scale should then be brought under the cursor. If the cursor is then moved to the appropriate X/R value for the second component, X_y/R_t say, it will mark off a distance $|x| + |y| - l$ on the bottom scale, corresponding to a reading of $|\theta + \phi - 90°|$. As before, the sign of the angle will be that common to the two X/R ratios.

X_x/R_t and X_y/R_t of Unlike Signs. When X_x/R_t and X_y/R_t differ in sign the reading corresponding to a distance $|x - y|$ along the bottom scale from the left-hand end must be found. The way in which this may be done should be clear by now. The sign given to the angle should be that of the larger of the two X/R ratios.

Application of Method.

In this section examples will be shown of the agreement that can be obtained between computed and measured characteristics in various circumstances.

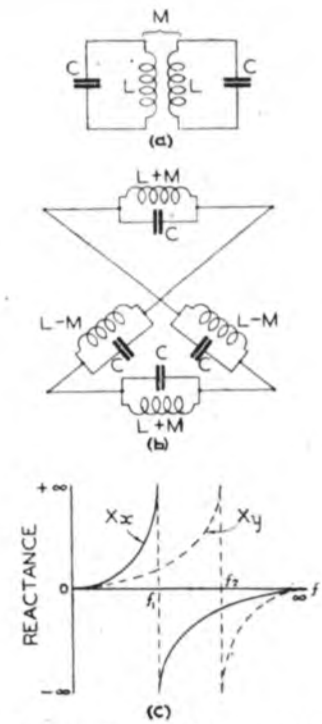

FIG. 6.—TUNED TRANSFORMER AND EQUIVALENT LATTICE.

The tuned transformer shown in Fig. **6** (*a*) is a simple form of band-pass filter in frequent use. It is proposed to show how the insertion loss characteristic can be computed for equal terminating resistances of any value. The circuit of the equivalent lattice network, obtained by applying Bartlett's Theorem [3,4,5] is given in Fig. **6** (*b*), with a sketch at (*c*) showing how the series and lattice reactances, X_x, X_y, vary with frequency. The band, f_1, f_2, within which X_x and X_y differ in sign, is the pass band. It is easy to show that X_x and X_y are given by:

$$X_x = \frac{1}{2\pi C} \cdot \frac{f}{f_1^2 - f^2}, \quad X_y = \frac{1}{2\pi C} \cdot \frac{f}{f_2^2 - f^2}$$

The image impedance, Z_i, is found from:

$$Z_i = -j\sqrt{X_x X_y}$$

and the nominal image impedance R_i is the value Z_i assumes when $f = \sqrt{f_1 f_2}$. Carrying out the necessary substitutions:

$$\frac{X_x}{nR_i} = \frac{1}{n} \cdot \frac{f(f_2 - f_1)}{f_1^2 - f^2}, \quad \frac{X_y}{nR_i} = \frac{1}{n} \cdot \frac{f(f_2 - f_1)}{f_2^2 - f^2}$$

The X/R values for any terminating resistance nR_i may be calculated from these expressions. The insertion loss characteristic and, if required, the phase change characteristic may then be determined using any one of the methods described earlier in the article.

A transformer of this type was made, conforming as closely as possible to the following parameter values: $R_i = 1000\Omega$, $\sqrt{f_1 f_2} = 60$ kc/s, $f_1 = 55$ kc/s. Its insertion loss characteristics were computed and measured for terminations corresponding to $n = 1{\cdot}3$ and $n = 2{\cdot}0$. Dissipation associated with the self inductance of each winding was allowed for by assuming the equivalent parallel resistance as constant

For references 1-13 *see* October, 1942, issue.

and treating it as part of the terminating resistance. No allowance was made for dissipation in the mutual inductance although iron dust cores were used. Nevertheless, the computed and measured characteristics, shown in Fig. **7** (*a*) and (*b*), are in close agreement.

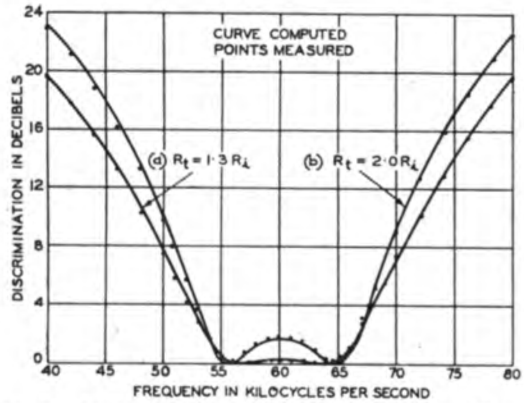

FIG. 7.—INSERTION LOSS CHARACTERISTICS OF TUNED TRANSFORMER.

For the sake of completeness expressions for the transformer elements are given explicitly below :

$$C=\frac{1}{2\pi R_1\,(f_2-f_1)}\cdot L=\frac{1}{8\pi^2 C}\left(\frac{1}{f_1^2}+\frac{1}{f_2^2}\right)\cdot M=\frac{1}{8\pi^2 C}\left(\frac{1}{f_1^2}-\frac{1}{f_2^2}\right)$$

The impedance level on one side of the transformer may be changed by a factor F by multiplying the corresponding L and C values by F and 1/F respectively and changing M to $\sqrt{F}$ times its original value. Any insertion loss or phase computations must, of course, be made before the change is introduced.

The second example relates to a band-pass crystal filter of a type that has been described by Mason.[7] When in lattice form the filter has the circuit shown in Fig. **8** (*a*), where the resonators are indicated by

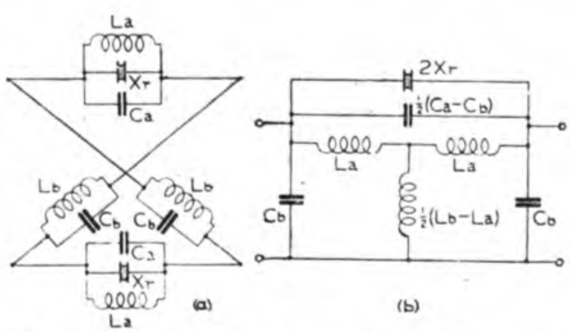

FIG. 8.—EQUIVALENT CRYSTAL FILTER NETWORK.

X_r, proportional to their reactance at any given frequency. Modification of the shape of the insertion loss characteristic by coil dissipation may largely be avoided if the equivalent parallel resistances of all four coils are arranged to be equal, and greater than the resultant effective resistance with which it is desired to terminate the filter. This dissipation then has the same effect as two resistances, each equal to the equivalent parallel resistance of an inductor, one across the input terminals, the other across the output terminals. The external resistances to which the filter is connected should therefore have such a value that, in parallel with the resistances representing coil dissipation, they terminate the filter correctly. This method of resistance compensation is approximate in so far as it ignores losses in the resonator, and it does not allow for changes of equivalent parallel resistance with frequency.

Using Bartlett's Theorem it is easy to show that the bridged-T network in Fig. **8** (*b*) is an unbalanced equivalent of the lattice network, and adding resistance in series with the stem of the T or across the resonator has the same effect as reducing the equivalent parallel resistance of L_b or L_a respectively, in the lattice network. Resistance compensation may therefore be effected in the bridged-T as well as in the lattice network.

In Fig. **9** the computed and measured insertion loss

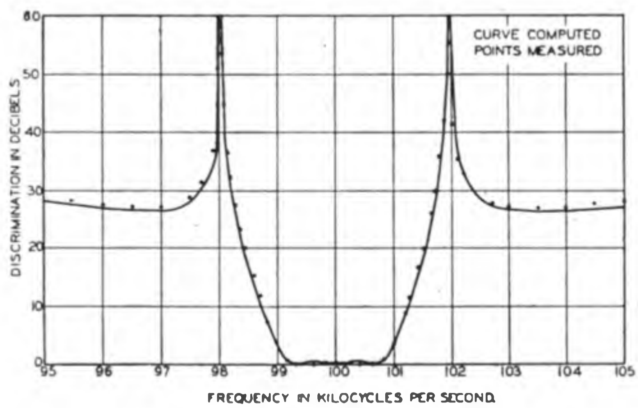

FIG. 9.—INSERTION LOSS CHARACTERISTIC OF CRYSTAL FILTER.

characteristics of a bridged-T filter of this type are compared. In the computations no allowance whatever was made for dissipation. The inductive reactances in the filter were actually realised as two coupled coils with the mutual inductance taking the place of the inductor $(L_b - L_a)/2$ in Fig. **8** (*b*). The resistance compensation was adjusted empirically by adding resistance in the stem of the T until the peaks of attenuation were well defined, and then altering both terminating resistances together until the response in the pass-band was satisfactory.

The two previous examples refer to filters in which resistance compensation was used. When this is not possible dissipation may modify the shape of the insertion loss and phase characteristics considerably. Fortunately, the effect can usually be estimated with reasonable accuracy, starting from the non-dissipative characteristics. In U.S. Patent Specification 2054794 Dietzold quotes the following relationships which appear to have been discovered originally by Bode[14] :

If $\triangle L$ and $\triangle \psi$ are changes in the insertion loss and phase change of a filter due to the introduction of dissipation :

$$\triangle L \fallingdotseq 8{\cdot}7\,\omega\rho\,\frac{\partial\psi}{\partial\omega}\ \text{decibels}$$

$$\triangle\psi \fallingdotseq -\frac{\omega\rho}{8{\cdot}7}\cdot\frac{\partial L}{\partial\omega}\ \text{radians}$$

[14] *See* footnote on p. 83 of Bell Monograph B-1186.

where ω is $2\pi \times$ frequency, ρ is the average power factor of the filter elements, and the derivatives are those for the corresponding dissipationless network.

The former of these two expressions has been used to estimate the effect of dissipation in a filter having

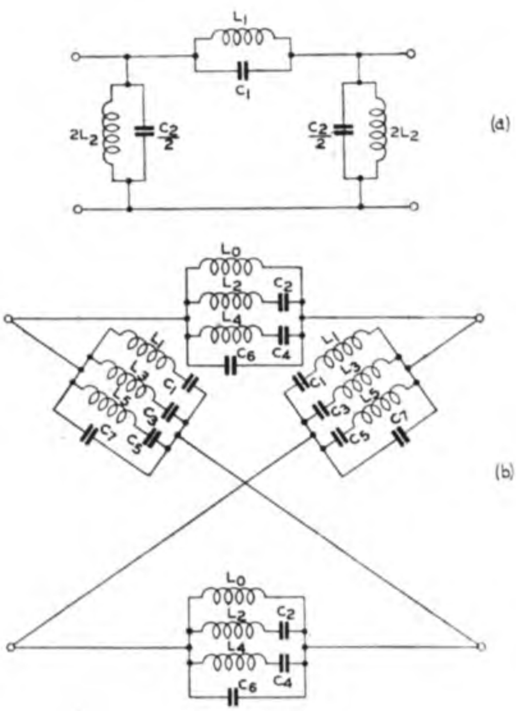

FIG. 10.—FILTERS HAVING THE CHARACTERISTICS SHOWN IN FIGS. 11 AND 12.

the circuit shown in Fig. **10** (*a*). The computed insertion loss characteristic for the non-dissipative case is shown by curve (i) in Fig. **11**, the characteristic obtained by adding a correction computed for an

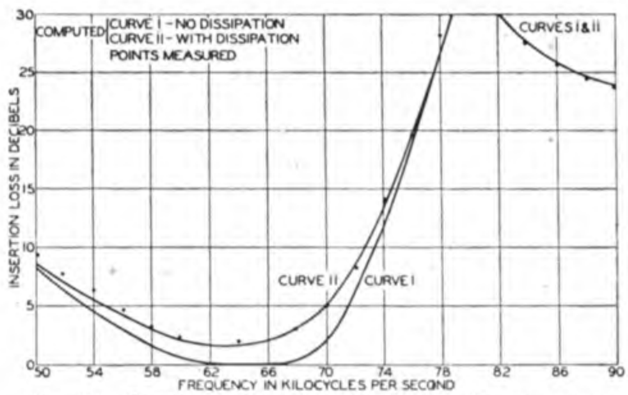

FIG. **11**.—EFFECT OF DISSIPATION ON FILTER PERFORMANCE.

average power factor of 0·017 is shown by curve (ii), while the points represent the measured performance of a filter having the same element values and the same dissipation at the mid-band frequency.

The fourth and final example refers to a low-pass filter designed to have a substantially linear insertion phase characteristic up to and beyond the cut-off. The circuit of the filter is shown in Fig. **10** (*b*). The insertion loss and phase characteristics, computed assuming no dissipation present, are compared with the measured performance in Fig. **12**, curves (*a*) and (*b*) respectively. It will be seen from the results that dissipation does not modify the performance very

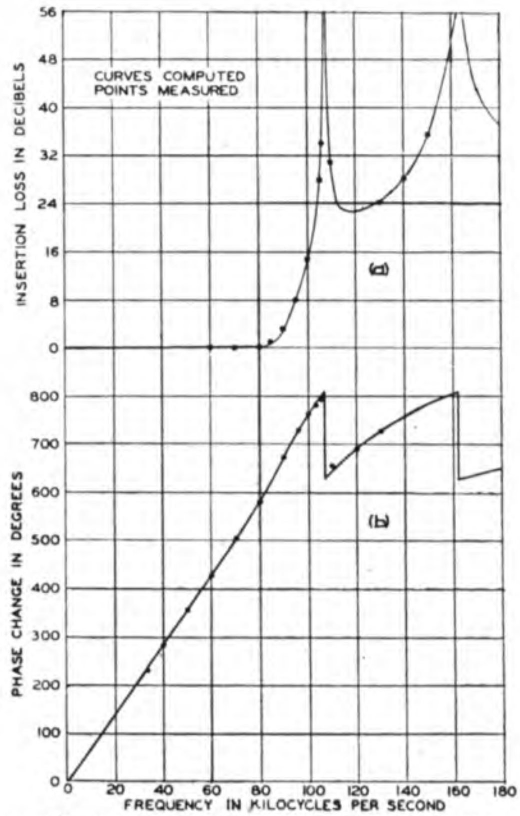

FIG. **12**.—INSERTION LOSS AND PHASE CHANGE OF LOW-PASS FILTER.

much. The insertion loss characteristic is not affected appreciably because, apart from the discontinuities, at no point does the slope of the phase characteristic reach a very high value. It is interesting to note that near the first discontinuity in the computed phase characteristic the measured values depart from the curve in the direction demanded by the expression for $\triangle \psi$ given above.

Conclusions.

A method of computing insertion loss and phase change has been described which is simple in comparison with that normally used, and may be applied to any reactance network capable of being transformed into a symmetrical network plus an ideal transformer. Provided the effects of dissipation can be ignored the method is exact. For relatively low values of loss and where the phase change need not be predicted with great accuracy two charts or a special slide-rule may be used to shorten the calculations. The insertion loss and phase characteristics computed for a non-dissipative network may be corrected approximately to allow for dissipation.

Acknowledgment.

The authors have pleasure in acknowledging their indebtedness to Miss J. M. Elliott for computing the numerical data involved in the preparation of this article.

A Standby Generating Plant

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U.D.C. 621.311

A standby power plant is described which is considerably larger than that normally installed in Post Office buildings. Three diesel engine alternators are installed, each providing a continuous output of 250 kW. The nature of the building involved provided some problems of layout and installation

Introduction.

A STANDBY oil engine plant has recently been installed in a new Post Office building in circumstances which were somewhat unusual so far as the Department is concerned. The building was designed to withstand a certain degree of aerial bombardment and has no openings in the outer walls except the main entrances and certain apertures in connection with the ventilating plant, all of which are protected by blast screens. The building will be fully staffed, and it was therefore necessary to provide artificial ventilation with complete air conditioning to maintain reasonable working conditions. The absence of wall openings also meant that the artificial lighting would be required for the whole of the period during which the building was occupied.

This entire dependence of the ventilation and illumination in the building upon artificial sources caused considerably greater importance than is normally the case to be attached to the continuance of the power supply. The conclusion was reached that, although the power supply could normally be obtained from either of two separate sources, this was not sufficient safeguard under present conditions to ensure that under no circumstances would there be a power supply failure for a period exceeding about five minutes.

It was therefore decided that a complete standby generating plant driven by a prime mover, installed within the building itself and capable of supplying the whole building load continuously, was essential, and it is this plant which is discussed in this article.

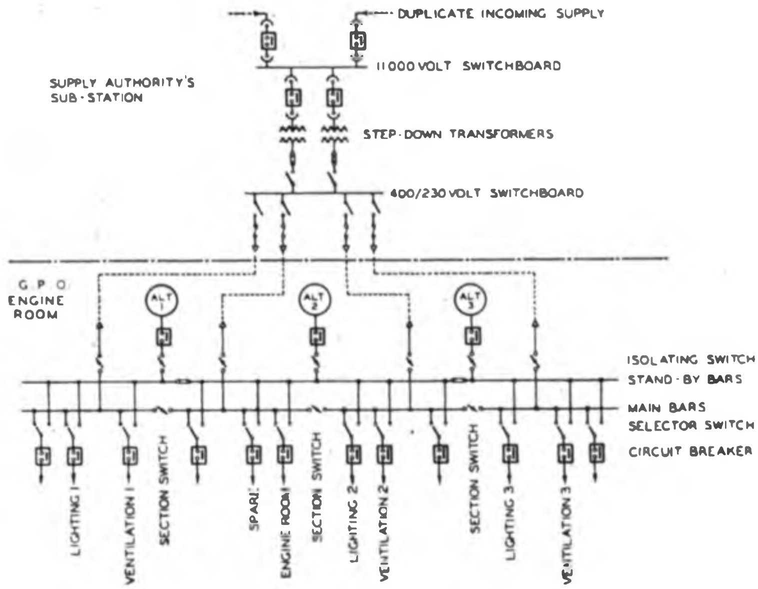


FIG. 2.—SCHEMATIC DIAGRAM OF MAIN POWER SUPPLY AND SWITCHBOARD.

General Description of Plant.

The main switchboard for the building from which all the power supplies are distributed is illustrated in Fig. 1. The switchboard has duplicate busbars and is of the metal-clad cubicle type. Each of the outgoing circuits is controlled by an oil circuit-breaker of 25,000 kVA breaking capacity. The circuit-breaker is interlocked with a selector switch which is used to connect the outgoing circuit to either of the sets of busbars or, if required, to isolate the circuit from both. Interlocking is provided which prevents access to the cubicle concerned being obtained until the equipment inside has been isolated and which also prevents the selector switch being operated except when the oil circuit-breaker is in the open position. The front or main set of busbars is divided into four sections which can be coupled together by switches designed for on-load operation, and each section is fed by a separate cable from the Supply Authority's sub-station installed elsewhere in the building. It was necessary to have four separate cables to limit the current rating of the protective gear in the substation to the maximum

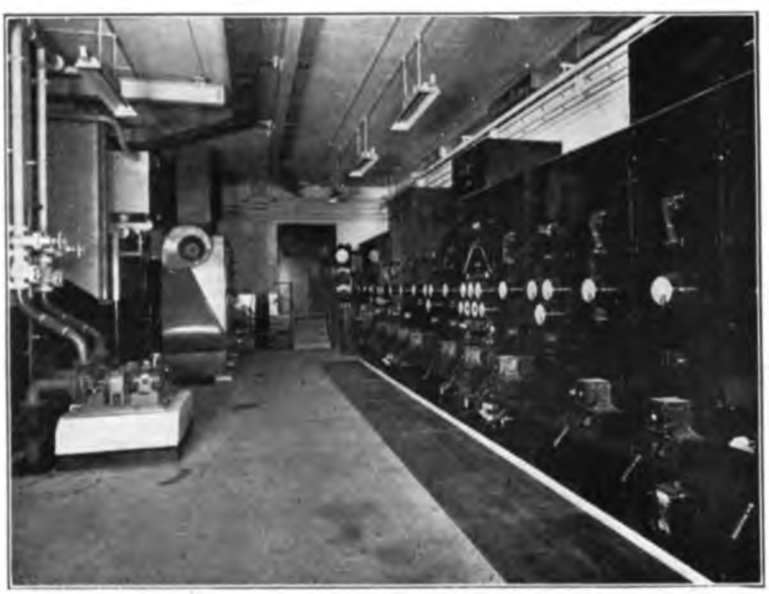


FIG. 1.—GENERAL VIEW OF SWITCHBOARD.

Fig. 3.—General View of Plant.

value permitted by the Supply Authority. The back or standby set of busbars is divided into three sections which are normally connected together but which can be divided by the removal of links, accessible when the busbars are off-load. Each section of the standby busbars is fed by one engine alternator set. Fig. 2 shows details of the main power supply and the general circuit diagram of the switchboard.

The agreement made with the Supply Authority for the normal power supply stipulated that it should be impossible to connect the output of the alternators with the normal supply, and the arrangement of connections as described above ensures this. Various other schemes were considered, but the majority of them had the disadvantage that some interlocking between circuit-breakers was required or that the outgoing circuits were divided up in a manner which necessitated the running of all the sets irrespective of whether the load conditions required it or not. None of the alternatives had the flexibility which is given by the use of sectionalised duplicate busbars, and which will be of advantage under various different sets of circumstances which might arise, e.g. where their system conditions would not permit the Supply Authority to meet the whole of the building requirements, or where it was desired to load up one engine alternator set for test purposes without disturbing the more important of the outgoing circuits.

Three oil engine alternator sets are installed to provide the standby supply. The twelve-hour rating of each engine is 388 h.p. (the largest size available in the medium speed range of engines) and the output of each alternator is 315 kVA at 0·8 power factor, equivalent to 252 kW, continuous rating. It will be observed that the output of the engine is in excess of that required to drive the alternator ; this was intentional and was specified so that the sets could be run continuously if necessary without distress and to give adequate overload capacity under adverse atmospheric conditions, a state of affairs which might arise in the event of any plant being damaged. The three sets are shown in the general view in Fig. 3.

Each engine is of the air-less injection, compression ignition type working on a four-stroke cycle. It is a medium speed eight-cylinder engine, running at 600 r.p.m. and was manufactured by Messrs. W. H. Allen, Sons & Co., Ltd., of Bedford, who were the main contractors for the installation. Each alternator is of the salient pole, revolving field, protected type, ventilated by a centrifugal fan mounted on the main shaft. The exciter is of the normal D.C. generator construction with similar protection and ventilation. It is compound wound and is fitted with commutating poles. For the reasons given later the exciter is mounted above the alternator and is belt driven from the main shaft by a triple vee-type belt. The voltage control is by a hand-operated rheostat or automatic voltage regulator, both of which are con-

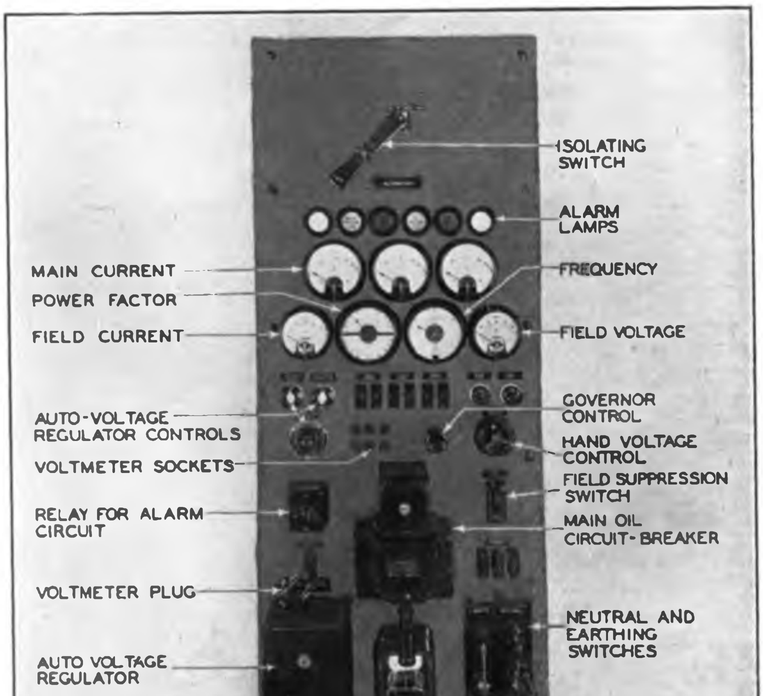


Fig. 4—Control Panel.

nected in the exciter shunt field circuit and are mounted on the alternator control panel. The alternator control panel associated with each set also has mounted upon it the remote control for the governor which is required for speed adjustment, for paralleling operations, and also for adjusting the division of load between the sets. Alarm signal lamps which operate in conjunction with a hooter are also mounted on the control panel, and indicate failure or excessive temperature of cooling water and lubricating oil supplies. A white lamp indicates that the alarm circuit is in order, one of four red lamps indicates a faulty condition and a yellow lamp indicates that the hooter has been switched off. The indication of each lamp is shown by a stencil illuminated by it.

Fig. **4** is a view of an individual control panel.

The governor control and the alarms under certain circumstances may be required to operate when there is no supply connected to either set of busbars, and they are therefore fed from a 50 V battery. This battery also supplies the emergency lighting in the engine room which is switched on automatically by the action of a relay when the normal lighting fails. The whole of the electrical equipment is by the Metropolitan-Vickers Co., Ltd.

The engine cooling water is circulated between a mixing tank and the engine jacket by one of a pair of duplicate electrically driven centrifugal pumps. The mixing tank, the pumps and the interconnecting pipework are common to all engines. The temperature of the water in the mixing tank is controlled by circulating a portion through one or more of the three water coolers installed. These coolers are of the evaporative type and were manufactured by Messrs. Heenan & Froude, Ltd.

A separate pump for circulating the water between the mixing tank and the cooler is provided for each cooler. The air required by the coolers is drawn from the engine room by fans integral with them and is discharged into the main ventilation exhaust duct. This air is led into the engine room at a point remote from the coolers so that an appreciable air circulation is maintained which ensures that the conditions in the engine room remain reasonable even when all three engines are running. The quantity of air required by the engines and the coolers is in excess of that supplied by the ventilating plant under normal conditions and, to provide the extra amount required, an additional fan is run and certain modifications are made to the air circuit when the engine and coolers are in operation. Remote control for the fans concerned, with suitable signal lamps, is provided in the engine room so that the engine driver can set up, in the minimum amount of time, the required conditions in the ventilating plant for running the engines and, if necessary, restart the essential parts of this plant after a complete failure of the power supply.

The main supply of fuel oil for the engines is stored in two tanks which are described later. Oil is transferred from these tanks to the daily service tanks associated with each engine by an electrically driven Mirrlees I M O pump or, alternatively, by a hand-operated pump of the semi-rotary type. Facilities are also provided for filling the service tanks from drums in the engine room and for removing sludge from various points in the fuel oil system. Duplicate filters for the fuel oil are provided on each engine.

The engines are of the dry sump type. The lubricating oil for each engine is stored in a tank installed in a pit in the floor adjacent to it and is pumped from there to the engine bearings, etc., through duplicate filters and a pressure control valve by an engine-driven gear type pump. The oil drains into the engine crank case whence it is pumped via an oil cooler back to the storage tank by a similar pump of somewhat larger capacity. A hand-operated pump of the semi-rotary type is also fitted for priming the lubricating system preparatory to running the engine. The capacity of the oil storage tank is about 70 galls. The oil cooler is connected in the circuit of the engine jacket cooling water.

Two separate exhaust silencers, both of Burgess manufacture, are fitted in the exhaust pipe of each engine; one is fitted as near as possible to the engine and the other a few feet from the open end. Steel is used throughout for the exhaust pipe since it was considered that the more usual cast iron might not stand up to the treatment the building was designed to withstand.

The engines are started by compressed air which is stored in cylinders at a pressure of 300 lbs. per square inch. Three cylinders, each of which will supply sufficient air for six normal starts without recharging, are provided and are interconnected so that any cylinder can be used to start any engine. Two compressors, one driven by a 3½ h.p. petrol engine and the other by an electric motor of similar capacity, are installed for recharging the air cylinders. The compressors were manufactured by the Hamworthy Engineering Co., Ltd.

Installation.

The building is of heavily reinforced monolithic concrete construction, with closely spaced steel bar reinforcing about 2 in. below the surface of the walls. The engine room occupied portions of two adjacent bays in the building, the intervening wall being replaced by a number of pillars of equivalent strength. The general layout of the plant is shown in Fig. **5**, from which it will be seen that the engines occupy one bay while the switchboard and coolers occupy the other.

The maximum span across one bay that could be permitted was less than 25 ft., so that the normal arrangement of engine alternator and exciter mounted in line could not be adopted, and it was necessary to mount the exciter over the alternator. In this connection it should perhaps be stated that while a higher speed engine or one of the same speed fitted with supercharging would have occupied less floor space, it was necessary to rule both these types out on account of the somewhat stringent conditions imposed with regard to noise within the building.

The amount of noise set up by the engines was considered with more than usual care for several reasons, the main ones being that the nature of the building construction gave no assistance whatever in damping out structure-borne noise and that as the

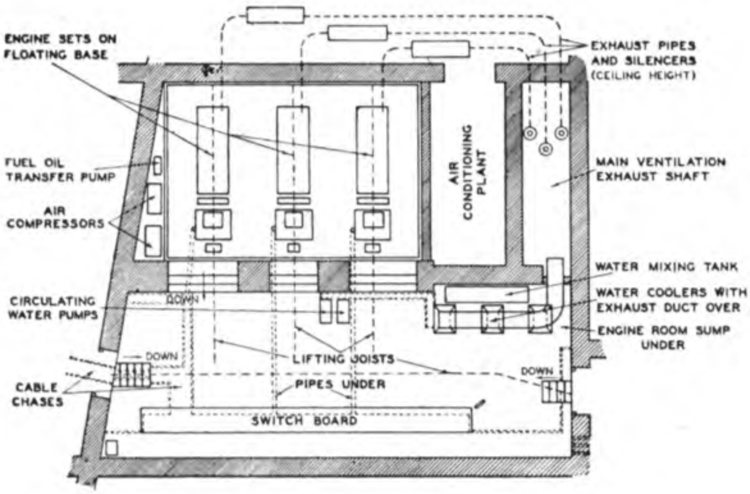


FIG. 5.—LAYOUT OF ENGINE ROOM.

building was constructed on a concrete raft formed as part of the structure it was not possible to build separate foundations for the engines.

The engines are actually mounted on a block of concrete 4 ft. thick and about 22 ft. by 30 ft. in area. This block is entirely separate from the remainder of the building and is supported by a mat of "Coresil," which is prepared cork material manufactured by Messrs. W. Christie & Grey, Ltd., resting on the floor of the engine room with an air gap of 6 in. on all sides of the block. The engine base plates are in the form of a box built up of rolled steel joist sections welded together and embedded in the concrete block. This method of mounting has in practice proved particularly successful in isolating from the remainder of the structure the vibrations which are inherent in any engine having reciprocating parts.

It was not possible to raise the floor level in the other bay of the engine room up to that of the engine foundation block because of the headroom required by the water coolers, and it was therefore necessary to provide steps between the pillars as shown in Fig. **5**. These have not proved to be the cause of any great difficulty because the lifting joist which is provided over each engine was extended sufficiently far to enable engine parts to be picked up or landed at either floor level.

The overall height in the engine room from the bottom of the engine foundation block to the ceiling is 16 ft. This height was not required in the other rooms on this floor of the building, and it was therefore possible to raise the floor level in these rooms by about 5 ft. without any inconvenience and to utilise the space thus made available below these floors as storage tanks for the fuel oil for the engines. Two tanks with adequate capacity were provided by this means. Each tank is equipped with a float type level gauge with an indicator fixed in the engine room, and has a separate vent pipe leading to the top of the building. A foam pipe which terminates near the building entrance is also provided for each tank. This pipe is for flooding the tank with foam for fire extinguishing purposes.

It was evident that the type of construction adopted would not permit the cutting away, which is normally done when the building work is complete, for fixing and for the passage of pipes, etc., through walls and ceilings and that therefore the position of every hole that would be required, except small fixing holes for rawlplugs, etc., which were not deep enough to reach the reinforcing, would have to be planned before the building construction commenced and would have to be formed by the insertion of suitable shuttering before the concrete was run. Small holes through walls up to about 6 in. diameter were formed by the insertion of steel sleeves which remained *in situ*, but larger holes and holes required for fixing bolts were made by the use of wooden formers.

It was necessary therefore to lay out the whole of the pipework, cable and conduit runs at a very early stage of the work; some of the laying out had in fact to be done before the contract for the plant was placed. Although this work is not done in detail normally until the plant is actually installed, there would have been no inherent difficulty in doing it at this earlier stage had it not been for the fact that in addition to the runs required in connection with the engine room plant there were runs for heating pipes, cold water pipes, sewage pipes, ventilation ducts and cable and conduit for power distribution in the building, all of which required to be allotted space and almost all of which were being installed by separate contractors. It was, however, possible to alleviate the position to a small extent by arranging for the engine room floor to be left about 2 ft. below its finished level and by arranging that as many pipes and cables run in connection with the engine room plant should be run in in chases or in pipes formed in the floor filling when it was run in at a later date. A similar arrangement was made with regard to the floating engine foundation block, which was of a somewhat complicated shape—in this case the concrete level was left by the builders at a level somewhat more than four feet below the finished level. With this early planning it was possible for the contractor to cut and bend all pipes at his works and to deliver them to the site ready fitted with flanges for immediate erection and thus save an appreciable amount of time for work on site. The only modification to the original layout that was necessary was to accommodate another contractor who was an earlier arrival on the site and who had used the wrong holes in one of the walls for his pipe runs.

Some difficulty was experienced in designing the runs for the larger cables on account of the difference in level between the engine room floor and the floors of surrounding rooms. This was overcome by arranging that access to the engine room should be by an easy flight of steps formed in concrete and that steel pipes should be set in this concrete at an angle of about 40° and should terminate in chases at the top and bottom of the steps. With this arrangement it was possible to avoid any sharp bends in the cables without occupying any additional floor space.

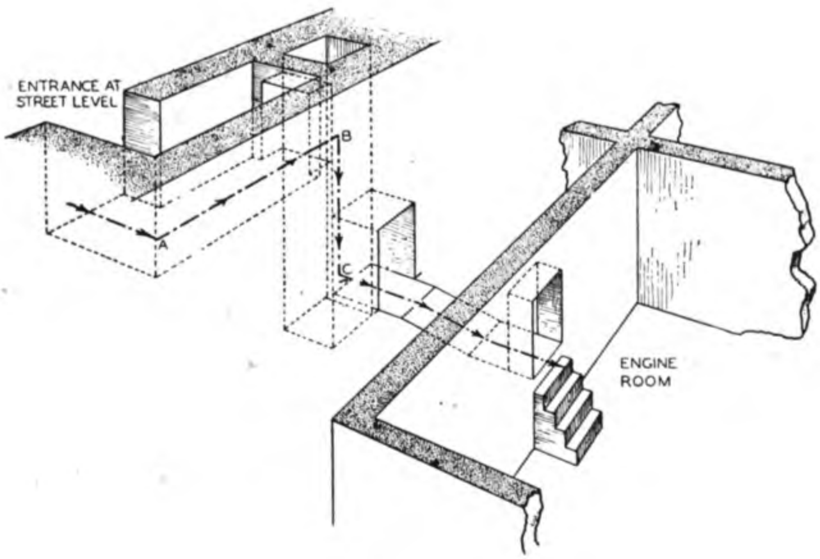


FIG. 6.—ISOMETRIC VIEW OF ENTRY TO ENGINE ROOM.

The engine room is not on the ground floor level, and as has already been stated, the entrances to the building are protected by blast screens, and it was therefore evident that the access to the engine room would not be simple. It was not practicable to leave the construction of some portion of the outside walls until after the major items of plant had been entered since the joint between the patch constructed later and the surrounding concrete would be a weak point in the building construction. Fig. **6** is an isometric drawing showing the path into the engine room, from which it will be observed that there were three right-angle bends all in different planes along the route.

The largest items of plant to be got in were the main bodies of the oil engines, and while the building work was still at an early stage a small scale model was made of that portion including the entrance, with which some experiments were made with models of the engines to the same scale. Models were made with the engines dismantled in various ways and these were all tried in the entrance and the various fouling points noted. As a result it was arranged that certain alterations should be made to the building plans—in most cases the bevelling of corners—and that the engine would be delivered to the site mounted on a wooden sledge arrangement to facilitate manœuvring and shorn of all external demountable parts with the exception of the cylinder heads. These were left on to preserve the cylinder bores and pistons from the entry of foreign matter during transit. The result was a rectangular block approximately 12 ft. 0 in. long with a cross section about 4 ft. 6 in. high and 3 ft. 6 in. wide and weighing slightly more than 8 tons. Fig. **7** illustrates the first engine immediately after it was landed in its final position and before it was lowered by jacks from the wooden structure on to the prepared foundation.

Stout rings were set into the walls at certain strategic points which were decided upon in the small scale experiments, and these proved of great assistance in controlling the engine. Also a removable platform constructed of rolled steel joists and timbers was fixed at the point B in Fig. **6**.

The engines were delivered to the site by motor lorry and were unloaded with the shear legs and run into the entrance on rollers up to point A. At this point jacks and pulley blocks attached to the rings mentioned earlier were used to turn round the corner. The actual clearance between the engines and the corner wall when the engines were half-way round was less than 6 in., and this presented difficulty in that men working at one end could not pass readily to the other.

At the point B the forward end of the engine was lifted up the shaft by a 12-ton crab winch mounted higher up the building and the rear end was pulled towards the shaft by a set of pulley blocks arranged to give a horizontal pull. The result was that the engine gradually assumed a vertical position in the shaft. The work was comparatively simple until the engine reached an angle to the vertical of about 45°, beyond which point it was not possible to use rollers underneath. This difficulty was overcome by using additional lifting tackle in the shaft attached to the engine at a point somewhat to the rear of its centre of gravity. By adjusting the two sets of tackle simultaneously it was then possible to lift the engine completely from the ground and to adjust the angle at which it was hanging while it was in mid air. The engine was lowered down the shaft in a vertical position

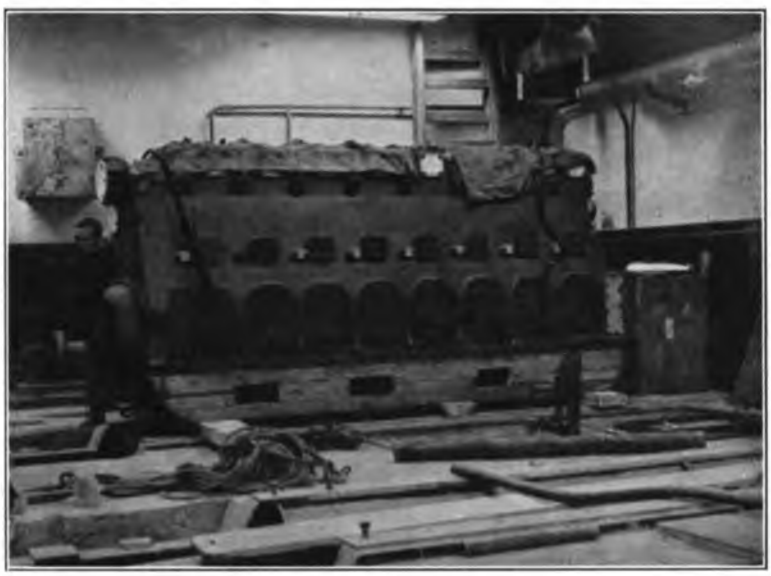


FIG. 7.—ENGINE BEFORE LOWERING TO FOUNDATION.

and at the same time was twisted through 90°, so that when it reached the point C it was possible by a reversal of the process at the point B to draw the engine out of the shaft in a horizontal position. At point C at one position of the engine the maximum clearance at the fouling points was less than ½in., so that very nice management of the tackle was necessary to get the engine round without jamming.

At the entrance to the engine room there was a drop of about 4 ft., and to negotiate this a "bird-cage" of timber was built up to the entrance level. The engine was run on to this and then, with the aid of the overhead crane and jacks, it was dropped to engine room floor level as the timber was removed plank by plank. This process was then reversed to ift it again to the level of the foundation block and on to which it was rolled.

Five days were taken up in getting the first engine into position, although this was reduced to three days for the third as experience was gained. The main entrance was, of course, blocked while the engines were being negotiated between points A and B, and it was necessary for the times of their arrival to be co-ordinated with the work of other contractors, and to cause the minimum amount of delay, the work was confined as far as possible to week-ends.

The other items of plant were got in without much trouble, since with the exception of the coolers, which were comparatively light, all the plant could be taken round the various corners without turning.

The engine base plates were each delivered in two parts, which were assembled on site and, as they arrived some time before the building was finished, it was possible to get them into the engine room by a more direct route than that taken by the remainder of the plant.

Conclusion.

The plant has now been in commission for some time and has been run at regular intervals for testing purposes and to acquaint the staff concerned with its operation. The plant is, of course, designed for starting up after a complete failure of the main power supply when there would be no power available in the engine room until the first engine had been connected to the busbars. All the plant in the engine room, including the lighting, is therefore supplied from one circuit-breaker on the switchboard, which is the first to be closed after the first engine is run up. To simulate a power shut-down for testing purposes this breaker is tripped, thus enabling the operating staff to start up the engines under the actual conditions which would be met in an emergency.

The more important of the items in the building, such as the compressor for the refrigerating plant, are in duplicate, and these have been connected up to the switchboard in such a manner that by making use of the duplicate busbars it is possible to load up an engine on test by connecting reserve plant to the stand-by supply and leaving running plant on the main supply.

Quick Action Pipe Coupling

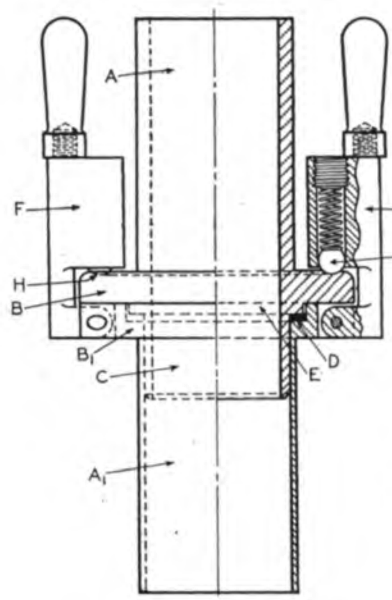
This quick-action coupling was designed for coupling a flexible hose on a producer-gas trailer to a rigid pipe on towing vehicle. It is also suitable for low pressure liquid or gas pipe lines generally, which necessitate the coupling of one rigid and one flexible pipe or two flexible pipes.

The coupling consists in the main of two short metal pipes, A and A_1, each flanged at one end, the flanges (B and B_1) being so designed that they form a spigot joint connection C when placed face to face. To ensure a gas or liquid-tight joint, a leather washer D is interposed between shoulder E of flange B and flange B_1.

The coupling of the flanges is effected by two arms F which carry spring-loaded balls G, the arms being hinged to flange B_1 diametrically opposite each other. Movement of the arms towards flange B until they lie parallel to the line of piping causes the spring-loaded balls G to engage in an annular groove H formed in the outer face of flange B. The spring loading of the balls is such that adequate pressure is applied to keep the flange joint tight.

When the coupling is used to connect a rigid pipe to a flexible one, tube A with its flange and other components constitute the end of the flexible pipe.

A cover cap with spigot and leather washer and pull-off ring, having the outer face grooved as flange B,



is provided for sealing pipe A_1, when pipe A with its flange and spigot are detached.

The Application of Carrier Systems to Submarine Cables—Part II

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This article, which is continued from the October issue, discusses the design bases for terminal equipment of submarine telephone cables having high attenuation. Some experimental data on cables and equipment are given.

In Part 1 of this article it has been shown how the maximum permissible attenuation of a submarine telephone cable can be calculated if specified circuit noise requirements are to be fulfilled with a transmitting amplifier of a given output power. Methods of line equalisation have also been discussed in relation to the performance of available amplifiers. It remains to be shown how nearly the theoretical limiting conditions can be realised in practice and, in particular, how extraneous noise and crosstalk may prevent complete realisation of the optimum design.

Effect of Cable Crosstalk on Circuit Stability.

In two-cable schemes the effect of near-end crosstalk is to reduce the stability of the higher frequency circuits and/or to increase the overall attenuation at which they may be operated. It is readily shown, for example, that if, in a single 4-wire loop having equal attenuations and gains in each line, the near-end cable crosstalk at each end is equal to the cable attenuation, the limiting overall attenuation at which the circuit is stable with the ends open-circuited is increased from zero to 4·2 db. This represents approximately the worst crosstalk conditions which can be tolerated. In practice both line attenuations and near-end crosstalk attenuations may be unequal, and when crosstalk is the limiting factor this necessitates a redistribution of the terminal gains so that instability is reached simultaneously in the two singing paths.

Measurements of Near-end Cable Crosstalk.

Unfortunately there is, at present, inadequate information concerning near-end crosstalk between submarine cables used for two-cable schemes. It is known to be dependent on the proximity of the cables at the landing point and on shore, and also on the nature of the earthing arrangements employed, but it has so far been impossible to make exhaustive measurements on existing cables.

The shore ends are lead-covered, and the armouring is preferably continued over the land sections to the cable terminating box. On land, the cables are laid in separate trenches and are separated from each other as far as possible. The outer conductor, lead sheath and armouring are separated by wrappings of tape and jute respectively. The insulation of the outer conductor should be preserved at the cable terminating box and direct capacitance between the inner conductor and the station earth should be carefully avoided; the arrangement of some existing boxes is not satisfactory in this respect. The armouring or, in certain instances, the lead sheath is in contact with the racking and thence with the station earth; it is usually satisfactory if the armouring or lead sheath forms the station earth.

Measurements of near-end crosstalk have been taken at four cable terminals as follows: the crosstalk-frequency characteristics are given in Fig. **1**:—

(*a*) At Aldeburgh. Here the repeater station is 150 yards from the sea, and the cables are in separate trenches. It is known that connecting the outer conductors of the two cables to the station earth causes instability of some of the low-frequency carrier circuits.

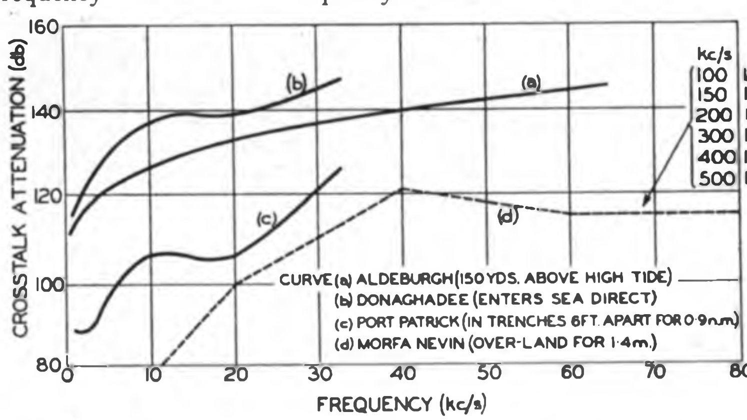

Fig. 1.—Coaxial Paragutta Cables—Near-end Crosstalk.

(*b*) At Donaghadee. Here the repeater station is very close to the sea and the conditions are as near ideal as can be expected.

(*c*) At Portpatrick. Here the cables run overland for 0·9 nautical miles in trenches six feet apart. They are leaded and armoured. The crosstalk is seen to be inferior to that at Aldeburgh and Donaghadee.

(*d*) At Morfa Nevin. Here the cables run overland for 1·4 miles; they are also leaded and armoured. The crosstalk at frequencies below 60 kc/s is worse than that in the other cases measured.

From these results it is clear that, where possible, the submarine cable termination should be as close as possible to the landing point. Where this is done near-end crosstalk should not be a limiting factor in the provision of circuits, but where the land section is considerable such near-end crosstalk may be the limiting factor. Thus, with 10 W transmitting amplifiers, the maximum permissible attenuation length will be between 125 and 135 db. depending on the number of circuits and the permissible noise limit, and if it is assumed that the limiting near-end crosstalk is equal to the cable attenuation then the crosstalk will certainly be the limiting factor at Morfa Nevin and possibly at Portpatrick also.

The near-end crosstalk measurements at Morfa Nevin were extended to 500 kc/s and the effect of various earth connections was investigated. The results are given in Table 1.

TABLE 1.

NEAR-END CROSSTALK BETWEEN SUBMARINE CABLES AT MORFA NEVIN.

f kc/s	Outer Conductors Free	Outer Conductors Connected	Outer Conductors to R.S.E.*	R.S.E. to Rec. only	R.S.E. to Send only	Each outer conductor to R.S.E. via		
						0·005μF	1 μF	0·0002μF
10	78 db.	68	68	78	78			
20	> 98	92	> 98			96	96	98
40	122	118	> 128	> 120	> 120			
60	116	112	124					
80	116	106	122					
100	120	106	118	114	114	104	110	126
150	118	98	110					
200	118	96	106					
300	114	90	96					
400	110	86	90			78	86	90
500	106	82	84					

* Repeater Station Earth.

These results do not appear to be entirely logical, but the precise mechanism of this crosstalk is not yet investigated; two coaxial pairs with their outer conductors in contact at earth potential should have a crosstalk attenuation which increases with frequency. From the general trend of other test results below 60 kc/s it appears that the unusual crosstalk characteristic in this instance should be attributed to the land section.

FILTERS.

System Filters.

In schemes involving expensive submarine cable links it is desirable to make full use of the available frequency spectrum, and low-frequency systems (usually duplex) are operated in the frequency band below 12 kc/s; to combine the two systems, filters are employed. The system filters may be inserted either adjacent to the cable or on the office side of the low-pass directional filter if one is fitted. So far, they have always been fitted between the directional filters and the cable, to minimise the amount of equipment to be simulated in the 2-wire balances, but in this position air-cored coils must always be used for the high-pass filter and the end sections of the low-pass filter on single-cable schemes to avoid intermodulation. On two-cable schemes (without emergency filters) dust-cored coils are satisfactory.

The required discrimination of the system filters depends on the type of scheme (i.e. two-cable without emergency filters, or single-cable) and the cable lengths involved. In the simplest condition, where both the 1+2 circuit system and the 12-circuit system are worked 4-wire, it is necessary to provide only sufficient attenuation to ensure that a negligible fraction of the power from each system is absorbed by the complementary filter. If the low-frequency system is worked duplex with a two-cable scheme, it is necessary for the system filter to prevent

(*a*) transmitted signals on either system from loading the receiving amplifiers at the near end on the other system. (This may possibly be taken care of by the line equalisers in certain circumstances);

(*b*) modulation products from the transmitting amplifier on one system interfering with the low-level received signals on the other system.

If the low-frequency system is worked duplex on a single-cable scheme, the same considerations must be taken into account. In neither this nor the two-cable case will the optimum filter design be the same at both terminals, but a common design of filter, incorporating the more severe requirements, is usually adopted.

To simplify the low-pass filter to be reproduced in the 2-wire balance, and, incidentally, to effect a saving in filter elements, the arrangement shown in Fig. 2 has been adopted. That part of the low-pass filter in the 2-wire circuit (the basic filter) is sufficient to ensure that the 4-wire terminating set and low-frequency amplifiers do not form a serious non-linear shunt on the high-frequency system; any such shunt will be responsible for inter-channel interference in the high-frequency system. Additional low-pass filters are connected in the 4-wire circuits as required, and it is found that such additional filters are required only as shown in the diagram. The basic filters and their counterparts in the 2-wire balances must be carefully constructed if good balance return losses are to be obtained. In practice, tolerances of 0·5 per cent. have been found necessary to ensure adequate matching, and, even so, a measure of matching of individual components is desirable. With cut-off frequencies of 10 kc/s, return losses of 50 db. may be required from the filters alone at

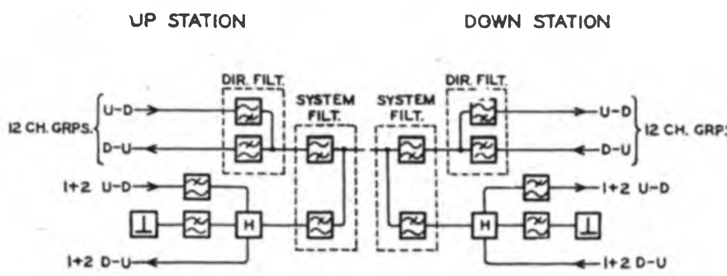

FIG. 2.—ARRANGEMENT OF FILTERS FOR SINGLE-CABLE SCHEMES.

frequencies up to 9·0 kc/s. Despite the rather large values of capacitance, the condensers must be of the clamped mica type to ensure adequate accuracy stability. The coils in the 4-wire filters can be wound on dust-cores and, although clamped paper condensers would otherwise be suitable, the capacitance values (for the usual 600 Ω filters) are too low to admit of their use ; mica condensers are therefore used in these filters also.

Directional Filters.

Channel and group filters are designed to operate satisfactorily when all channels and groups are transmitted in the same direction at approximately equal levels. The loop loss through the directional filters should therefore, as a first approximation, be equal to the line attenuation ; near-end signals will then be attenuated to exactly the same extent as if they are transmitted along the cable.

Intermodulation in directional filters must be carefully avoided owing to the very considerable level differences existing at the line end. Coils near the filter junction must certainly be air-cored, but coils remote from the junction could have low-hysteresis dust-cores (e.g., carbonyl iron, Grade E). A close study of this point has not so far been made, and to err on the safe side air-cored coils have been used throughout on systems of high attenuation. On systems having comparatively low attenuation and using 1 W transmitting amplifiers, high-grade dust-cores have been used throughout in the directional filters (e.g. Belfast–Stranraer).

Earthing System

Connections to Repeater Station Earth.

At a repeater station the main station earth connection is to the junction point of the 130 V and 24 V batteries, and leads are usually run as shown in Fig. **3**. Valve heaters are connected between " FIL. BATT." and " E.V.R.", between which points a regulated 21 V is maintained. This is the only connection which should be made to " E.V.R." at a repeater station ; all other connections should be to " RACK E," and on the bay mounting the receiving amplifiers a condenser (say, 1 μF paper) should be connected between " E.V.R." and " RACK E " busbars to ensure that no A.C. potential difference exists between these points. If this is not done, high-frequency noise (e.g. radio) is liable to be picked up via the capacitance between the grid of the first valve and its heater.

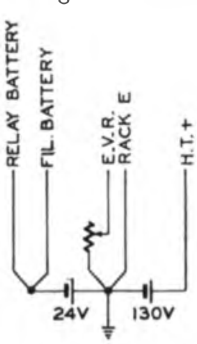

Fig. 3.—Normal Repeater Station Power Supplies.

On the bays mounting the carrier terminal equipment a heavy insulated copper earth bar is fitted down the bay and connected at its upper end to the " RACK E " busbar ; the earth connections from each unit are taken direct to this bar.

Where a balanced land cable section occurs adjacent to the terminal equipment it is evident that the common side of all unbalanced filters must be connected to the station earth ; care must be taken to ensure that two such earth connections are not made, otherwise currents will flow in the earthing system. A single earth connection is used to fix the potential of one point on each circuit.

Noise Pick-up from Earth System.

Without Balanced-pair Land Cable Section.—The station earth and the outer conductor of the submarine cable will not be in contact. Noise voltages will therefore be developed between them, and these must be prevented from causing interference in the receiving amplifiers. It has been possible to make only a few measurements of such noise voltages, and typical figures, measured at Morfa Nevin on the Anglo-Eire cable, are given below.

(1) Total open circuit noise voltage (R.M.S.) measured between 5 and 35 kc/s = 1·6 to 3·0 mV steady with peaks up to 7·5 mV.
(2) Total open circuit noise voltage (R.M.S.) measured above 35 kc/s = 0·15 to 0·3 mV steady with peaks up to 0·8 mV.
(3) Open circuit voltages of the order of 1 mV were measured with a wave analyser at various frequencies between 17 and 650 kc/s, morse transmission being identified in most instances.

Thus, it may be assumed that noise voltages of the order 1 mV may occur between the station earth and the outer cable conductor, and these should desirably be attenuated so that the transverse voltage appearing at the input to the first receiving amplifier is less than that due to thermal noise (i.e. —139 db.). Noise and crosstalk currents flowing in the outer conductor via shunt couplings to the station earth will cause a potential gradient which, in turn, will cause transverse currents in the cable pair. To minimise these currents the common side of the line filters, together with appropriate screens, should be connected to the outer conductor and a double-screened transformer interposed before the first receiving amplifier as in Fig. **4**. For single-cable schemes it is not practicable to insert such a transformer in the line owing to the severe design requirements. The noise voltage is then applied between the screens and, if these are complete, noise currents cannot flow in the transformer windings, and thereby generate transverse voltages. It can be shown that in this arrangement

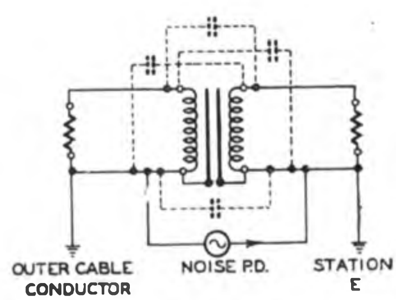

Fig. 4.—Double-Screened Transformer.

(1) there is a preferred poling of the windings which tends to cause the effects of the residual capacitances to cancel each other ;
(2) the extent of the cancellation in (1) above is greatest when the transformer has unity ratio ;

(3) with the preferred poling, it is possible to increase the degree of cancellation by an added condenser;
(4) for a transformer of given ratio, the signal/noise ratio is inversely proportional to the square root of the circuit impedance.
(5) The signal/noise ratio is inversely proportional to frequency.

In an experimental transformer designed to operate between 200 Ω impedances the voltage attenuation of a signal applied to the screens exceeds 100 db. at all frequencies up to 500 kc/s. Thus, if 1 mV of noise is applied between the screens, the noise level across the windings is always below —153 db., i.e. at least 14 db. below the level of resistance noise.

Alternatively, or in addition, it is possible greatly to reduce the effect of the shunt couplings by connecting a longitudinal choke, wound with coaxial pair, between the cable termination and the equipment. If this choke has adequate impedance to longitudinal currents, the station earth may be connected to the outer conductor on the equipment side of the choke, and the requirements for the insulation and screening of the line filters are thereby relaxed.

In one instance, where noise originated close to the terminal station, a choke consisting of 80 turns on 5 mil mumetal laminations reduced the circuit noise by about 70 db; where the noise originates at a more remote point the improvement will be less.

With Balanced Pair Land Cable Section.—The noise voltage still exists between the submarine cable and the station earth; indeed, owing to the greater geographical separation, it is likely to be greater. The double-screened transformer no longer presents a solution since the two earths are not at the same station, but a longitudinal choke wound with coaxial pair may be fitted at the ends of the submarine cable as described above. The noise P.D. involved is then that between the station earths at the ends of the land cable section.

The best arrangement so far devised is to fit balanced and single-screened transformers at each end of the balanced cable, the screens being connected to the appropriate earths as in Fig. 5. It is

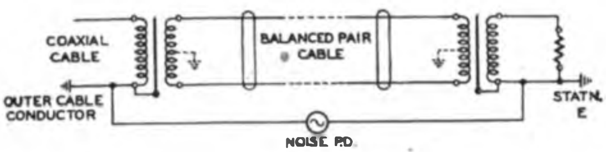

FIG. 5.—CONNECTIONS TO BALANCED PAIR CABLE.

then necessary to ensure that the transverse noise voltage developed across the pair by the longitudinal currents, acting through the circuit unbalances, shall be small. The method of doing this will depend on whether the unbalances are in the line, terminal transformers or both, and whether they are series or shunt unbalances. In practice, the capacitance unbalance of the terminal transformers can be reduced to 5 $\mu\mu$F or less below 500 kc/s, and the capacitance between the line winding and the screen is sufficiently low to constitute a substantial series impedance. In a single cable scheme there are very severe requirements in respect of intermodulation which restrict the design and make it impracticable to make the winding-to-screen capacitance very low. The most important unbalances are those of wire-to-earth capacitance along the line and since, at the terminals, there is a substantial series impedance, the transverse voltage is most readily restricted by earthing the centre-points of the transformer (line) windings. If the cable is fairly long it may then be necessary to include additional series impedances in the form of longitudinal chokes (arranged to be non-inductive to the pair circuit) and also additional centre-tapped shunt chokes to give low impedances to earth. This problem has not yet been fully investigated, but it is thought that a satisfactory arrangement of high series impedances and low shunt impedances in the earth circuits should be practicable. Reduction of the wire-to-earth unbalances in manufacture or by added condensers may be necessary in extreme cases.

Typical attenuations of voltages applied between the screens of a pair of transformers (suitable for a single-cable scheme) connected back-to-back, are given in Table 2. Each transformer is designed to operate between a 50 Ω unbalanced circuit and a 200 Ω balanced circuit and the calculated suppressions shown are deduced from measured admittance unbalances.

TABLE 2.

Frequency in kc/s	Suppression in db.	
	Calc.	Meas.
20	94	94
40	89	88·5
100	81	81·0
160	78	77·0
200	75	75·5
250	69	74·5
300	67	72·0

The conditions with balanced-pair land cables are less satisfactory, from the point of view of noise, than when the equipment is adjacent to the submarine cable, and although excessive noise has not so far been experienced it is probable that radio interference will make certain channels unworkable in extreme cases.

INTERMODULATION IN LINE EQUIPMENT.

For single-cable schemes, intermodulation requirements are extremely severe. For filter coils associated with both directions of transmission air-cored toroids have always been employed, and this is satisfactory, but it is impossible to avoid the use of ferro-magnetic cores in line transformers. These transformers must occur wherever there are balanced-pair land cables between the terminal equipment and the submarine cable; those adjacent to the terminal equipment will have the most severe requirements.

Fig. 6 shows the levels occurring at the terminal transformers of single-cable systems of limiting attenuation, for 1 to 4 transmitted groups. The maximum transmitted level is taken as + 22 db.,

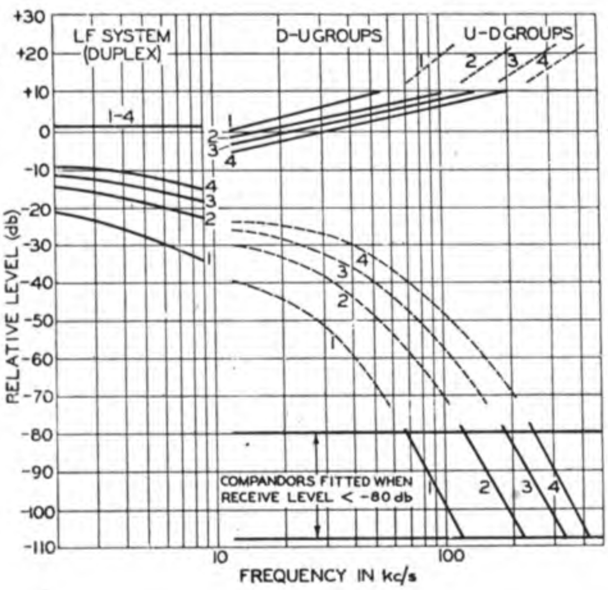

FIG. 6.—CARRIER SYSTEMS OF LIMITING ATTENUATION ON SINGLE CABLES—TERMINAL TRANSMISSION LEVEL. 1 to 4 GROUPS.

and the equalisation is as previously suggested. Levels for a 1+2 circuit duplex system are included on the usual basis of a transmitted level of +5 db. (i.e. +1 db. to line). At one end of the cable the dotted curves will apply, together with both of the 1+2 circuit level curves; at the other end all the full curves will apply.

The following types of interference must be considered:

(1) From the transmitted 1+2 circuit group to the received D-U 12-channel groups (i.e. 12–60—12–204 kc/s).
(2) From the transmitted 1+2 circuit group to the received U-D 12-channel groups (i.e. 72–120—244–436 kc/s).
(3) From the transmitted D-U 12-channel groups to the received U-D 12-channel groups.
(4) From the transmitted U-D 12-channel groups to the received D-U 12-channel groups.
(5) From the transmitted D-U 12-channel groups to the 1+2 circuit system.
(6) From the transmitted U-D 12-channel groups to the 1+2 circuit system.

It will be seen from Fig. 6 that in the limiting condition the U-D 12-channel groups will have all channels equipped with compandors, and these will serve to reduce the intermodulation noise in accordance with the usual law.

The design of transformers to transmit these wide level differences without excessive intermodulation is outside the scope of the present article. It will, however, suffice to indicate that suitable transformers for circuits transmitting frequencies from 300 c/s to 300 kc/s have been made and extension of the upper frequency limit to 500 kc/s is practicable. Such transformers may have a ratio of more than 25,000 between their open-circuit and short-circuit inductances, and they will transmit frequencies of 20 c/s without appreciable loss.

Conclusions.

The problem of the provision of carrier systems on submarine cables to the limits permitted by the attenuation has been considered generally and the difficulties examined. Such systems have been installed on several submarine cables, but the most severe conditions have not yet been encountered. The problems involved have not all been fully and satisfactorily solved, but the present article summarises experience to date.

In general it is possible to provide circuits meeting the P.O. and C.C.I.F. noise limits over cables having attenuations up to about 130 db., assuming the use of 10W transmitting amplifiers—the highest output so far obtained by use of repeater station batteries (21 and 130 V). Noise due to radio interference is likely to prove troublesome in certain cases, and this is more readily dealt with when there are no balanced-pair cables between the submarine cable and the terminal repeater station. Such cables should be avoided where possible.

Severe intermodulation requirements are encountered in single-cable schemes, but these have been met satisfactorily.

Book Review

" The Telephone Handbook." By J. Poole, A.M.I.E.E. Wh.Sc. 510 pp. 397 ill. Pitmans, 25s.

The eighth edition of Poole's " Practical Telephone Handbook " has been completely revised by two Post Office engineers, N. V. Knight and W. Prickett, and now appears under the slightly modified title of " The Telephone Handbook." The present book sets out to deal with the fundamental theory and practice of telephony, and does not confuse the main issues by too much detail. In general it covers the syllabuses of City and Guilds examinations in Telephony, Grades I and II, and the theoretical side of Transmission and Lines, Grade I and part of Grade II, i.e. manual and automatic (non-director) exchange practice, including subscribers' instruments and P.M.B.X.s, together with an introduction to transmission theory and an outline of audio and carrier repeater practice.

The book starts badly with an unnecessary chapter on alternating current theory, in the first four pages of which an alternator is shown with a commutator, ω is referred to as a constant, and flux and flux density are confused! In a book on Telephony restricted to 500 pages this chapter and one later in the book dealing solely with primary and secondary cells could well have been omitted and the space devoted to purely telephone matters.

Nor does the second chapter dealing with Telephone Instrument Circuits open more propitiously, for it commences with the half truth, " Any moving body makes a sound." Similar statements appear at intervals throughout the book. Another irritating point is the frequent use of former and latter, sometimes incorrectly. These are, however, minor blemishes and detract only

(*Continued on page* 138).

Air Raid Damage to Post Office Telecommunications

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Part II.—Telephone Exchanges

The second of these articles on damage to Post Office telecommunications deals with the damage suffered by telephone exchanges. Some typical examples are given and methods of restoring service indicated.

The First Exchange to be Bombed.

TO-DAY it is only by an effort that we can recall our immediate reactions to the news which reached us one morning in August, 1940, that a telephone exchange had been destroyed during an air raid on a North East coast town. Fortunately on this occasion that early report was exaggerated. A bomb had gone through the roof of the building, had exploded on contact with the switchroom floor—the first floor—and all services had stopped, but the damage did not turn out to be as serious as was at first feared. Of the five officers on duty at 12.30 a.m. one was killed ; the others had miraculous escapes—one fell with the floor of the room in which the bomb exploded to the ground floor, where a displaced girder shielded him from the masonry which crashed down after him. The switchboard, of five positions, was destroyed ; the collapse of the switchroom wall severely damaged the outer end of the battery room, the end cells in both main batteries and the positive battery. The power plant and automatic equipment were badly fouled by clouds of dust and small débris. The building remained structurally sound, due no doubt to the high standard of its construction.

By 3 a.m. a private branch exchange switchboard was being despatched from the Zone Centre and the emergency staff was on duty at the stricken exchange. At 9 a.m. two more P.B.X.s were on their way. By noon service was provided for 31 emergency subscribers' lines, for six call offices, and for seven junctions to nearby towns. On the following day service was given to 100 lines to complete Stage I of the restoration.

In the meantime the Engineer-in-Chief's Office, on being asked if it were possible to obtain suitable replacing bridge-control positions, arranged for the withdrawal of four that were stored at a London exchange and for their installation by the contractors. A counter E.M.F. unit was sent by passenger train, while one battery was being reconstructed from the two damaged batteries to enable float working to be introduced ; and on the morning following the raid 25 traction-type cells were despatched from the manufacturers. Within five days the exchange was giving service to all its subscribers and three P.B.X. positions were in use as an auto-manual switchboard.

FIG. 1.—COMPLETE DESTRUCTION OF A LONDON TELEPHONE EXCHANGE BUILDING.

Damage by Dust.

No one is likely to claim that telephone exchanges, apart from the fact that they are, with few exceptions, well-built steel-framed buildings, are particularly able to withstand the effects of bombing. An example of the damage which may be caused by a heavy H.E. bomb is illustrated by Fig. 1. Switchboard suites were usually placed on the top floor of an exchange to get the maximum amount of light by way of a central skylight. Air-conditioning plant is associated with the apparatus rooms to keep the automatic switches dry and dust free. Cable chambers are damp-proofed to maintain the high standard of insulation essential to each telephone circuit. Even if the bomb does not score a direct hit it usually shatters windows for some distance around (Fig. 2), and throws up a great cloud of dust, some of which enters the apparatus rooms. As soon as this dust has settled the maintenance staff have to get busy on the equipment with vacuum cleaners. This is not always sufficient ; at one exchange where nearby buildings were demolished such large quantities of dust blew in through the broken windows that many of the switches could no longer be operated. A new technique for cleaning the selector banks was tried out here by washing off the dust with a pressure spray. It consisted in directing a jet of air-blown mist spray of "Dekalin"—a non-toxic solution—on the dust-

Fig. 2.—Effect of Blast on a Provincial Telephone Exchange Building.

choked apparatus. This method proved to be so satisfactory that portable spray equipment was obtained and held by the Engineer-in-Chief's Office for despatch to any exchange as required; later this equipment was used for cleaning apparatus at three large exchanges which had suffered extensively from dust. An idea of the damage caused to the equipment by H.E. bombs may be gathered from Fig. **3**.

At another damaged exchange the equipment was affected by the water used in fire fighting and became badly corroded; so much so that it was surmised that battery acid had become mixed with the water. To remedy this the experiment was successfully tried of removing the corrosion from the affected parts by subjecting them to the action of jets of small shot or sand. At another exchange where similar corrosion occurred, and where it was inconvenient to remove the equipment for sand-blasting, dental type rotary brushes were used to remove the corrosion products.

Fire Damage.

With perhaps one or two possible exceptions during daylight attacks, there has never been any very serious suggestion that telephone exchanges have been deliberately selected as targets by enemy bombers. The larger exchange is generally, of economic necessity, right in the centre of a town, and has suffered with other buildings there. Most of us have, however, had sufficient experience of night bombing to sympathise with a Midland colleague, who reported :—

"It seems that the attack must have been definitely aimed at the exchange building as bombs were dropped on premises all around, while incendiary bombs fell on the building itself. Three fell on the roof and were promptly extinguished by the Post Office staff, but serious danger to the premises was threatened for some hours by fires in buildings just across the adjoining streets. So great was the heat that apparatus and switchrooms were in serious danger, while at one time the black-out curtains and window fittings caught fire. No serious damage was done to the exchange though much urgent work was necessary during the day to repair the effects of water and to replace the burnt window curtains and fittings."

In point of fact the number of exchanges permanently damaged has not been relatively large. This is mainly because the enemy has only rarely succeeded in doing them any very appreciable damage with incendiary bombs. Throughout the country the staffs on duty, including volunteer fire-fighting squads and Home Guards, have dealt resolutely with that type of bomb, and the greatest danger has usually been that from adjacent blazing buildings. The following incidents are typical. A large bomb struck a building opposite the exchange, starting a fire which developed so rapidly that flames were soon entering the windows of the exchange building on the first and second floors. Black-out curtains and the wooden framework of windows began to burn, but were quickly extinguished by the combined efforts of. the fire fighters and the exchange staff on duty. Meanwhile water sprayed on

Fig. 3.—Damage to Automatic Equipment by H.E. Bomb.

the outside walls of the building by the Fire Brigade began to pour in through the windows. This was also dealt with effectively. The Fire Brigade then issued a warning to keep away from that side of the exchange as there was danger that the buildings opposite would collapse. Bombs fell continuously in the vicinity. At 2.30 a.m. the electric light failed, as did the emergency lighting, making it necessary to carry on the exchange maintenance with the aid of electric torches. Water caused considerable damage to automatic equipment and to cabling on the ground, first and second floors of the building. An example of an exchange which suffered in this way is given in Fig. **4**. At this exchange the fire fighters saved the building though, unfortunately, not without loss to themselves.

FIG. **4**.—A LARGE PROVINCIAL EXCHANGE BUILDING SAVED FROM DESTRUCTION BY FIRE.

Water has put exchanges out of action altogether. Incendiary bombs penetrated the roof of an exchange in the North Eastern Region, but it took floods of water from jets being poured on a fire in an adjacent building to bring the automatic equipment to a standstill.

Black-out Difficulties.

The necessity to conform to black-out regulations can also cause service and maintenance difficulties. An example is where a bomb fell close to an exchange building, blew out a number of windows and doors, and displaced two screens on one side of the building. Further work in the manual switchroom was impossible because the fuses had to be withdrawn to prevent signal lamp glows being seen. At another exchange, when blast damaged the blackout curtains, the electric light was switched off and candles used for illumination. Again, at an exchange where the windows were blown in the police insisted on the removal of the main fuse because of lamp glows. At an exchange where mercury-arc rectifiers are used for battery charging, the window blinds were displaced by blast; later the rectifiers were switched on under automatic control, and the light from their bulbs could be seen clearly at a distance. It was thought worth while, therefore, to consider blacking all such bulbs or, alternatively, fitting light screens to them.

Effect of Street Cable Damage.

The equipment at an automatic exchange can be seriously affected by external cable damage. During one of the early attacks on a South Wales town two maintenance engineers remained on duty in the automatic exchange (while others took refuge in the basement) as a number of continuous hunting switches made it clear that cables had been damaged in the town. Non-essential circuits were disconnected, but the number of faults on the remainder still caused congestion, and the two workmen proceeded to trace and plug out faulty circuits. The bombing continued with little respite, and as faults increased the automatic traffic gradually deteriorated. Nearby bombing became very intense and the men decided to retire to the refuge. A quarter of an hour later they returned to the apparatus room to find it full of smoke due to an incendiary bomb which had penetrated the roof and was burning on the cable trench at the foot of the main distribution frame. With the aid of fire-fighting appliances they got the fire under control and extinguished it in about 20 minutes. Later, all the switches in the automatic exchange became locked because of the number of faults, and put the exchange completely out of service for nearly three hours. The congestion had been caused not by traffic but by faulty lines in damaged cables. Later there were attacks on three successive nights on another South Wales town. On the third night the public direct current supply on which the exchange's motor generators depended for charging the batteries was interrupted. Because of the large number of faulty circuits the automatic equipment became seriously congested, and the exchange's two batteries became heavily discharged. To continue to give service to the vitally essential subscribers it was necessary to reduce the number of working lines to as few as 28 out of a total of approximately 3,200.

Power Supply Breakdowns.

It was frequently necessary to bring portable charging sets into operation at exchanges while damaged mains of public electricity suppliers were being repaired. In one telephone area, where the electricity mains were out of action for two days, 14 engine-driven charging sets were brought into use. The Engineering Department's pre-war fleet of 160 portable generating sets, with a total capacity of 1,200 kW, has been increased during three years of war to 275 sets with a total capacity of 2,500 kW. Suitable second-hand, as well as new sets, have been acquired.

In addition to these portable sets a large reserve of stationary engine generating sets has been formed. At eight zone centres sets with a total capacity of

2,000 kW are installed. In addition twelve 50 V, 1,500 Ah a day, power plants have been provided for use with semi-automatic emergency exchanges. Existing power plant at 50 exchanges is also being converted to work on the float system to meet the increased load due to war-time conditions.

FIG. 5.—A TYPICAL TEMPORARY EXCHANGE BUREAU.

Emergency Arrangements.

Restoration plans were worked out before the war against the probability of extensive damage to telephone exchanges and subscribers' circuits. Details of these have been improved from time to time in the light of experience. Since it is essential that subscribers with "immediate action" lines should be able to originate calls in almost any circumstances of cable damage their circuits are segregated into groups with sole access, under emergency conditions, to a number of first selectors equal to, or greater than, the number of these circuits. Protected underground refuge switchboards have been installed in the more important exchanges to maintain essential services during heavy bombardments by enemy aircraft. To give service to all public kiosks when the main switchboard has to be vacated the capacity of the existing refuge positions was increased by fitting switch and indicator cases, each providing for an additional 40 circuits, to the refuge switchboards.

To avoid the dislocation of service to essential subscribers, should both the main and emergency exchanges be disabled by enemy action, a scheme was adopted for important towns whereby their circuits could be diverted to selected satellite, or "fringe," exchanges by the use of junction lines. Cross-connection frames were installed in protected accommodation at the cen ral exchanges to join these junctions to auto-manual switchboards at the selected outer exchanges.

So far as the ordinary subscriber is concerned experience of the effect of damage in automatic areas led to arrangements being made for the interception of calls incoming to subscribers whose premises or lines had been damaged so that callers could be assisted to get in touch with those subscribers. The circuits affected were bunched on a group of final selectors which were terminated on a manual board. The improvised services by way of temporary telephone bureaux (Fig. 5) set up in heavily blitzed areas have been greatly appreciated. Premises for these bureaux were obtained and call office stations installed as rapidly as possible. Calls could be made on payment of the ordinary call box fees — facilities were given at at least one of these bureaux for a subscriber whose normal service had been lost to rent a table telephone for his exclusive use—and a staff in attendance gave such assistance as was possible.

The bureau service overcame the immediate difficulties of priority subscribers with very little delay, but for the restoration of service to other important subscribers more extensive emergency arrangements were necessary. Fig. 6 shows a typical emergency exchange installed and brought into service after heavy damage had been experienced in a provincial town.

FIG. 6.—A TYPICAL EMERGENCY EXCHANGE.

Group Inverter Equipment

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The author describes the equipment now being installed to invert the frequency band transmitted on 12-circuit systems and so enable equipment of earlier types to be worked to terminals employing the more recently agreed C.C.I.F. frequencies. The inverter equipment comprises the inverter unit and associated amplifiers and frequency generating equipment.

Introduction.

PRIOR to the summer of 1938 there existed in this country two types of 12-circuit carrier system[1], known as carrier systems Nos. 5 and 6; each of these transmitted line signals corresponding to the lower sidebands of the 12 carrier frequencies spaced at 4 kc/s intervals between 16 and 60 kc/s. However, in 1938 the C.C.I.F. recommended that for international purposes groups of twelve channels as presented at an international boundary should be assembled as the twelve upper sidebands of the carrier frequencies spaced at 4 kc/s intervals between 12 and 56 kc/s. For reasons indicated in an earlier article[2] it was decided that new 12-circuit carrier systems introduced in this country should assemble 12-channel groups to meet the C.C.I.F. recommendations for boundary conditions of an international group.

It is apparent that inversion of the frequency spectrum (12 to 60 kc/s) as generated by the transmitting half of the channel equipment of carrier systems Nos. 5 and 6 will produce a spectrum having the form required of later 12-circuit systems. This article is concerned with the features of equipment which has been introduced to carry out the required inversion and so enable systems of the old and modern types to be interworked. In view of the very large number of channel equipments of the Nos. 5 and 6 types which exist in this country and of the rapidity with which equipments of the No. 7 type are being installed, a fairly considerable number of inverter installations will be required.

The factors affecting the design of a group inverter unit and also the choice of carrier frequencies have been the subject of an earlier article[3]; it is not proposed to duplicate the information here. It is pointed out, however, that the earlier article was concerned with an experimental model whereas this article is concerned rather with the final development of that model, i.e. the item as actually manufactured and installed.

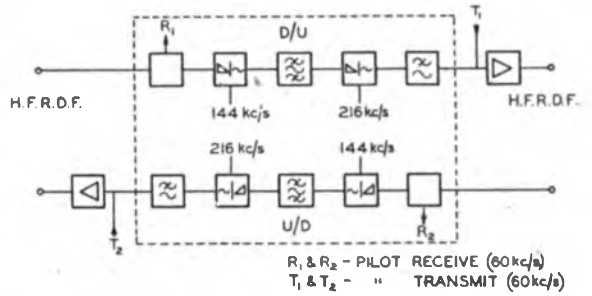

FIG. 1.—SCHEMATIC DIAGRAM OF INVERTER AND ASSOCIATED LINE AMPLIFIERS.

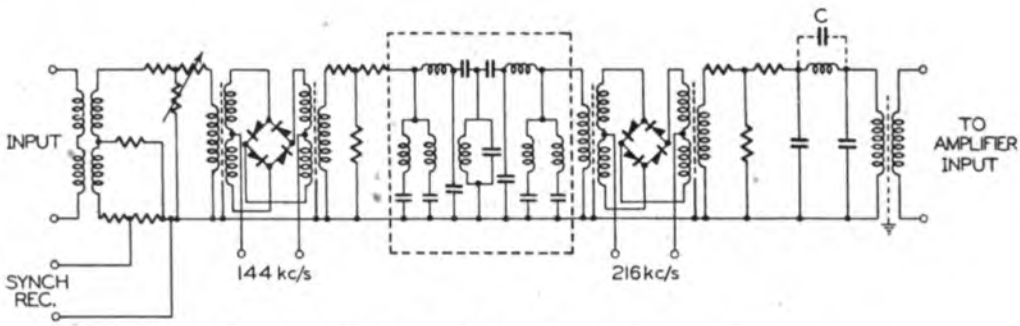

FIG. 2.—SCHEMATIC DIAGRAM OF ONE INVERTER PATH.

FIG. 3.—INVERTER UNIT.

[1] *I.P.O.E.E.* Printed Paper No. 171.

[2] *P.O.E.E.J.*, Vol. 34, p. 101, and Vol. 34, p. 161.

[3] *P.O.E.E.J.*, Vol. 33, p. 183.

For association with an inverter proper it is necessary to have carrier frequency generators and line amplifiers; the latter are necessary as the inverter has considerable loss and an amplifier of 12-circuit type (or equivalent) is required for association with each inverter path. As an inverter may have to be associated with any 12-circuit group terminating or passing through a station it is necessary for its association with other equipment to be on a flexible basis; for this reason each inverter path is associated with the high frequency repeater distribution frame (H.F.R.D.F.). The interconnection of inverter and miscellaneous apparatus required for a single 12-circuit group is indicated in Fig. **1**. That portion of the diagram within broken lines is mounted on one panel, the two amplifiers being mounted separately. The loss through each inverter path and the associated amplifier is adjusted to be approximately zero over the frequency range 12 to 60 kc/s.

The Inverter Unit.

Fig. **2** illustrates in schematic form a single inverter path; two such paths comprise one inverter unit which is accommodated on a panel 10½ in. in depth as shown in Fig. **3**. The input terminals of each inverter path are associated with the H.F.R.D.F. and the equipment offers an impedance of 140 Ω non-reactive, the test signal level being 5 db. above 1 mW. By means of a circuit associated with the secondary of the input transformer a part of the signal is made available at the "synch. rec." terminals; at this point all of the signal band is available, but there is also the 60 kc/s pilot signal. This received pilot signal is associated with the pilot receiving and carrier synchronising equipment in the manner appropriate to the basic carrier generating equipment. It is necessary to provide this pilot receiving facility as all incoming pairs carry (or will carry in the future) a pilot signal, and it is desirable that it shall be possible to utilise any pilot signal incoming to a station for the synchronising of carrier frequency generating equipment. It should be observed that after transmission through the inverter the 60 kc/s pilot signal is reproduced as a signal of 12 kc/s and it is therefore necessary to reintroduce the 60 kc/s pilot, and this is done at the input of the line amplifier, one of which follows each inverter path.

Frequency changers are all of the double balanced type and employ copper oxide rectifier elements. The construction of all circuit elements is normal, the components of the band-pass filter being contained in a sealed can. The condenser C across one of the coils of the low-pass output filter is used to effect approximate parallel resonance at 216 kc/s; this assists in keeping the magnitude of carrier leak to a tolerable level.

Six inverter units are mounted on each side of a double-sided 10 ft. 6 in. bay (Fig. 4) of standard dimensions; one of these baysides also accommodates the "B" amplifiers, "carrier fail" alarm panel and distribution busbars.

Carrier Frequency Generating Equipment.

The two carrier frequencies employed are 144 and 216 kc/s; these are both multiples of 4 kc/s. It is apparent that the carrier supplies could have been generated from controlled oscillators feeding inverter equipment only; however, to keep the amount of new apparatus to a minimum it was decided that inverter carrier generating equipment should be "driven" from carrier frequency generating equipment which normally feeds terminal apparatus of the Nos. 5, 6 and 7 types. A further factor which influenced this decision was the introduction of a common carrier frequency control scheme for the whole of the country; the "motor control" method of obtaining isochronism has been standardised for carrier generating equipment of the Nos. 5, 6 and 7 types. To derive the inverter carrier frequency supplies from independent oscillator equipment would have meant the provision of additional synchronising equipment as well as additional oscillators.

It was necessary to design the inverter carrier frequency generating equipment for control by any one of the following types of master supply:—

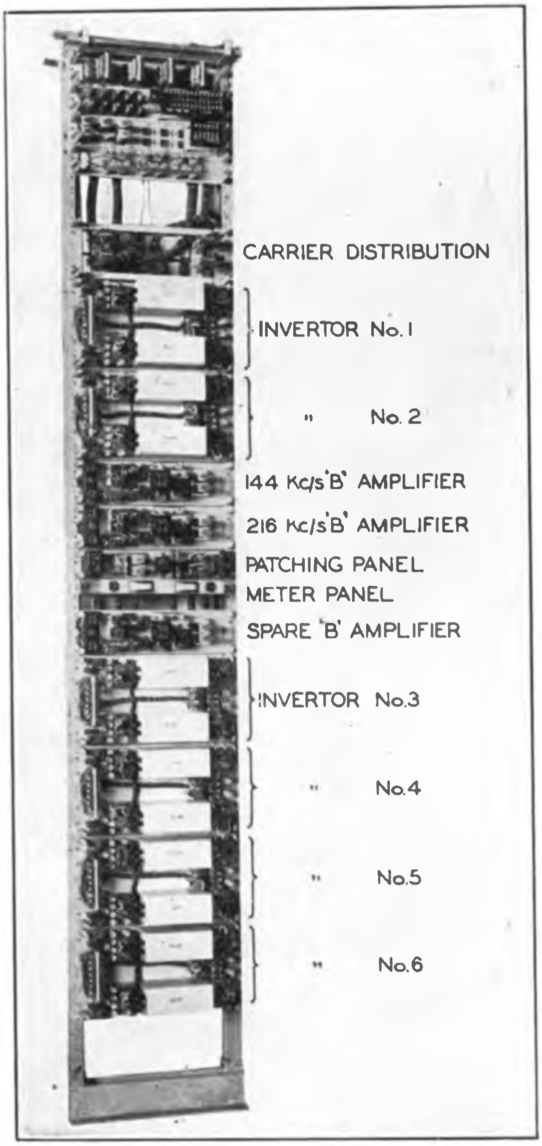

Fig. 4.—Bay of Inverter Units and Associated Equipment.

(1) High accuracy 1 kc/s tone which is available at a number of repeater stations throughout the country.
(2) 4 kc/s tone as produced by carrier generating equipment of the No. 5 type.
(3) 1 or 2 kc/s tone as produced by carrier generating equipment of the No. 6 type.
(4) 4 kc/s tone as produced by carrier generating equipment of the No. 7 type.

It was necessary to arrange that both normal and standby sources of the above types should be available to " drive " the carrier generating equipment. It was apparent that 4 kc/s could be taken as the basic frequency from which to derive the required frequencies and that additional equipment could be provided as required to effect any other frequency multiplication. The carrier generating equipment common to all types of supply is indicated in block

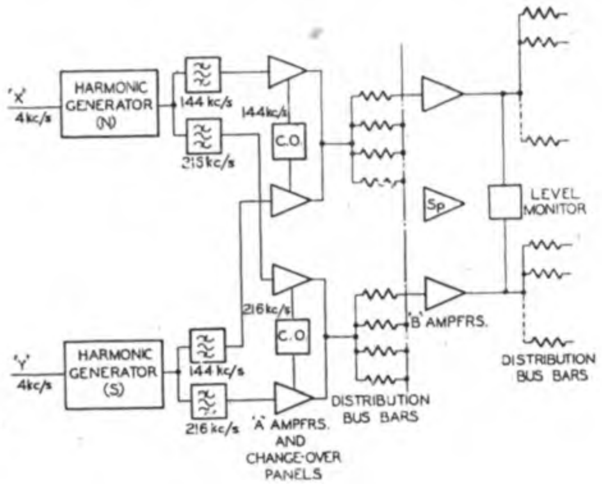

Fig. 5.—Schematic Diagram of Inverter Carrier Generating Equipment.

schematic form in Fig. **5**, the additional apparatus necessary in individual stations being shown in Fig. **6**.

Considering Fig. **5**, sources of 4 kc/s tone are applied simultaneously at points " X " and " Y " and feed duplicate harmonic generators. These harmonic generators are identical with those used for channel carrier frequency generation in the No. 7 type carrier equipment and employ the overloaded coil principle to produce a " peaked " output waveform. At the output of each of the harmonic generators there are two crystal filters in parallel to select the wanted supplies of 144 and 216 kc/s ; the filters offer considerable attenuation to frequencies other than those required. At the output of each filter there is a two-stage amplifier ; the outputs of each pair of amplifiers handling a particular frequency are paralleled. To avoid level variations it is necessary to ensure that only one of the amplifiers of each pair supplies power at any one time to the distribution busbars ; this is effected by a change-over panel associated with each pair of these (often called " A ") amplifiers. Output power from whichever amplifier is supplying the load is used in the change-over panel to provide a bias to suppress the output of the other amplifier of the pair ; in the event of the failure of output from the working amplifier the bias is removed and the second amplifier takes over the load. Change-over in either direction is automatic, but may also be performed manually for test purposes. The output

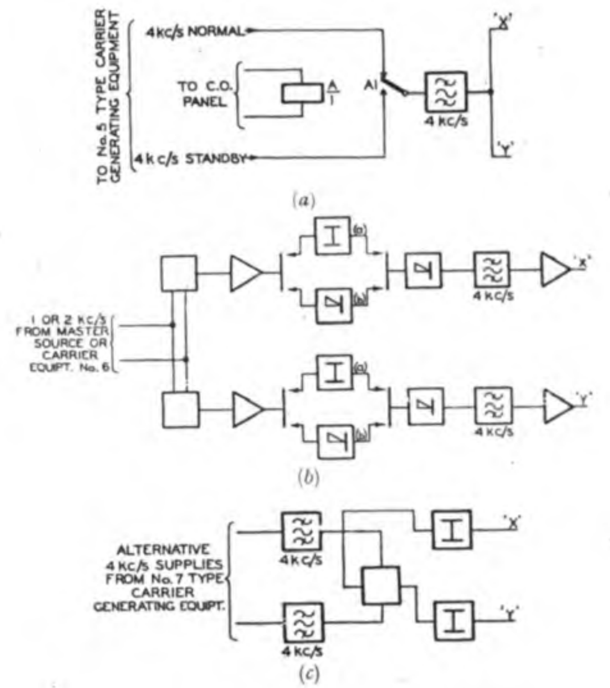

Fig. 6.—Schematic Diagrams of Auxiliary Generating Equipment.

of each pair of " A " amplifiers feeds a constant impedance busbar which provides for four outlets each capable of feeding one bay of 12 inverter units.

The power as supplied by the " A " amplifiers is not sufficient to " drive " 48 inverter units, and each inverter bay is therefore provided with additional (or " B ") amplifiers, these being provided on the basis of two workers (one for each carrier frequency) and a common spare. There is no automatic change over from a working " B " amplifier to the spare, but an alarm operates if the supply of either frequency fails, and the spare amplifier may be brought into service by " U " links. The output of each of the working " B " amplifiers feeds a constant impedance busbar from which 12 inverter units may be supplied.

Turning now to Figs. 6 (*a*), (*b*) and (*c*), each of these represents a panel of which only one is provided on any particular inverter installation. When the basic frequency is derived from carrier system No. 5 generating equipment (Fig. **6** (*a*)) two 4 kc/s supplies are available, one from the normal and the other from the standby oscillator ; the appropriate change-over panel determines which of these is carrying the load at any particular moment so an extension of this change-over panel is provided in order that the appropriate supply may be available to the inverter carrier frequency generating equipment. The 4 kc/s filter is provided to ensure that unwanted frequencies are not applied to the harmonic generators.

Where the 4 kc/s supplies are derived from the oscillators of carrier system No. 7 installations no additional change-over arrangement is necessary as an automatic supply suppressing arrangement is available on the channel carrier generating equipment. Fig. **6** (*c*) shows the arrangement of the appropriate panel on the inverter generator bay and no explanation of its operation appears necessary.

If the basic supply is of 1 or 2 kc/s (from a high accuracy master supply or from channel-carrier generating equipment of the carrier system No. 6 type), then the arrangement illustrated in Fig. **6** (*b*) is adopted. Either of the two incoming supplies passes through two input transformers in series (normally only one of the supplies will be providing current at any one time) and hence each of the amplifiers will be carrying a supply of either 1 or 2 kc/s as the case may be. If the supply is of 1 kc/s paths (*b*) of Fig. **6** (*b*) are wired into circuit, and this brings into use two frequency doubler stages in cascade. The output of the second frequency doubler stage of each path feeds via a filter and amplifier to the input of the inverter harmonic generators. If the basic supply is of 2 kc/s then paths (*a*) of Fig. **6** (*b*) are appropriate and only one stage of frequency doubling is effective. It is apparent that failure of either of the two doubler paths is guarded against by the change-over feature associated with the " A " amplifiers.

All of the inverter carrier frequency generating equipment is mounted upon one side of a standard 10 ft. 6 in. bay (Fig. **7**) but, as mentioned earlier, the " B " amplifiers are found on the inverter bays. As the inverter generators are driven by supplies already synchronised within the carrier network it is not necessary to provide special synchronising equipment on the inverter generator bays proper.

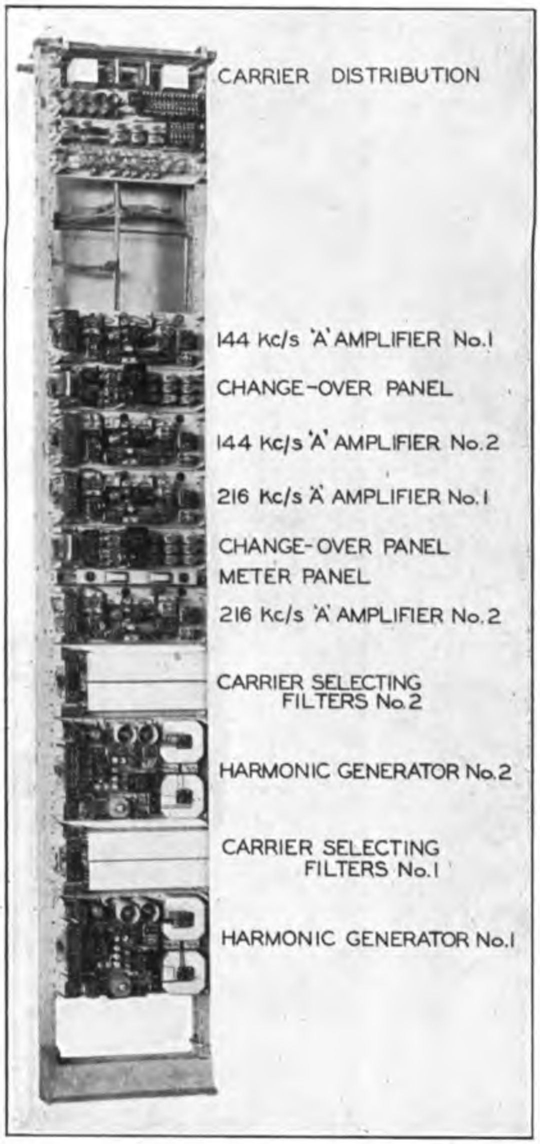

Fig. 7.—Carrier Frequency Generating Equipment.

Association with other Equipment.

As has been mentioned earlier, each inverter path must have associated with it an amplifier to provide a gain to offset the loss in the inverter itself ; line amplifiers identical with those used in association with the channel equipment of 12-circuit systems are provided for this purpose. As these line amplifiers are provided in bays carrying eight working amplifiers and a spare, a unit inverter installation may be considered as comprised of one inverter carrier frequency generator bay, one inverter bay and three line amplifier bays.

Performance.

An inverter is an unfortunate piece of apparatus in that it assists transmission in no way, and though necessary can only degrade the performance of circuits passing through it ; it is therefore desirable that it should have a sensibly flat gain/frequency characteristic, and produce the minimum of inter-channel and inter-group crosstalk. All of these characteristics cannot be obtained in perfection without undue cost, and the result is therefore a compromise ; the characteristics obtained are, however, good and the use of inverters is not likely to degrade to any noticeable extent the quality of the channels passing through them.

The performance of inverters tested up to the time of writing is as follows :—

Loss—frequency characteristic.—The loss of an inverter path as measured with an input signal of 30 kc/s may be between 54·8 and 56·3 db. ; this comparatively small variation is unimportant as it may be counteracted by adjustment of the associated line amplifiers. The envelope of loss-frequency characteristics measured as loss relative to the loss

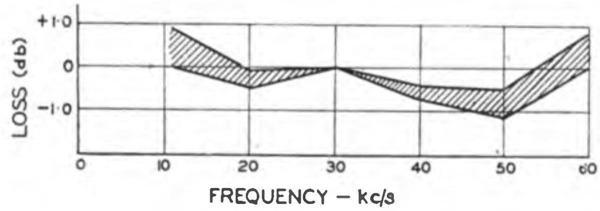

Fig. 8.—Envelope of Relative Loss-Frequency Characteristic of Inverter.

with an input signal of 30 kc/s is shown in Fig. **8** ; the characteristic is quite satisfactory, the maximum overall spread being less than 2 db.

Input impedance.—This falls between the limits 139 and 141Ω and is sensibly non-reactive.

Output impedance.—With condenser C of Fig. 2 having a value of 200 $\mu\mu$F a typical output impedance characteristic as measured at the output transformer terminals is as shown in Fig. 9.

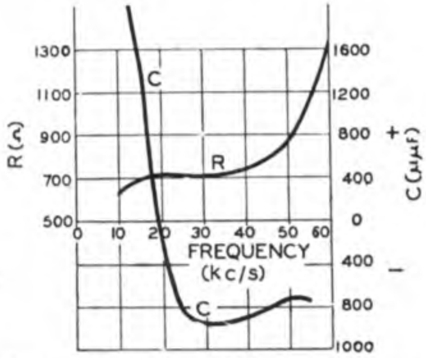

Fig. 9.—Output Impedance—Frequency Characteristic of Inverter.

Carrier leak.—This can be measured only at the output of the line amplifiers; it is comprised almost solely of 216 kc/s leak and has a value about 23 db. below the test signal level of the point in question. The importance of this leak is small, as owing to its frequency it is rapidly attenuated in a 12-circuit line, and for a group subjected to group modulation the resulting leak frequency is adequately suppressed.

Carrier level.—The carrier level as measured at the distribution busbars on the inverter bay is nominally 2·0 V and, in general, will not fall below 1·7 V. A drop of carrier level of about 3·0 db. at the output of the "A" amplifiers will cause automatic changeover; the alarm panel at the output of the "B" amplifiers operates on failure of carrier supply.

Interchannel interference.—Tests have been carried out using the "go" and "return" halves of a channel equipment of No. 5 type looped via three line amplifiers and two inverter paths; it will be appreciated that under these circumstances 12 unidirectional channels were set up and these were arranged to have an overall gain of 8 db. Measurements were made of inter-channel interference under the above conditions; these showed that the interference was only slightly worse than when 12 similar channels were set up using no inverter paths, i.e. with the halves of a channel equipment looped via one line amplifier only.

Interference was measured employing two speakers disturbing pairs of channels with an input level 8 db. below R.T.P., i.e. equivalent to 4 db. below R.T.P. at a zero level 2-wire test point. Under these conditions the weighted psophometric P.D. at a + 4 db. test level point ranged from 0·2 to 0·9 mV, which is satisfactory.

Inter-group crosstalk.—The group-to-group crosstalk as measured at the H.F.R.D.F. was in the main better than 85 db., the worst (and only figure of that value for all combinations of disturbing and disturbed groups) being 80 db.

While carrying out the tests on the first installation of inverter equipment much useful experience was gained in the effect of multiple crosstalk paths, particularly those via common earth and battery circuits. It was shown to be particularly important to ensure that the two carrier supplies were free to a very high degree from crosstalk of the other carrier frequency.

Location of Inverter Installations.

It has been necessary to consider where inverter equipment should be installed, as it is apparent that three courses are open in this connection. The inverters may be sited at the stations accommodating the No. 5 or 6 type equipment, at the stations accommodating the No. 7 type equipment or at points remote from the channel equipment and intermediate on the route. Arguments may be advanced in support of any of these sitings, but in view of the necessity of maintaining a maximum of flexibility under present-day conditions it has generally been considered desirable to site inverter installations at focal points, i.e. at the junction of numbers of 12-circuit routes at which an H.F.R.D.F. is available. It is apparent therefore that certain groups employing an inverter may be utilising inverted sidebands for one section of route and erect sidebands for the remainder.

It is important when working with 12-channel groups employing inverters to realise that channels employing the one end of the 12–60 kc/s range at the transmitting end of the group will employ the other end of the range at the remote terminal; in many cases this will affect channel numbering.

Consideration is being given to the desirability or otherwise of employing inverters at each end of a co-axial cable super-group when the groups are terminated upon channel equipments of the No. 5 or 6 types. Group translating equipment is designed to receive and to deliver groups of 12 channels assembled as inverted sidebands in the range 60–108 kc/s; however, if group-modulating equipment of standard design is employed to translate sidebands as delivered by Nos. 5 and 6 channel equipments into the 60–108 kc/s range then the sidebands are erect as presented to the group translating equipment, and this is undesirable. The difficulty could be overcome by employing inverter paths at each end of the co-axial cable super-group.

Conclusion.

The test results quoted in this article are those appropriate to an initial installation of inverter units as made by Standard Telephones & Cables, Ltd.; there is every reason to believe that future deliveries will have similar characteristics and that the very similar units being produced by the General Electric Co. will also have as good a performance.

Pneumatic Grinding Machine for Cutting Steel and Wrought Iron Pipes Containing Working Cables

F. E. PLUMPTON

U.D.C. 621.93 : 621.315.23.

The author describes a pneumatic grinding machine which has been developed for cutting steel or wrought iron pipes containing working cables. The pneumatic machine has certain advantages over the earlier electrical model, chief of which is its independence of electricity supplies

Introduction.

SINCE the article in the January, 1942, issue of THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL entitled " Equipment for cutting steel and wrought iron pipes containing working cables " was written, the development of a pneumatic machine to perform the same operation as the electric machine previously used has proceeded. Experience with the electric machine showed that there is considerable difficulty in arranging for an electricity supply to an excavation particularly where the work is in the middle of a road, on a bridge, or remote from consumers' premises. Air compressors are employed by the Post Office and it was considered that a machine capable of being driven by these units would be more convenient, as the pipe-cutting equipment would then be independent of outside sources of power. Frequently it would be convenient to use the air compressor, firstly for operating road-breaking tools to gain access to the pipe, and secondly to drive the grinding machine to cut away the steel pipes. The requirements of such a machine are that it should have ample power, should run at a fairly high speed under load and should be of a minimum width on each side of the centre line of the cutting element. Various designs were made up and trials made with these experimental machines were of considerable assistance in the development of the machine.

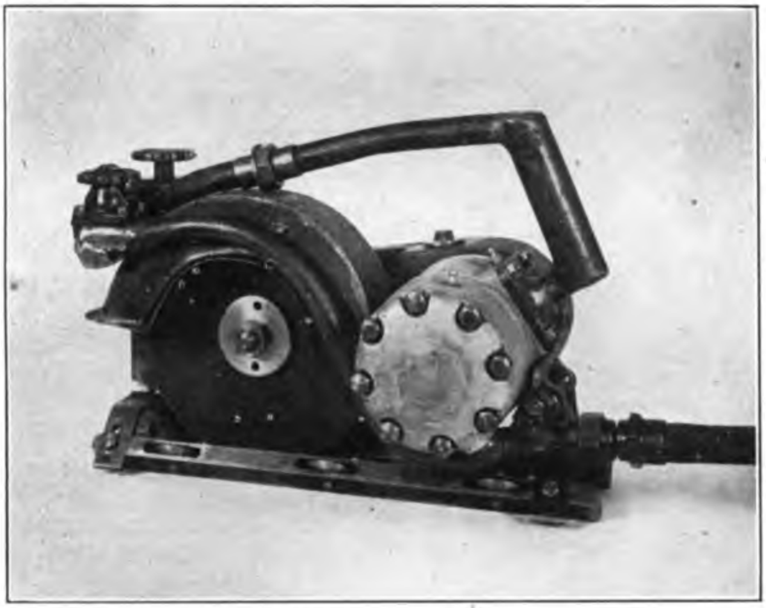

FIG. 1.—MODEL D MACHINE (SIDE VIEW).

MODEL D MACHINE

The latest machine (Model D) has been designed with rigidity and compactness as the keynotes, the overall dimensions being: length 16 in., width 9 in., height 11 in. Figs. 1 and 2 give some indication of its form.

No attempt has been made to keep the weight of the machine low and it scales about 40 lbs. This figure may seem high for a portable machine, but the weight assists in keeping the machine down on the work. Attention has been paid to the balance so that the centre of gravity lies low down at the back approximately in the plane of the cutting element. This arrangement reduces to a minimum any tendency to roll or for the back of the machine to kick when in use.

The Carrier.

The arrangement of the carrier is similar to that already developed for use with the electric machines. It has, however, been elaborated and adjustments provided to enable the machine to be used on pipes

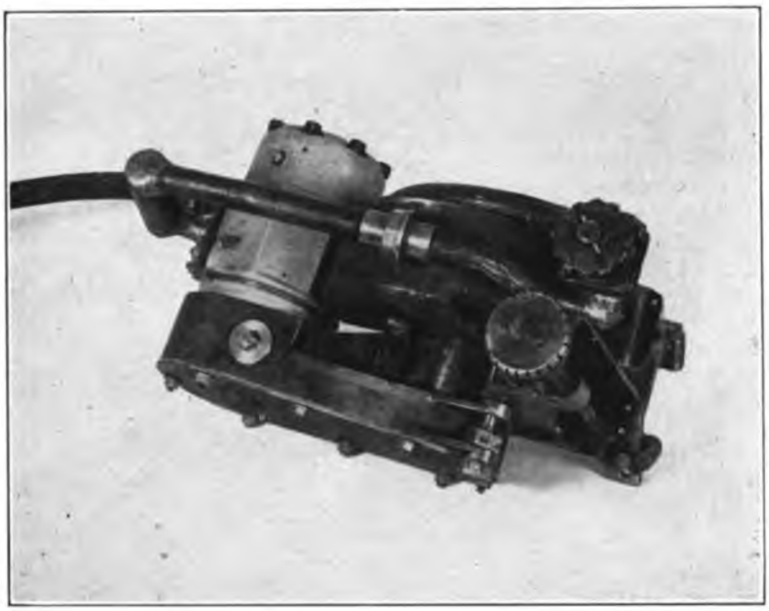

FIG. 2.—MODEL D MACHINE (PLAN VIEW)

of different diameters as well as on flat surfaces. The wheel frames are stronger than those fitted to earlier carriers and three pairs of wheels are fitted. The wheel fixings are made from one side of the wheel frames so that the other side is smooth.

Adjustment of the wheel frames for different sizes of pipe is effected by unscrewing the four bolts holding the wheel frames to the end pieces, and re-assembling in a different set of drillings (Fig. **3**).

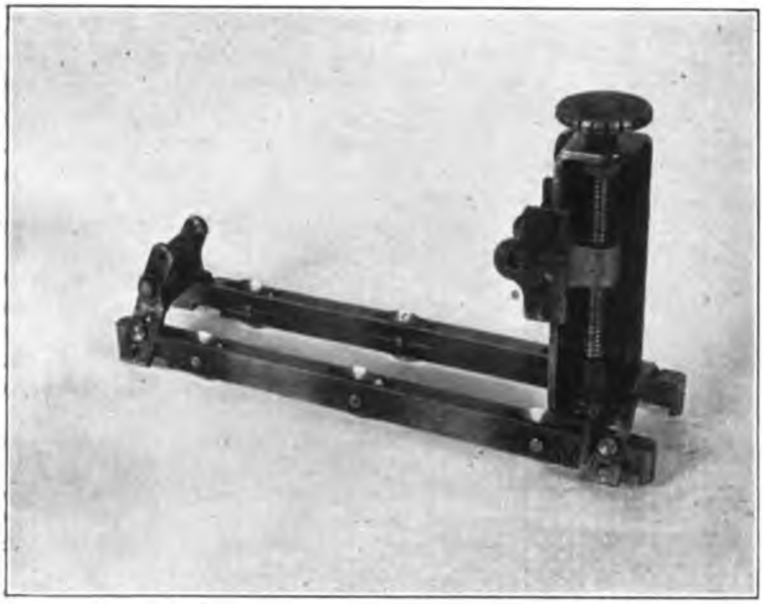

Fig. **3**.—Machine Carrier.

Drillings are provided, catering for pipes from 1½ to 4 in. diameter. The drillings are preferred to the slots used on a previous type of adjustable carrier as they ensure that the wheel frames are in exact alignment. The number of drillings in the end pieces does not exceed four, so that when the machine is being used on a small diameter pipe, the projection of the end pieces beyond the sides of the wheel frames does not foul adjoining pipes. It has been found that accurate alignment of the wheel frames with the plane of the cutting element is of vital importance if breakages are to be kept to a minimum and straight cuts made.

The end pieces fit into slots milled in the wheel frames. With this arrangement the end pieces are kept square with the wheel frames and the carrier assembly is prevented from lozenging as it is moved along the pipe. In one face of the wheel frames slots are milled to a uniform depth, whereas in the opposite face they are milled at an angle of 45 degrees to the face. This second set of slots enables the machine to be used on a flat plate, the end pieces being fitted into the 45 degree slots so that the wheels assume a vertical position as shown in Fig. **3** and run on the flat surface to be cut. When the machine is to be used as a circular saw for cutting timber, the wheel frames are reversed longitudinally and again assembled in the 45 degree slots so that the running wheels lie on their sides with the wheel fixings uppermost, the sides of the wheel frames acting as a sole plate for carrying the weight of the machine.

The front end piece carries the feed screw mechanism used to control the depth of cut and to compensate for wear of the abrasive discs. The assembly is of rigid construction offset from the plane of the abrasive disc and provided with a baffle to prevent the sparks and dust thrown off by the cutting element from striking the feed mechanism. At the lower end of the feed screw a steady is provided which is also used as a stop to prevent the machine being lowered on the carrier beyond the safe limit.

The rear end piece is provided with a hinged link which forms the back fixing of the machine.

The Mechanism.

The mechanism is carried on a channel section backplate $\frac{3}{16}$-in. thick of welded construction. The countershaft housing is welded into this backplate and is provided with longitudinal stiffening webs. The countershaft is carried on two ball races, location being effected by the larger race which is fitted at the driving end, and retained in the housing by a "Seeger" circlip. The ball race at the end carrying the cutting element is a push-in fit into the counter-shaft housing and is located only indirectly by the position taken up by the inner race on the countershaft assembly.

A labyrinth oil trap and felt washer are fitted at the driving end to retain oil in the chain case and to prevent loss through the countershaft housing. A similar arrangement at the outer end excludes the dust thrown off by the cutting element.

Transmission of power from the air motor to the countershaft is by a roller chain of 0·375 in. pitch and 0·206 in. width. The chain runs in an oil bath (Fig. **4**) fitted with a special deflector designed to direct some of the oil on to the inside of the lower run of the chain. From this position the oil must pass between the rollers of the chain as it is flung off. The counter-shaft end of the chain case is fitted fairly close to the chain so that a definite circulation of oil in the case is produced by the movement of the chain itself. Considerable pressure of oil is generated by this movement, and since the photographs were taken an oil pipe has been fitted from a point on the centre line of the chain, level with the countershaft to discharge on the inside of the lower run of the chain as it leaves the driver pinion, so that lubrication of the chain is further improved.

The chain runs on specially heat-treated steel pinions, and in view of the high speed at which it operates it is riveted endless and utilises no cranked links. Some doubts were entertained in the early stages as to the satisfactory working of the chain drive, particularly in view of the fact that on the experimental machine cycle chain was used. A length of cycle chain which has now been in service under load for many hours shows no sign of wear apart from the initial wear which is inevitable with a chain drive and in view of the superior quality of the 0·375 × 0·202 in. chain used in the Model D machine no anxiety is now felt on this score.

The compressed air motor is of the rotary vane type developing about 2½ h.p. and is governed at 5,500 r.p.m. It is controlled by a screw valve and mounted on the backplate by eight long bolts passing through the housing. These bolts pass through slots cut in the

Fig. 4.—Chain Oil Bath.

backplate, providing adjustment for the chain drive by sliding the air motor longitudinally. The variation in the length of the horizontal portion of the piping is taken up at the screwed union in the middle. As the chain is of 0·375 in. pitch and runs on short centres it is not considered necessary to provide more than about $\frac{3}{16}$ in. movement in this adjustment, as the chain would need replacement if this movement was insufficient to compensate for wear.

The machine has been designed primarily as a pneumatic grinder for splitting steel pipes and a reduction ratio of 21 to 25 between the motor and the countershaft is provided as it has been found that an operating speed of from 3,500 r.p.m. to 4,000 r.p.m. gives the best results with the abrasive discs at present in use. Under load the speed drops to between these figures. When used as a circular saw for timber the governed speed is rather high, but this is easily reduced where necessary by the control valve mounted on the machine. The advantages of governor control would of course be lost under these conditions.

Abrasive Discs.

In the development of this machine tests have been directed to finding the most suitable size and type of abrasive disc. The abrasive discs are intended primarily for cut-off operations in factories, and they have to a large extent replaced circular saws and similar devices in this sphere. Under factory conditions the power available is not limited by considerations of size or weight and usually it is possible to arrange a very rigid mounting. Discs are frequently operated at speeds up to 16,000 surface feet per minute. Conditions obtaining with portable machines impose very difficult requirements on the abrasive discs owing to the limited power available and the vibration of the machines while the cut is being made. In view of these factors it has been found necessary to reduce the operating speed to about 7,000 surface feet per minute.

It has been found that the best results on portable machines from every aspect are given by the thinnest discs available. The thickness of the disc is governed by the size of grit of the abrasive from which it is made, the bonding material used and the maximum speed at which the disc is to operate. These factors are now well understood by manufacturers who can supply discs to meet any given conditions or materials within wide limits, different manufacturers supplying discs of almost identical performance.

It appears that the disc which best meets Post Office requirements for cutting steel pipes on the machines at present in use, both electric and pneumatic, is 8 in. in diameter mounting on a 1 in. arbor. A disc $\frac{1}{16}$ in. thick appears to give the most satisfactory results. The thinness of this disc reduces the amount of metal to be removed as the slot is narrow, and consequently the power required to drive the disc is a minimum, so that the speed under load is well maintained. The thinness of the disc also gives it maximum flexibility so that it is able to tolerate inaccuracies in the alignment of the machine on the pipe and the risk of breakages is correspondingly reduced. If the abrasive discs are fitted between large clamping plates, the disc is held rigidly, with the result that a slight deviation of the machine from the true line of cut causes breakage of the disc. With small clamping plates it has been found that the give in the disc allows more tolerance in this respect.

The length of cut given by the best types of disc on Post Office steel pipes $\frac{3}{16}$ in. thick is about 15 ft. and does not seem to vary greatly between fairly wide limits of machine speed. It also appears to be independent of the rate at which the cut is made.

Method of Use

The length of pipe to be removed is first cut circumferentially at each end with the ordinary wheeled pipe cutters. Wooden blocks are inserted to lift the unwanted section of pipe away from the cables to avoid damage to the cables and to prevent the pipe rolling on the cables. The wheel frames of the carrier are adjusted to the most suitable position for the size of pipe in hand. The most convenient position for the start of the cut is such that the back wheels of the machine just rest on the pipe. Other local conditions may, however, make it necessary to start the cut at another point. The air valve is slightly opened and with the machine running slowly the disc is lowered on to the pipe by the hand feed. When the disc touches the pipe the air valve is opened fully and the disc lowered until a cut has been made through the thickness of the metal of the pipe. In this operation, the hand feed may be turned quite quickly as the cutting speed of the disc is high, penetration of the pipe being made in a few seconds.

The machine is then gently pushed along the pipe. Great pressure is not required, although it is advantageous to hold the machine down on the pipe. In this way a cut is made along the pipe. As the end is reached the front wheels of the carrier pass beyond the end of the pipe and the weight of the machine is carried on the centre and rear wheels so that the cut can be made to the end of the pipe without the dropping which was liable to occur with the earlier four-wheeled carriers. Care must be exercised as the end of the slot is cut, as some pipes have a tendency to spring either open or closed when this point is reached, and disc breakage may occur.

The machine is lifted off the pipe, turned to face the opposite direction and replaced on the pipe near the starting point of the cut. These operations are repeated for the few remaining inches of cut between the beginning of the slot and the other end of the pipe.

Observations.

The advantages of the pneumatic machine over the electric machines at present in use include the following :—

(1) Universal availability, as the machine can be driven from a mobile compressor or from a factory compressed air installation.
(2) Complete independence of electricity supply enables the machine to be brought into use quickly without the need of co-operation from other undertakers or of portable petrol electric generators.
(3) Superior performance owing to greater power of the motor.
(4) Greater robustness of compressed air motor as compared with the electric motor. The pneumatic machine is not damaged if the motor is stalled or run in an overloaded condition for any length of time.

Some performance figures of the new machine may be of interest. The following figures obtained under experimental conditions are probably better than those which will be obtained in practice. Even so, it is not thought that an expectation of one foot of cut per minute is unduly optimistic.

Length of cut ..	15 in.
Time	40 sec.

In view of the speed of cut, the question arises whether it is still economical to force the pipes open in the way described in the previous article where they can be revolved on the cables. In cutting a pipe, say 1 yard in length, the time taken to make the cut would be approximately three minutes, so that two cuts could be made in about eight minutes (allowing time for setting up) and the pipe removed in two halves. The time required to force open one yard of pipe is approximately thirty minutes and it would appear, therefore, that this operation could be dispensed with except where the pipe has been flattened and forcing open is unavoidable.

A provisional patent specification has been filed in respect of the machine.

Acknowledgments.

It is desired to acknowledge the assistance given by the undermentioned, who were consulted at various stages in the development of the machine.

Messrs. Roscoe & Howard, who made up and modified the various machines and carriers.

Messrs. Holman Bros., Ltd., who recommended and supplied suitable power units and pneumatic fittings for the machines.

The Carborundum Co., Ltd., and The Universal Grinding Wheel Co., Ltd., who supplied various abrasive discs for trial purposes.

The Renold & Coventry Chain Co., Ltd., who recommended and supplied a suitable type of chain for the machines,

and Mr. G. Nash.

Book Review—*Continued from page* 125.

slightly from the very clear descriptions of the principles of the various pieces of apparatus and of the associated circuits.

My main criticism lies with the matters not dealt with. No handbook on telephony is complete without reference to the Director system. Non-Director circuits and trunking arrangements are dealt with in 23 pages, and presumably an outline of Director working could have been covered in a similar space, i.e. less than the number of pages devoted to batteries. Also the 2,000 type selector and associated circuits constitute such an important and fundamental change to automatic switching practice that their omission cannot be condoned on the grounds quoted in the preface that "the descriptions of existing plant and circuits will suffice for examination purposes for a few years to come." Other less important omissions from this section of the book include trunking theory, differential signalling, 2VF signalling, U.A.X.'s and the P.M.B.X.1A.

The final chapters, occupying slightly more than one-third of the book, relate to telephone transmission. The subject is dealt with mathematically and a knowledge of hyperbolic functions is assumed. After an introductory chapter on transmission theory, line characteristics and loading are dealt with, followed by chapters on filters, equalisers, valves and repeaters. Final chapters deal with carrier systems, submarine cables and transmission standards.

Minor points of criticism of this section include the treatment of crosstalk purely from the electrostatic viewpoint (Fig. 285), lettering faults on Figs. 296 and 299, the description of carrier systems now almost obsolete, and the statement that "when more than two or three carrier channels are required in each pair, the use of separate cables for go and return channels must be considered."

The book does not attempt to cover radio telephony or external plant construction.

It is hoped that the 9th edition will see a general cleaning-up of these various minor points which detract somewhat from what is otherwise an excellent book. By keeping to basic principles throughout and avoiding the temptation to go into lengthy details—particularly with regard to circuit descriptions—the authors have produced a very readable book which is well worth a place on every telephone engineer's bookshelf.

H. L.

Notes and Comments

Roll of Honour

The Board of Editors deeply regrets to have to record the deaths of the following members of the Engineering Department :—

While serving with the Armed Forces, including Home Guard

Belfast Telephone Area	Faulkner, T. J.	Skilled Workman, Class II	Lance Corporal, Royal Corps of Signals
Bradford Telephone Area	Travers, T.	Unestablished Skilled Workman	Leading Aircraftman, Royal Air Force
Canterbury Telephone Area	Spratt, L. F. K.	Unestablished Skilled Workman	Sergeant Observer, Royal Air Force
Cardiff Telephone Area	Cradock, L. F.	Unestablished Skilled Workman,	Sub-Lieutenant, Fleet Air Arm
Colchester Telephone Area	Markland, R. W.	Unestablished Skilled Workman	Acting Leading Airman, Fleet Air Arm
Dundee Telephone Area	Stein, D. M.	Unestablished Draughtsman	Pilot Officer, Royal Air Force
Engineering Department	Dunn, M.	Skilled Workman, Class I	Pilot Officer, Royal Air Force
Engineering Department	Roper, L. W.	Inspector	Aircraftman, Class II, Royal Air Force
Exeter Telephone Area	Coad, J. W.	Unestablished Skilled Workman	Sergeant, Royal Air Force
Gloucester Telephone Area	Denton, I. W.	Unestablished Skilled Workman	Private, Royal Warwickshire Regiment
Leeds Telephone Area	Shelton, W.	Unestablished Skilled Workman	Trooper, 9th Lancers
London Telecommunications Region	Billett, G. A.	Unestablished Skilled Workman	Signalman, Royal Corps of Signals
London Telecommunications Region	Burke, J.	Unestablished Skilled Workman	Leading Aircraftman, Royal Air Force
London Telecommunications Region	Davies, D. J.	Skilled Workman, Class II	Lance Corporal, Royal Corps of Signals
London Telecommunications Region	Deedman, J. A.	Youth-in-training	Aircraftman, Class II, Royal Air Force
Norwich Telephone Area	Ellis, R. F.	Unestablished Skilled Workman	Radio Observer, Royal Air Force
Taunton Telephone Area	Williams, E. J.	Unestablished Skilled Workman, Class II	Trooper, Royal Armoured Corps

Recent Awards

The Board of Editors has learnt with great pleasure of the honours recently conferred on the following members of the Engineering Department :—

While serving with the Armed Forces, including Home Guard

Dundee Telephone Area	Blair, A. J.	Unestablished Skilled Workman	Sergeant, Royal Corps of Signals	Military Medal
Edinburgh Telephone Area	Burgess, J. A.	Unestablished Skilled Workman	Flight Sergeant, Royal Air Force	Distinguished Flying Medal
Liverpool Telephone Area	Hewson, E.	Inspector	Corporal Royal Corps of Signals	*Medal of the Order of the British Empire
London Telecommunications Region	Ostler, C. W.	Skilled Workman, Class II	Signalman, Royal Corps of Signals	British Empire Medal

* Shown erroneously in the October, 1942, issue as Order of the British Empire.

Regional Notes

South Western Region

AIR RAID ON BATH

Air raids have produced for P.O. engineers in all parts of the country problems in repair work which would have been more than surprising in peace time. But even though unusual works have ceased to be surprising some of them may nevertheless be worth recording for the information and interest of readers. Here are some examples from Bath.

Steel Shelter and Skilsaw

At the approach to a bridge a bomb which burst near the surface had caused considerable damage and confusion to many services. The P.O. track consisted of five 2-in. W.I. pipes and one 3-in. C.I. pipe, containing altogether five large cables. The pipes had been broken and forced above the surface, but the cables were still working except for a few circuits. Earthenware ducts would have been completely demolished. After detailed inspection and temporary repairs, 24-hour shift work for permanent restoration was organised. As further raids were to be expected a two-section jointer's steel shelter was erected. A number of these shelters had been provided for just such work, but they had not previously had more than a test assembly.

The shelter was supported above the crater on timbering, and as the photograph shows plenty of rubble was available in lieu of sand-bags.

For the final restoration an additional manhole 11 yards from the original manhole had to be built, which involved the removal of the iron and steel pipes from the cable. This was work for the Skilsaw, a new tool which has been described in a previous issue of this Journal. It proved to be invaluable and cut through the iron pipe with the greatest ease : for the W.I. pipes, which were only 2 in. diameter, modifications had to be made to the cradle guide of the tool. The cuts made totalled 31 ft. 6 in. and took approximately 12 hours. The experience with the tool was very valuable and afterwards we were able to make a number of suggestions for minor improvements.

The Moving Manhole.

Another serious incident affecting main trunk cables resulted in a manhole being moved bodily towards a bomb crater. Four C.I. pipes were broken in the track, leaving 2-in. gaps, whilst the manhole itself was quite undamaged. Repair operations were complicated by the presence of an unexploded bomb a few yards from the manhole dropped on a second raid.

Another Bomb Story

This we think is really unusual : A 500-lb. bomb had cut the arms off a D.P. on its way down and gone to earth near the base of the pole. The Bomb Disposal Squad found that the bomb had " jerked " through a cellar wall and entered the cellar horizontally. This cellar was the resident's air raid shelter and the bomb had neatly laid itself under the bed !

Scottish Region

MOBILE CANTEEN

A mobile canteen has been prepared in the Edinburgh Telephone Area for the use of all grades of the Area staff principally under blitz conditions, but also under such conditions as storm repairs, cable breakdowns, etc., where staff may be employed for lengthy periods without the opportunities of refreshment. A subscribers' apparatus delivery van has been utilised for the purpose and is provided with suitable detachable fittings which are normally stored so that the van is kept in service for its normal functions until specially required for canteen purposes. Certain minor alterations have been made to the internal arrangements of the van which, in fact, are found to facilitate the work of the van, and the fittings provided include three five-gallon vacuum containers which can be used for transporting hot food such as soup, stews, tea, etc., and a five-gallon container with oil heater to provide hot water for washing, and also crockery and cutlery in suitable quantities. Arrangements for the food supply have been made with the Local Food Officer and at least a hundred hot meals at the outset can be provided. The total cost of providing all fittings and food for this canteen has been met by the staff of all grades in the Area.

POLE DAMAGE BY BIRDS

Damage, of an unusual nature, occurred recently to a rural pole route in the Argyllshire area, when a number of poles were attacked by birds of the woodpecker species.

The affected portion of the route consists of home-grown larch poles, 1935 series, many of which, although in a good state of preservation, had large, conical-shape cavities in the timber, principally in the area occupied by the pole fixtures. A few poles had been so damaged as to necessitate immediate renewal. Preliminary preventive measures consisted of applying a liberal dressing of creosote and tar to the affected portions of the poles, but this method failed to prevent further attacks, and was objectionable to linemen working on the route.

Based on the theory that although no " hum " was noticeable to the human ear, the birds could detect a sound which suggested to them the presence of a grub or beetle inside the pole, the familiar silencing method of wrapping lead strip round the line wires was applied. This was immediately successful in curbing the activities of the birds, and the attacks ceased, being renewed only when the lead strip was temporarily removed.

Poles which had been damaged, but not to the extent of justifying renewal, were also treated by plugging the cavities with compound No. 5, which, however, was found to be unsatisfactory under summer conditions. A more suitable filling was ultimately found in mixture No. 2, which provided an effective seal against the ingress of moisture under all conditions.

A. M.

Staff Changes

Promotions

Name	Region	Date
Exec. Engr. to Asst. Staff Engr.		
*Franklin, R. H.	E.-in-C.O.	23.9.42
Hibbs, A.	E.-in-C.O.	23.9.42
Asst. Engr. to Exec. Engr.		
Blackburn, E.	N.W. Reg.	27.8.42
Bray, W. J.	E.-in-C.O.	8.9.42
Thorn, B. K.	Mid. Reg.	27.8.42
Clibbon, H. A.	N.W. Reg. to E.-in-C.O.	24.9.42
Birch, S.	N.E. Reg. to Scot. Reg.	26.10.42
*Bucknall, F. R. B.	Scot. Reg.	26.10.42
Markby, E. J.	Scot. Reg.	26.10.42
Smith, J.	E.-in-C.O.	12.10.42
Chief Insp. to Asst. Engr.		
Evans, W. A. A.	L.T. Reg.	28.8.42
Andrews, W. E. T.	H.C. Reg.	21.8.42
Wright, F. E.	N.E. Reg.	13.9.42
Morgan, C. A.	L.T. Reg. (Seconded to Contracts Dept.)	4.10.42
Roberts, W. J.	N.W. Reg. to S.W. Reg.	4.10.42
Willmot, C. J.	H.C. Reg.	15.10.42
Hancock, L.	Mid. Reg.	15.10.42
Evans, T.	N.W. Reg.	30.10.42
Quinn, P.	Scot. Reg.	15.11.42
Chief Insp. to Chief Insp. with Tempy. Allce.		
Lockwood, R. A.	H.C. Reg.	15.10.42
Draughtsman Cl. I to Senior Draughtsman.		
Ivory, B.	N.W. Reg. to W. & B.C. Reg.	2.8.42
Insp. to Chief Insp.		
Burcher, P.	Mid. Reg.	13.9.42
Hale, C. S.	S.W. Reg. to N.W. Reg.	20.9.42
Insp. to Chief Insp.—cont.		
Adams, G. H.	S.W. Reg. to L.T. Reg.	2.8.42
Wareham, J. H.	N.W. Reg.	19.4.42
Walker, W. A.	N.E. Reg.	14.9.42
Whitehead, E. H.	H.C. Reg.	27.9.42
Heyburn, L. G.	H.C. Reg.	12.4.42
Large, G. V.	N.W. Reg. to W. & B.C. Reg.	30.8.42
Moore, B. H.	L.T. Reg.	28.8.42
Smith, W. R.	H.C. Reg.	31.7.42
Howard, J. K.	S.W. Reg. to W. & B.C. Reg.	11.10.42
Saunders, C. T.	E.-in-C.O.	1.3.40
Ritchie, G. B.	Scot. Reg.	1.11.42
Apperley, H. L.	S.W. Reg.	31.8.41
Gearing, A.	E.-in-C.O.	12.10.42
Norris, H. E.	H.C. Reg.	26.5.42
Dean, G. A.	W. & B.C. Reg.	6.9.42
Bridges, G. W. M.	Test Section, London	12.10.42
Scutt, R. S.	H.C. Reg.	11.10.42
Rutland, G. A.	S.W. Reg.	8.9.42
Nelson, J.	Scot. Reg. to N.W. Reg.	29.11.42
Draughtsman Cl. II to Draughtsman Cl. I.		
Polling, T. W.	E.-in-C.O.	4.8.42
Pratt, B.	N.W. Reg.	1.9.42
Brasier, C. J.	L.P. Reg. to N.W. Reg.	6.9.42
S.W.I. to Insp.		
Steed, C. A.	E.-in-C.O.	12.9.42
Whitaker, F. S.	Test Section, London	27.8.42
Powell, A. E.	Test Section, B'ham	19.8.42
Roberts, G. H.	Cable Test Section, London	21.6.42
Dunlop, W. G.	E.-in-C.O.	28.2.42
Wyatt, E. J. R.	L.T. Reg. to E.-in-C.O.	20.4.42
Cowland, T. A.	L.T. Reg. to E.-in-C.O.	23.4.42

* Promoted "in absentia." All promotions "acting."

Appointments

Name	Region	Date
Proby. Asst. Engr.		
Truslove, E. H.	L.T. Reg.	6.7.42
Proby. Asst. Engr.—cont.		
Jemmeson, A. E.	Scot. Reg.	14.9.42

Retirements

Name	Region	Date
R.M.T.O.		
Griffiths, W. R.	H.C. Reg.	31.10.42
Area Engr.		
Jones, L. J.	L.T.Reg.	25.11.42
Asst. Engr.		
Reynolds, E. J.	H.C. Reg.	11.10.42
Chief. Inspr. with Allce.		
Padget, A.	H.C. Reg.	4.9.42
Davidson, T.	Scot. Reg.	31.10.42
Chief Insp.		
Drane, H. J.	S.W. Reg.	6.11.42
Insp.		
Bazley, W.	L.T. Reg.	2.11.42
Heason, H. G.	H.C. Reg.	12.7.42
Williams, A. J.	S.W. Reg.	30.11.42

Deaths

Name	Region	Date
Chief. Insp.		
Cave, C. P.	H.C. Reg.	6.10.42
Insp.		
Brown, H. W. D.	L.T. Reg.	26.8.42
Insp.—cont.		
Roper, L. W.	E.-in-C.O. (killed on active service)	26.8.42
Bailey, A. J.	E.-in-C.O.	26.10.42

Transfers

Name	Region	Date	Name	Region	Date
Reg. Engr.			*Insp.*		
Stone, A. E. ..	.. H.C. Reg. to L.T. Reg. ..	20.7.42	Pratt, F. A. N.	.. L.T. Reg. to W. & B.C. Reg.	21.9.42
Area Engr.			Sugars, E. G. ..	.. L.T. Reg. to E.-in-C.O. ..	1.10.42
Pitcairn, A. C.	.. W. & B.C. Reg. to N.E. Reg.	12.10.42	Bailey, G. W.	.. Mid. Reg. to E.-in-C.O. ..	1.11.42
			Head, D. E. ..	.. Mid. Reg. to E.-in-C.O. ..	1.11.42
Asst. Engr.			*Proby. Insp.*		
Dixon, J. ..	.. W. & B.C. Reg. (Seconded to Contracts Dept.) to N.W. Reg.	8.10.42	Driver, E. R.	.. L.T. Reg. to E.-in-C.O. ..	21.9.42
			Parks, F. ..	.. N.E. Reg. to E.-in-C.O. ..	1.11.42
			Cooper, G. ..	.. N.W. Reg. to E.-in-C.O. ..	1.11.42

CLERICAL GRADES

Promotions

Name	Region	Date	Name	Region	Date
From E.O. to S.O.			*From C.O. to E.O.*		
			Holden, A. G.	.. H.C. Reg. to E.-in-C.O. ..	25.10.42
Daly, G. ..	.. E.-in-C.O.	14.8.42	*From Chief Supt. of Typists to H.C.O.*		
Granville, H. G.	.. E.-in-C.O.	14.8.42	Holmes, M. W. (Miss)	E.-in-C.O.	1.6.42

All promotions "acting."

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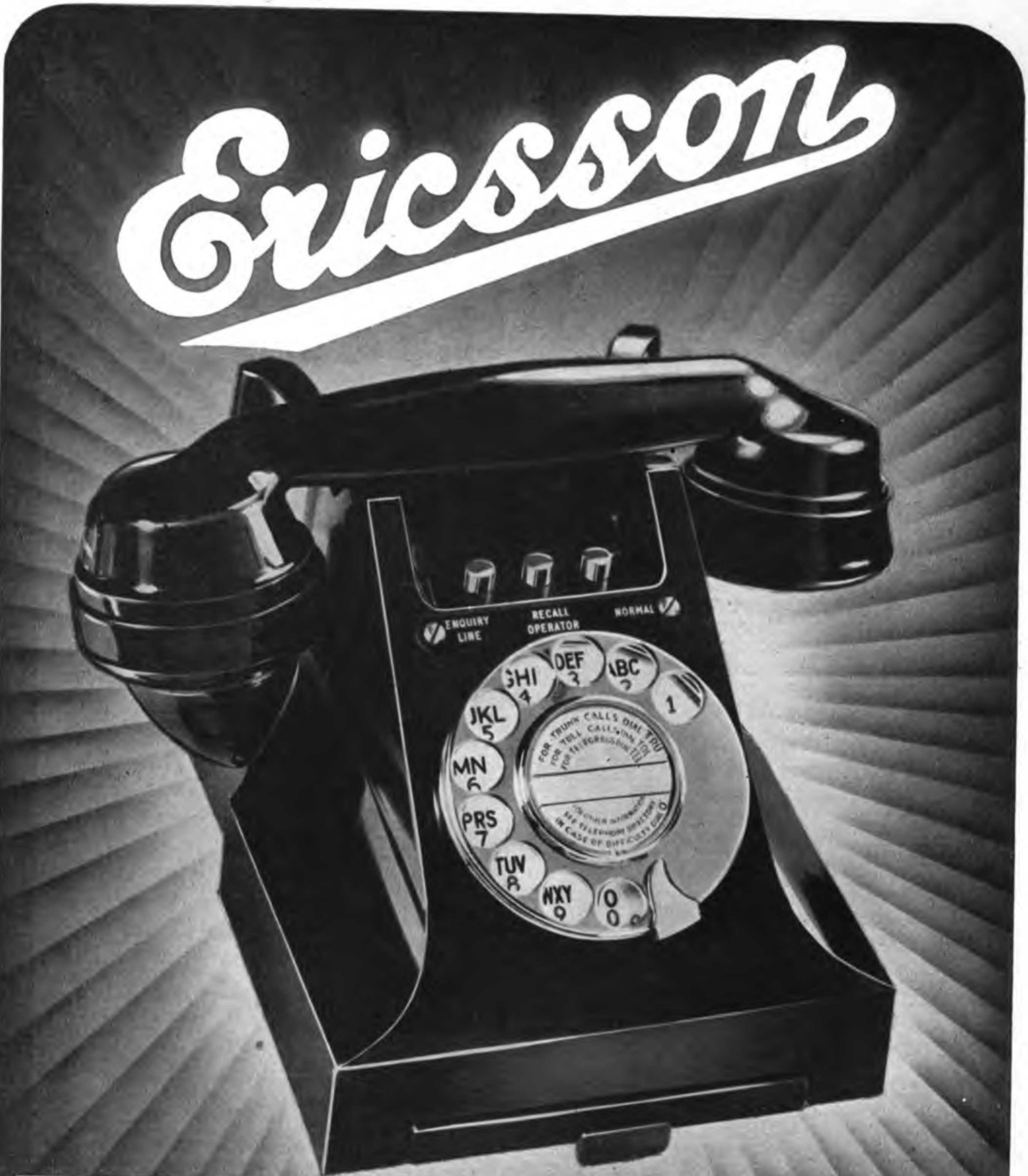
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