The Telecommunication Journal of Australia

No. 4 DECEMBER, 1936

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THE POSTAL ELECTRICAL SOCIETY OF VICTORIA

The

Telecommunication Journal of Australia

No. 4. *DECEMBER, 1936*

R. LAWSON, M.I.E. (AUST.)

THE appointment of Mr. R. Lawson as Chief Engineer is a very happy one.

In the 22 years of his service with the Postmaster-General's Department in Australia his duties have brought him into close touch with the officers of the Engineering Branch in all the States, and he is, therefore, well known to many of us. His personality has made him very popular with his colleagues, and the Engineering Branch is fortunate to have him at its head.

R. Lawson, M.I.E. (Aust.)

His association with Post Office activities goes back much further than the years he has spent in Australia, as he was a member of the staff of the British Post Office for some 16 years until he left to take up his new duties in Australia.

His service, first in Central Office, then as Superintending Engineer in South Australia, Victoria and New South Wales, and as Deputy Director, Victoria, has given him a thorough knowledge of the Australian Telephone and Telegraph Network, and will give him a sympathetic understanding of any problems which may arise.

Mr. Lawson has been chairman of both the Melbourne and Sydney Divisions of the Institute of Engineers (Aust.), and was a Councillor of that Institution for some years. He is also very interested in the Rotary Club, and has been a Director in both Sydney and Melbourne.

Mr. Lawson firmly believes that officers of the Department should establish as many contacts with the public as is possible, and he himself has spent much of his private time in making known details of the Department's general operations by lectures before various bodies and by other means. There is no doubt that the Department and its officers have a higher standing in the opinion of the community than ever before, and it is not too much to say that some credit for this is due to Mr. Lawson for bringing under notice the value of the work being done by us all in providing Communication Services throughout Australia.

In Great Britain, he was associated with the Institution of Post Office Engineers, and it will be remembered that before he came to Australia he wrote papers on "Wireless Telephony" and "Automatic Telephony," which were printed by the Institution as papers Nos. 21 and 34 respectively.

Whilst in New South Wales he was instrumental in founding the Engineering Lecture Society, which was responsible for the presentation of many outstanding papers.

Mr. Lawson has shown his appreciation of the efforts of the Society by attendance at its meetings, and has contributed a paper.

The Society extends its congratulations, and hopes that Mr. Lawson will have as happy a time in his new position as in those he has occupied previously.

THE BRITISH POST OFFICE TYPE 2000 LINE-FINDER SYSTEM

W. A. Phillips, A.M.I.E.E. Automatic Telephone and Electric Coy. Ltd. Liverpool

INTRODUCTION.

Originally invented nearly fifty years ago, the Strowger step-by-step system of automatic telephony is at present serving over 10,000,000 subscribers' lines in sixty-six different countries. Outstanding characteristics of Strowger equipment are the employment of fundamentally simple, individually-driven selector mechanisms and the straightforward decimal basis of the trunking arrangements.

At different periods the subscriber's line-switching apparatus has been developed in successive stages, namely, the Keith lineswitch, the non-homing uniselector (rotary lineswitch), which was followed by the homing type, and finally the line finder. These successive developments were radically different in design and construction, the Keith lineswitch being of the plunger type, the uniselector being of the single-motion rotary type, and the line finder of the two-motion, vertical and rotary, type.

On the other hand, the main or numerical position of the switching apparatus has always comprised the well-known two-motion mechanism at all numerical switching stages. Within the last few years the two-motion mechanism has also been adapted, with conspicuous success, to perform the line-finder function, with the result that in this system only one type of relay and one type of selector mechanism is employed.

A significant fact concerning the Strowger two-motion mechanism is that, up to quite recently, its design and construction remained practically unchanged for fully thirty years. A high degree of standardisation had been attained and had yielded highly satisfactory results in service. This basic fact of practically fixed design over so long a period definitely demonstrates the fundamental simplicity and universality of the two-motion selector and the soundness of its design and construction.

The world-wide economic depression of recent years has demanded concentrated efforts on the part of engineers towards effecting economies in every possible direction, particularly as regards the first costs of automatic equipment and the saving of floor space in exchange buildings. At the same time, no lowering of the grade of service given to the public could, of course, be tolerated. Highly satisfactory results have been secured by these efforts, examples being as follows:—

(a) The radical improvements and simplifications in the mounting arrangements by means of single-sided rack equipment.

(b) The perfecting and standardisation of the line-finder system having partial secondary trunking and plurality hunting of the line finders.

(c) The miniature type line and cut-off relays.

(d) The development and standardisation of the new B.P.O. Type 2000 two-motion selector mechanism, together with its simplified and improved mounting and circuit arrangements.

This article deals with the last-named and first describes the Type 2000 mechanism, which is the keystone of the entire system.

The Development of the Type 2000 Selector.

This selector was developed by the Automatic Telephone and Electric Co. Ltd., Liverpool, and adopted as a standard by the British Post Office.

The main objects aimed at in developing the Type 2000 selector were the attainment of substantial improvements, as compared with the existing design, as follows:—

(1) Reduction in overall dimensions.

(2) Improvement in operating characteristics.

(3) Simplification and greater permanence of adjustments and ease in replacement and maintenance operations.

(4) Greater flexibility of application.

(5) General economy.

A period of fully six years was spent in developing the new selector. It will be appreciated that it was a formidable task to produce a mechanism which would have the desired advantages over a model which had attained such a high degree of perfection. Every possibility for improvement was studied and in the earliest stages of the development work, numerous models embodying widely different design features and operating principles were made up and tried out. It is, of course, quite impossible to describe, even in the barest outline, the numerous studies, researches, experiments and tests involved in the development work. It must suffice to remark that the Type 2000 selector ultimately emerged as a consolidation and improvement of its eminent predecessor, from which it does not differ in any respect as regards the fundamental principle of operation.

The measure of progress achieved by the new design is roughly indicated by the following brief summary of accomplishments:—The new model saves approximately 40 per cent. in the cubic contents of self-contained selectors; effects a saving of 25 per cent. in weight per selector and hunts both vertically and horizontally at nearly twice the speed of its predecessor; enables all adjustments to be made in situ; can be jacked in and out of position instantly; accommodates up to ten banks of contacts as against a maximum of only three banks formerly possible, and has thereby assisted in the elucidation of switching problems.

has taken at least one vertical step. The operation is as follows:—

Upon the vertical magnet being impulsed one or more times, the wiper carriage is raised to the corresponding level and the helical restoring spring G is extended. In this position the rotary teeth on the hub come into alignment with the rotary pawl and detent, which are maintained in

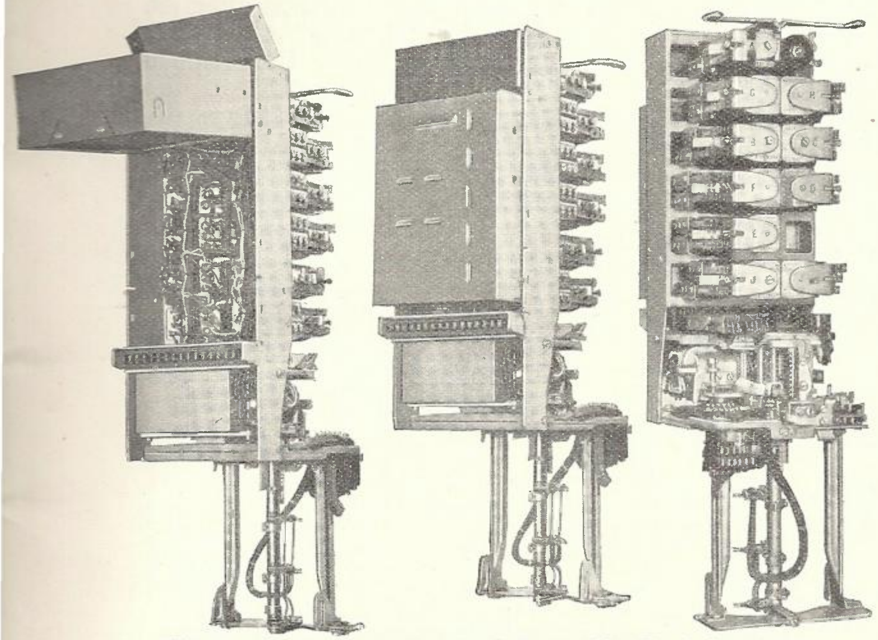


Fig. 1.—Three views of typical Type 2000 Final Selector.

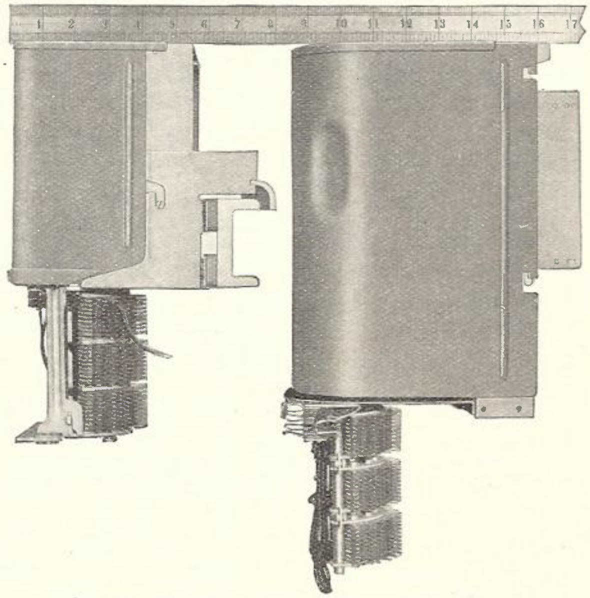


Fig. 2.—Showing comparative sizes of Type 2000 and Old Selectors.

Fig. 1 shows a typical Type 2000 selector, in this case a 200-point final selector; whilst Fig. 2 shows the comparative sizes of the previous standard and Type 2000 designs of 10/20 group selectors.

GENERAL CONSTRUCTION OF THE TYPE 2000 SELECTOR.

The Type 2000 selector operates on the so-called rectangular principle, the release action normally being by rotary movement in the forward direction off the level and then vertically downwards and back to the normal position under spring control. Fig. 3 shows the essential mechanical elements for controlling the vertical and rotary stepping movements of the wiper carriage, which are effected by two ratchet and pawl systems of extremely simple and straightforward design. The vertical ratchet A is of hardened steel and, with the wiper carriage in the normal position, is in alignment with the vertical pawl B. On the other hand, the rotary pawl D and detent E are positioned normally above the hub and do not come into alignment with the rotary teeth F until the wiper carriage

the correct position by adjustable stops, not shown. The rotary magnet next being impulsed, rotary action is imparted to the wiper carriage. Since the vertical ratchet is fixed to the hub, the first rotary step disengages it from the vertical pawl B and detent H. It is, therefore, necessary to employ other means to prevent the shaft from falling. This is accomplished by the entrance of the disc O into a notch of the comb plate K. During the forward rotary motion, the helical restoring spring is wound up.

On release, the wiper carriage is stepped by rotary action to the 12th step. In this position the notch L in the periphery of the disc comes into line with the comb plate, and the disc and wiper carriage are thus free to fall under the tension of the spring. During the fall of the carriage, the twelfth tooth of the hub slides along the rotary detent, becoming finally disengaged when the carriage reaches the normal level. The carriage then rotates backwards to normal under restoring spring tension.

It will be realised from the foregoing description that a separate release magnet is not used on the Type 2000 selector and that only vertical and rotary magnets are fitted.

In addition, however, to the normal forward, downward and backward release action described above, the release action can be accomplished in various other ways, as may be occasionally required. For example, the so-called rotary release action, as formerly employed on certain types of P.B.X. final selectors, is obtained by means of the engagement of the vertical pawl with an alternative type of rotary detent which the ver-

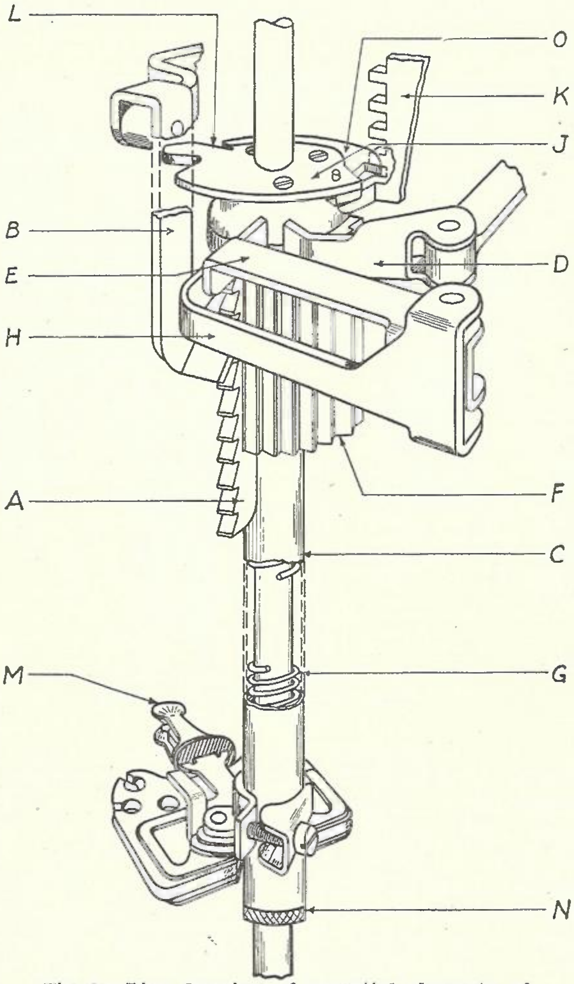


Fig 3.—Line drawing of essential elements of Type 2000 Mechanism.

tical magnet is caused to operate after the rotary hunting has taken place. Thus the vertical magnet also functions as a rotary release magnet, the method being as follows:—

Rotary Release.

When the wiper carriage is rotated away from the normal position, the vertical ratchet is moved out of its plane of engagement with the vertical pawl, thus making it possible to re-operate the vertical magnet without causing further vertical stepping of the wiper carriage. Advantage is taken of this fact to utilise the vertical magnet to control the rotary release function.

Referring to Fig. 4, a special rotary detent A is provided with a projecting tongue B which engages with the vertical pawl C in such a manner that each time the pawl moves upward, as shown by the arrow E, the detent is lifted out of engagement with the tooth D of the rotary hub in the direction of arrow F. During vertical stepping movements, the fact that the rotary detent is moving in and out of the first hub tooth is immaterial since the normal rotary position is determined by a stop. Upon reaching any desired level, the wiper carriage is free to rotate and the rotary detent can then function in the normal manner. In the event of all outlets on that level being engaged, the vertical magnet is caused to be re-operated at the eleventh rotary step, thus withdrawing the rotary detent and permitting the wiper carriage to rotate backwards and re-engage the vertical pawl and detent with the vertical ratchet. The

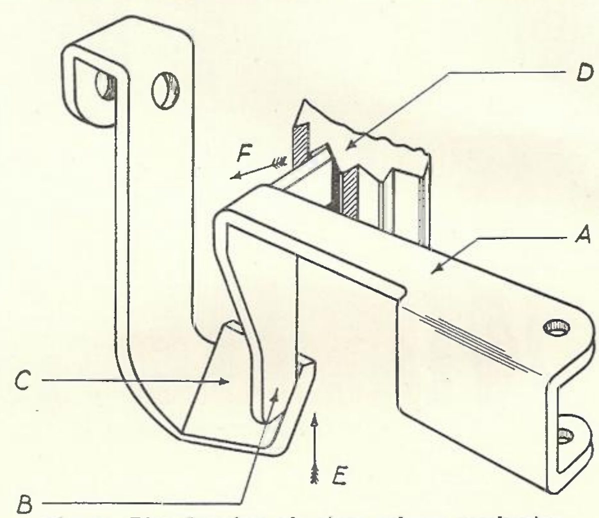


Fig. 4.—Line drawing of rotary release mechanism.

vertical magnet then releases and re-operates, this time stepping the carriage vertically to the next level, the armature then again releasing. Rotary hunting now takes place on the new level and the same cycle of operations can be repeated over all the levels in succession if required. Hunting over the entire ten levels of the bank occupies about six seconds.

The final complete release of the selector is accomplished in the normal manner by rotating off the level to the twelfth rotary step, where the carriage then falls to the normal level and rotates backwards under spring control.

DIGIT ABSORPTION.

The specially rapid release action required on digit absorbing selectors and discriminating selector repeaters for the absorption of one or more digits can be provided for in a variety of ways. These include (a) absorption by means of relays and special circuit arrangements; (b) absorption by the ordinary forward release action (suitable for the lower levels only); (c) absorption by backwards release action.

Of the above methods, (a) and (b) do not call for further comment. Method (c) is accomplished on the Type 2000 equipment by employing the vertical magnet for release purposes. The principle employed is that the first rotary step on any level converts the vertical magnet into a release magnet. The feature of construction which enables this to be accomplished is that the vertical ratchet is in this case pivoted vertically. The vertical ratchet has thus a free rotary movement and is retained in the normal position by means of a light spring.

During the vertical stepping action, the vertical detent rides in and out of the ratchet teeth in the normal manner, but the rotary detent, which is provided with a tongue engaging with the vertical pawl, rides in and out of the first rotary tooth. At the first rotary step, the vertical ratchet is stepped out of alignment with the vertical detent, which is adjusted to move inward about 1/16 in. towards the hub axis. To effect the backward release action, the vertical magnet is operated to withdraw the rotary detent, thus permitting the wiper carriage to restore to the normal rotary position. The vertical ratchet, however, being pivoted, swings aside when it strikes the side of the vertical detent, which does not therefore re-engage with the ratchet teeth. The wiper carriage consequently falls to the normal position, at which the displaced ratchet springs back into alignment with the vertical pawl.

It should be noted that this method of release may be effected from any rotary position on any level and is not limited to the first rotary step only.

WIPER CARRIAGES AND SPINDLES.

The wiper carriage is made as light as possible to reduce its inertia and consequently the power required of the magnets; this feature ensures maximum operating speed. Wiper carriages are available to accommodate various numbers of wipers, up to a maximum of ten pairs on ten separate contact banks, the driving mechanism being the same in all cases. It will be appreciated that this constitutes an important feature of the Type 2000 selector and adds considerably to its general flexibility. Previous designs employed a wiper shaft unsupported at the lower end and, with this arrangement, a maximum of three contact banks only was possible.

The spindles, which serve as guides only, are of liberal dimensions and are fixed rigidly at both ends. There is no possibility of the wipers vibrating on bank contacts with this form of construction, and consequently any microphonic noise which might be attributed to this cause is eliminated.

The wipers are fixed to the carriage by a clamp, which is so designed that any set of wipers can be removed without disturbing the others.

The spindle is of steel, tapered at the upper end, and is secured in position by means of a U clamp and a single screw at the bottom. This arrangement enables the spindle and wiper carriage, together with the lower shaft supporting plate, to be withdrawn readily as a complete unit by removing four nuts and bolts.

The much greater bank capacity of the Type 2000 selector offers numerous advantages, among which may be mentioned isolated guarding of subscribers' lines, 200-point P.B.X. final selectors without employing bank arcs and the switching of as many as twenty separate leads on any of 100 sets of contacts, or, alternatively, as many as ten separate leads on any of 200 sets of contacts. As examples of the last-mentioned advantage, it may be of interest to observe that the Type 2000 mechanism fitted with nine separate contact banks is being used for the automatic switching-in of thermionic repeaters and their line-balancing networks in trunk exchanges, and also as routiner access selectors.

MAGNETS.

One of the most fruitful phases of the work in developing the Type 2000 selector was that relating to magnet design and has resulted in the production of a single-coil magnet of extraordinary simplicity and robustness of construction, combined with greatly improved operating efficiency. The magnet, which is identical for both vertical and rotary functions, consists of a single casting of iron, the polepiece also serving as coil cheeks.

Investigations revealed the fact that cast iron, on account of its relatively high specific resistance, is particularly suitable for this type of magnet, since eddy current losses caused by the rapidly changing magnetic flux when hunting, are reduced to a minimum. This conclusion was clearly demonstrated as a result of experiments and tests on a large number of magnets of different types, including laminated, solid and slotted constructions, employing various grades of magnetic material.

An additional advantage of some importance is that the one-piece construction of the magnets renders them practically self-protecting, i.e., they are not damaged when inadvertently left energised for long periods. This is largely accounted for by the solid construction of the magnet and its large area of contact with the selector frame. The flow of heat is thus facilitated and limits the maximum temperature rise of the windings.

ARMATURES AND PAWLS.

The vertical and rotary magnet armatures are generally similar and comprise a plate of annealed Swedish iron riveted to an unannealed bracket of steel having high mechanical strength. A bracket provides the lugs for the armature and pawl bearings, which latter are of stainless steel rod 1/8 in. diameter and 1/4 in. long.

Fig. 5 shows the complete vertical and rotary

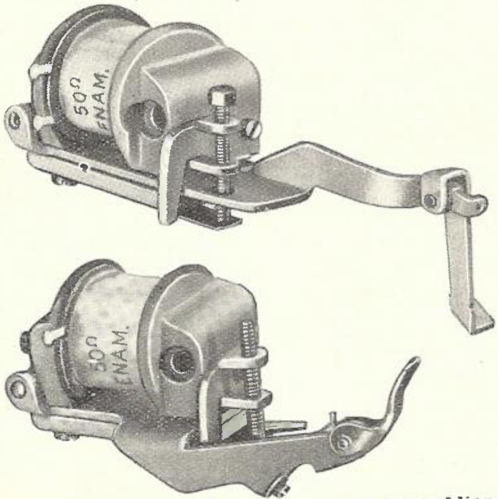


Fig. 5.—Vertical and rotary magnet assemblies.

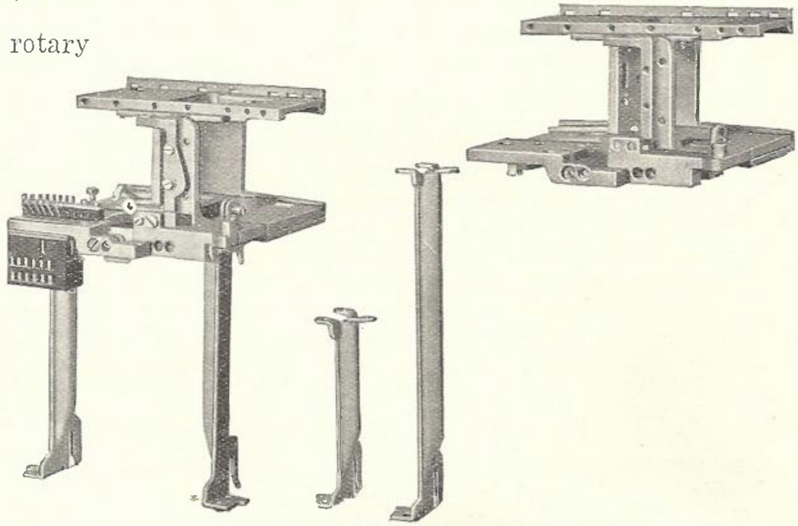


Fig. 6.—Frame and supporting brackets.

magnet assemblies, with armatures fitted. One end of the pivot pin is knurled and is driven into the pawl, and the other end is riveted into an internally serrated hole to ensure that the pawl cannot come loose in service.

The design of the ratchet teeth and pawls is such that any tendency towards a "pawl throw out" effect during the release stroke of the armature, is entirely eliminated. This is accomplished by ensuring that forces due to inertia tend to hold the pawls in engagement with the ratchet teeth.

FRAME.

The selector frame is shown in Fig. 6 and consists of upper and lower rectangular plates joined together by a central angle member, the whole being a robust one-piece diecasting. The two magnets are contained in the two side recesses. The contact spring assemblies are on the top plate and all the adjusting screws, stops, detents, etc., on the lower plate, mounted well forward, as will be seen by referring to Fig. 1.

Fig. 6 also shows the brackets for supporting the lower end of the wiper spindle. These brackets are of different lengths on selectors having two, three, four or up to ten banks of contacts.

CONTACT BANKS.

The line and private contact banks are robust products of high insulation resistance and of exceptionally uniform dimensions. Aluminium screening plates are placed between the levels and in the case of the line banks are commoned by means of a copper ribbon.

Mounting of the Contact Banks.

As shown in Fig. 7, the contact banks are rigidly secured to specially shaped cradles, by means of two long bolts and nuts. The cradles are cushioned with rubber pads for the purpose of reducing microphonic noises due to the stepping actions of adjacent selectors. The selectors seat in these cradles, being accurately located by tongues engaging at the top and bottom of the banks. This improved form of construction enables the selectors to be withdrawn and replaced with the utmost dispatch as shown in Fig. 8, no screws or nuts having to be removed, and there is no strain on the multiple wiring under any circumstances.

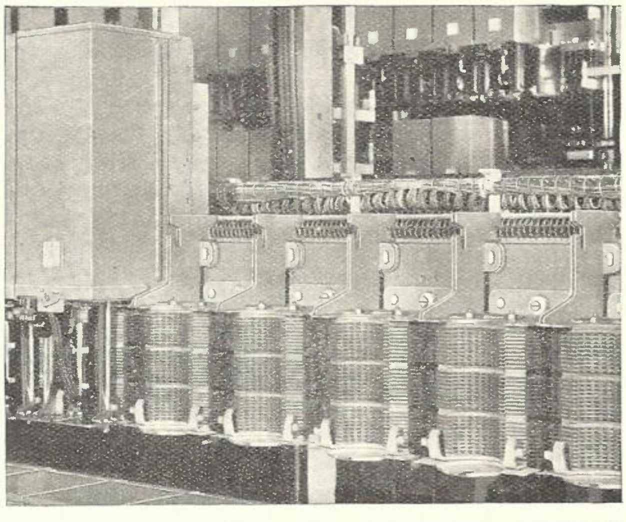


Fig. 7.—Showing rubber cushioned mountings of selector cradles and mounting of contact banks.

Wiring of Contacts Banks.

Closely associated with the question of contact bank design is that of bank wiring, which in the case of the Type 2000 selector is looped in accordance with long-established practice. Loop wiring has the important advantages of high insulation resistance, maximum electrical balance and, due to its comparatively wide air spacing, minimum cross-talk and general flexibility in manufacture. The wire employed is enamel-insulated silk and cotton-covered highest conductivity copper No. 25 S.W.G., the line wires being suitably twisted.

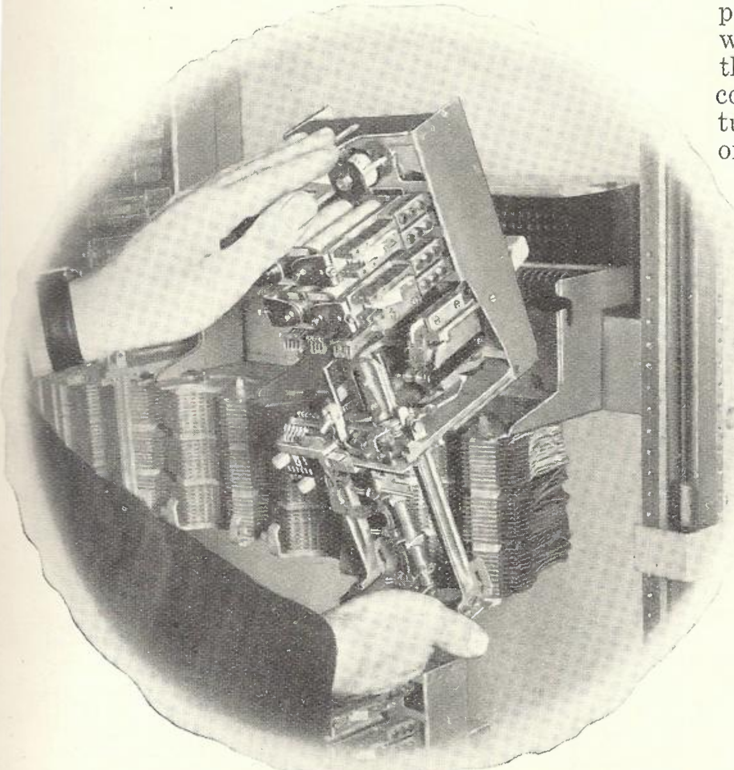


Fig. 8.—Showing ease of withdrawal and replacement of selector on shelf.

WIPERS.

The wipers are the outcome of one of the most important researches undertaken during the development of the selector, and possess unique characteristics.

It will be seen from Fig. 9 that the wiper springs are held together by a fibre collar located in notches a short distance back from the tips. The springs are bent outwards from the roots so that the tips are about 3/8 in. apart before this collar is put into position. The shape of the spring blank behind the collar is long and flexible. Between the wipers and extending through the collar to within a short distance of the tip is a rigid plate of insulating material.

The complete adjustment required by the wiper is that the springs must be about .010 in. clear of the insulator and the tips about .020 in. apart.

The results achieved by this form of construction are as follows:—

The pressure exerted by the springs when they engage a bank contact is dependent on the shape of the springs and on the amount of opening, so that accurate pressure is obtained by adjusting the tip gap only. The fibre collar anchors the two springs together so that they float up and down as a pair and equalise the pressure on upper and lower tips.

The blank shape provides such a degree of vertical flexibility behind the collar that there is practically no variation of contact pressure with wide inaccuracy in the vertical adjustment of the wiper tips opposite the bank levels. This completely compensates for the slight manufacturing inaccuracies which occur in the spacing of bank levels.

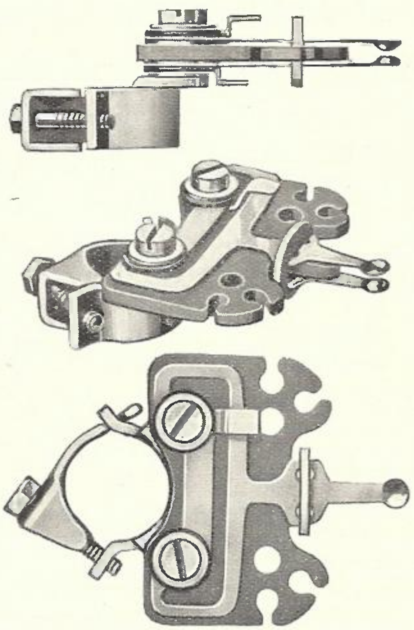


Fig. 9.—Contact Wipers.

The damping of the springs at a point along their length by the collar completely eliminates wiper bounce.

The rigid central insulator, which the springs nearly touch, prevents the tips vibrating during the vertical stepping of the selector, and thus makes any pause period before rotary "cut in" unnecessary. Immediately "cut in" occurs, the springs widen out well away from this insulator and are thus free of any restraining influence it might impose demanding accurate "cut-in" alignment.

The tips are a truncated cone in shape, the removal of the sharp point resulting in uniform wear over the life of the wiper. The greatest diameter of the tip is less than the space between bank contacts so that the wiper is non-bridging throughout its whole life and cannot be made to bridge, even with the grossest maladjustment.

Any wiper can be removed from a selector and replaced without disturbing the others.

MECHANICALLY OPERATED CONTACT SPRINGS.

Referring to Fig. 1, it will be seen that the various mechanically operated contact springs are assembled in a row on the top plate of the selector frame. The tags of the springs project through the mounting plate rearwards into the same field as the relay tags to facilitate and simplify the wiring operation, whilst the contact ends are well forward to ensure maximum visibility of each contact and accessibility for adjustment. Except in the case of interrupter springs, which are of special design, the springs are fitted with twin contacts. The springs are assembled in compact sets, each set being readily removable.

Each contact set is located in position by the end of the bracket passing into a slot at the back of the selector frame, and is secured by a single screw at the front. The twin contacts are on wide centres giving maximum visibility, and the design of the springs is such that contact bounce is completely eliminated.

The range and number of mechanically operated springs are as follows:—

	Max. Number available.
Off-normal springs	9
Rotary off-normal springs	8
11th Rotary-step springs	9
Vertical interrupter springs	3
Rotary interrupter springs	3
Level springs, single set	6
Level springs, two independent sets	3 each

The limitation in the number of springs in any set is one of space only, the magnets having ample power to operate bigger combinations. It is thus possible in certain cases where some combinations are not required to increase the number of springs in the next set. For instance, if rotary off-normal springs are not fitted, the off-normal spring set can be extended up to fourteen springs.

Interrupter Springs.

Fig. 10 shows the interrupter spring set, which is a distinct departure in design possessing very important characteristics. Its basic feature is that, although the contacts can be adjusted to "break" at the very end of the operating stroke of the armature, they do not "remake" until the extreme end of the return stroke. This ensures positive operating and release strokes of the armature when the springs are used to interrupt the magnet circuit by direct action. This design provides a degree of reliability of "self-interrupted drive" superior to that previously attained by the so-called "relay drive," and of course accomplishes it without the relay. Contact pressures of only 40-50 grammes are used instead of 150-200 grammes required on previous types of interrupter.

The device functions as follows:—There are two striking arms on the armature. Towards the end of the operating stroke one arm engages the rocker member and carries it over so that the contact spring is lifted off the fixed contact. The rocker is held in this position by the biasing

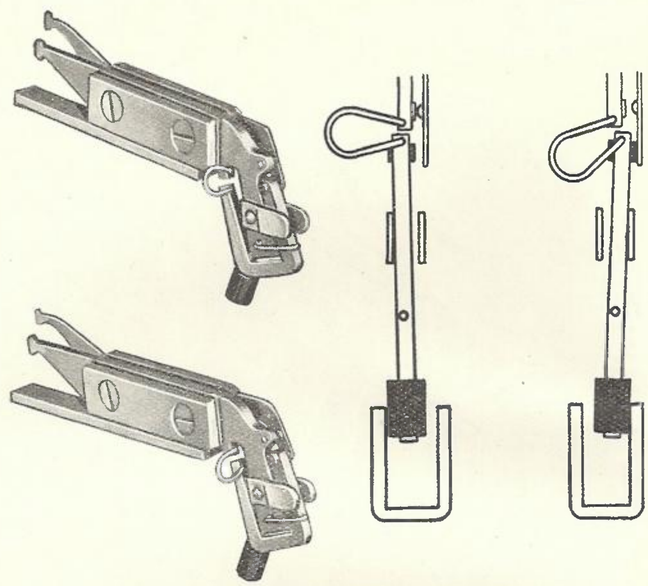


Fig. 10.—Interrupter springs assembly.

link spring. The contacts being now broken the armature returns. Towards the end of the return stroke, the second arm engages the opposite side of the rocker and carries it over again to its original position, allowing the contact spring to fall on to the fixed contact. The rocker is held in this position again by the biasing spring at the other extreme of its travel. The contacts now being remade, the armature moves forward again and the process is repeated until the operation is stopped.

The interrupter springs are available in either single break, single make, or single break-make combinations.

Off-Normal Springs.

These operate at the first vertical step and remain operated thereafter until within one rotary step of the home position, and reset during the final rotary movement to the normal position. The springs are operated by a trip action, resetting being effected by the rotary momentum of the wiper carriage.

Rotary Off-Normal Springs.

These springs operate at the first rotary step on all levels except the normal and release at the 12th rotary step.

The wiper carriage must first make at least one vertical step before the rotary off-normal springs can be operated. The first vertical step brings the periphery of the cam in line with the full diameter of the roller on the rotary off-normal lever. The first rotary step causes the roller to ride up an inclined cam face on to a cylindrical face, and moves the rotary off-normal lever to operate the springs.

During the release action of the selector, the roller drops into the recess on the cam at the 12th rotary step, thus releasing the rotary off-normal springs and the cam falls clear of the roller. During the subsequent reverse motion to the normal rotary position, the cam face clears the roller where the latter is of reduced diameter at the bottom, so that the rotary off-normal springs remain unoperated.

11th Rotary Step Springs.

These operate at the 11th rotary step on all levels except the normal, and release at the 12th rotary step. At the 11th rotary step on any but the normal level, a projecting cam lobe engages the roller on the operating lever and moves it to operate the springs. At the 12th rotary step the roller falls behind the cam lobe and the springs release. The cam falls and rotates back to normal, clearing the roller where it is of reduced diameter at the bottom.

Level Springs.

These springs, which can be in either one or two sets, can each be arranged to operate separately on any chosen level or levels, as determined by screwing a small roller on any one of ten positions. When the carriage rotates on the level on which the springs are actuated, they remain operated until the 12th rotary step, where they release. If necessary, the two sets can be arranged to operate on the same or adjacent levels, and by the substitution of cam blocks for the rollers the springs can be retained operated for a number of successive levels, or be made to operate and release and re-operate in any desired order.

It will be appreciated from the foregoing that the circuit designer has means of the greatest flexibility in adapting the Type 2000 selector to operational requirements.

VERTICAL BANK.

There are three alternative methods of mounting the vertical bank, depending upon requirements. It can be mounted solidly with the main contact banks, the contacts projecting toward the wiper carriage and can thus be multiplied or wired in any circuit external to the selector.

Alternatively the bank can be fixed to the frame extension so that it can be wired into the internal circuit of the selector, and will remain fixed to it when the selector is removed from the shelf.

In the third arrangement, an arm extending forward from the cradle carries a small bracket free to pivot on a vertical axis. The bank is secured to this bracket in front of the selector frame extension. The action of removing the selector from the shelf engages the frame extension with this bracket, which is caused to swing forward and to the right, thus automatically disengaging the bank from the wipers. The bracket carrying the bank is held in the "working" and "disengaged" positions by a spring plunger.

VERTICAL WIPERS.

The vertical wipers are fixed to a simple bracket, which is free to rotate on the wiper carriage tube, but which rises vertically with it. The vertical wipers thus rise and fall with the wiper carriage, but remain stationary when the latter rotates.

When either of the first two methods of mounting the vertical bank is used, the wipers are hinged in a vertical plane so that the tips can be swung downwards clear of the bank. When reset, the wipers locate accurately in position by the engagement of the clamping nut in a conical seating. This feature enables the wipers to be lowered free of the bank when the selector is being removed from the shelf. In the third method described, the hingeing of the wipers is not required.

P.B.X. BANK ARC.

Whilst the greatly increased contact bank capacity of the Type 2000 selector simplifies the provision for P.B.X. groups of all sizes by means of a fourth bank, an improved form of P.B.X. bank arc is also available for use in special cases.

The P.B.X. bank arc occupies a position in front of the main contact banks and is hinged so that it can be swung out to the right. This bank arc represents an improvement on the screwed pin type and consists of a stamped plate per level.

Each contact plate can very readily be withdrawn and replaced, whilst the individual contacts can readily be clipped off as is required for the last line in each P.B.X. group. The design thus provides convenient means for meeting the demands of growth in the sizes of P.B.X. groups.

This design has many advantages. In the first place, it permits the mounting of two separately insulated contact plates per level, thus rendering a 200-point arc available. The flat type of contact is also more suitable for wiper engagement and eliminates altogether the abnormal load formerly imposed upon the magnet by the pin type of contacts.

TEST JACK AND LAMP JACK.

The test jack consists of slotted rectangular blocks of moulded bakelite, built up in multiples of six test points. The lamp jack is a similar moulding, containing also a label holder and two test points. The complete assembly is secured by two screws below the left-hand lower corner of the frame. The test "U" links, available in two colours, provide convenient means for various testing purposes, including "busying," opening the release magnet circuit, etc.

TEST PLUG.

This is also a moulded component which can readily be assembled with six or twelve contacts.

GENERAL ASSEMBLY.

In accordance with the practice followed for many years for all Strowger equipment, the Type 2000 selector is in all cases assembled on the fully self-contained principle, the associated relays, condensers, resistances, etc., being mounted together with the mechanism to form a readily replaceable "jack-in" unit. With the exception of the spark-quench condensers, which are fixed to the rear of the mechanism, the condensers are accommodated in a compartment which is hinged at the top.

SELECTOR WIRING.

Except for the test jack and wipers, the selector wiring is confined entirely to the rear. The wire employed consists of a No. 25 SWG single conductor of highest conductivity tinned copper enamel insulated, having an inner covering of silk and an outer braiding of cotton. Four different colours are used, namely, white for live negative battery, red for earthed positive battery, blue-red for live positive battery (metering), and green for point to point wires. The open method of wiring is employed, the wires being run singly in an orderly manner and lightly bound together.

ADJUSTMENTS.

One of the outstanding features is the simplified means of adjustment provided, and the fact that each and every adjustment can be made from the front of the selector whilst it is in position on the shelf. Whilst the mechanically operated springs are all conveniently arranged

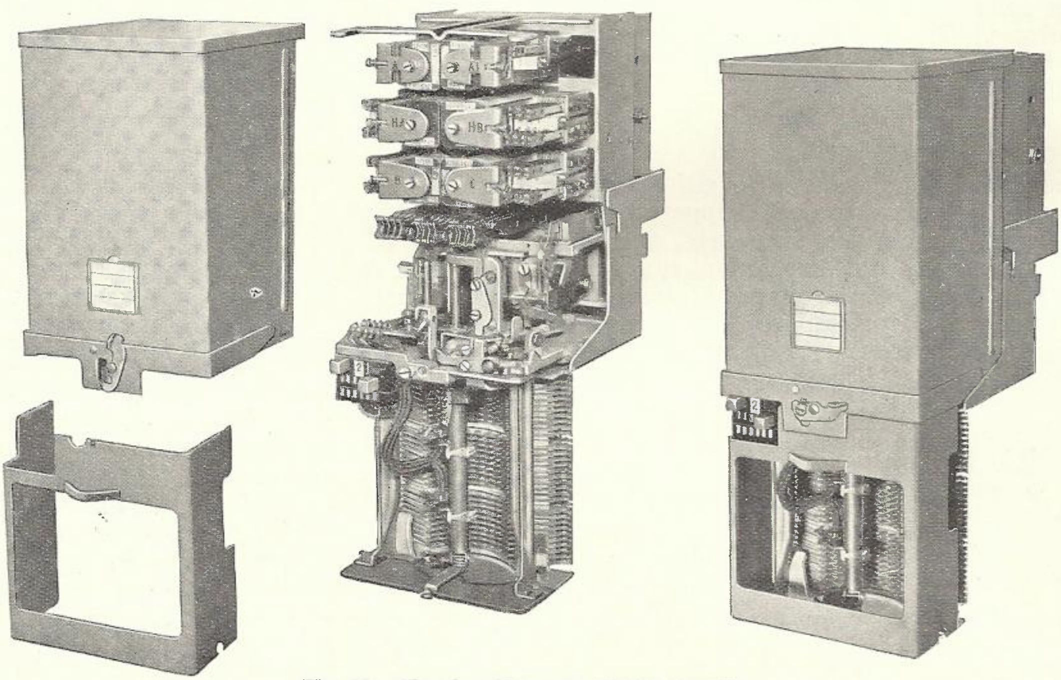


Fig. 11.—Showing two-part selector covers.

in the same plane between the top of the mechanism and the bottom relays, the various mechanical adjustments for the pawls, pawl guides, armature restoring spring tensions, etc., are for the most part placed well forward near the bottom plate of the frame and are, therefore, readily accessible. All the adjustments are inherently simple and a comprehensive set of tools has been developed to enable them to be effected in the minimum of time with maximum accuracy.

Various means are taken to eliminate the use of lock nuts on adjustable screws, since lock nuts have the disadvantage that they tend to

SELECTOR COVERS.

Fig. 11 shows a typical 600-point Type 2000 selector with cover on and off. The cover for each selector is in two portions, both being of the slip-on type. The lower portion encloses the bank contacts and wiper carriage, which are, however, visible through a transparent window. The top portion is fitted with a lever which serves to lock the two portions together when in position.

It will be appreciated that, in conjunction with the bottom plate attached to the contact banks, the lower cover almost entirely excludes the deposition of dust on the bank contacts.

disturb the adjustments when being tightened. The improved method has been the subject of considerable study and experiment, and has yielded results which, whilst greatly facilitating adjustments, ensure that they remain perfectly constant in service.

OPERATING CHARACTERISTICS.

The operating characteristics show a substantial improvement over those formerly attained. For example, the hunting speed is approximately twice as fast as any previous two-motion selector, both vertical and rotary. The Type 2000 selector also operates over wider limits of impulse speed and ratio variation and of line resistance, leakance and capacitance.

The rotary "cut-in" action is particularly rapid. The last rotary impulse is in two portions due to the "magnet lock" feature, which ensures a perfectly clean operation of the switching relay.

THE GENERAL APPLICATION OF THE TYPE 2000 SELECTOR.

The development of the Type 2000 selector has been influenced by all the considerations of modern service requirements, including the need for a highly efficient line finder. Due to its very high hunting speed and large bank capacity, the Type 2000 mechanism possesses innumerable advantages, being ideally suitable for the line finder function.

Line Finder.

For example, the Type 2000 selector hunts at approximately 50 steps per second, and, since in the most extreme case, as a line finder, it may possibly be required to take a total of twenty steps, a maximum period of less than half a second is involved.

Group and Final Selectors.

Since the Type 2000 mechanism is like its predecessor a two-motion step-by-step selector, having a decimal arrangement of its bank contacts, it follows that it provides an ideal for group and final selectors and conforms readily to operating and trunking requirements.

Besides performing all of the functions of the mechanism superseded, it also embodies additional features, which set new standards.

For example, whilst it can fulfill requirements for a 100-point or 200-point selector as readily or even more readily than its predecessor, it can in addition be easily adapted for use as a 400-point selector.

Further, the Type 2000 mechanism offers a wider range of facilities for special switching sequences such as those frequently required in the layout of networks having satellites of various capacities. It also provides, with greater simplicity and economy, for the full range of P.B.X. groups—not only of 200 lines, but also those of 400 lines.

Miscellaneous Applications.

The greatly increased contact bank capacity of the Type 2000 selector has already shown important operational advantages and economies in several cases where a large number of conductors require to be switched. Examples are the automatic insertion of thermionic repeaters and their associated balances in connecting their circuits on a trunk exchange and for routiner access equipment in automatic exchanges. In the former case the switching is extremely rapid, the operator merely depressing a start key into the low or high gain position. This operation marks a particular contact on the multiple of a group of finders, one of which is pre-selected. This finder immediately selects the

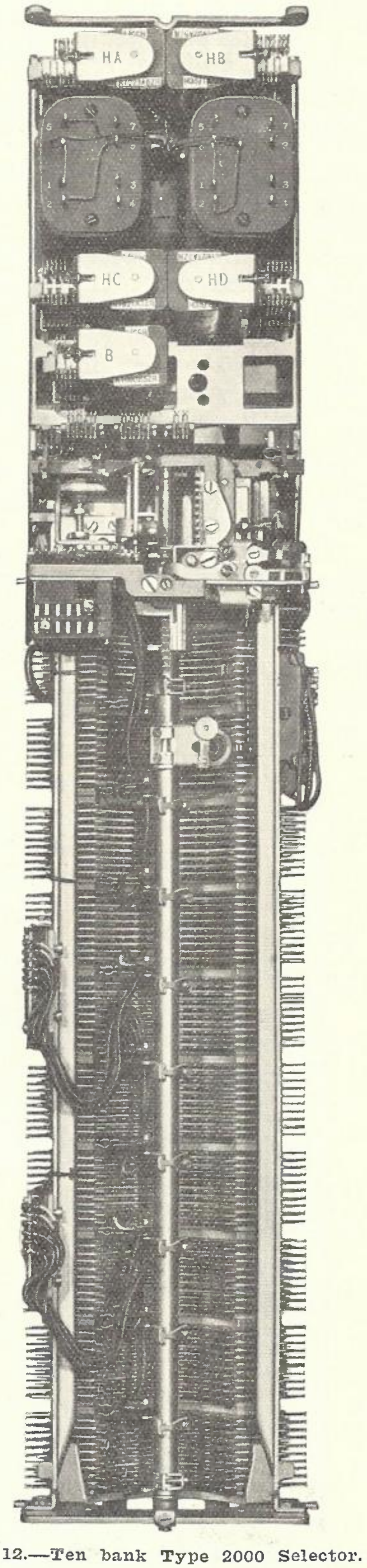


Fig. 12.—Ten bank Type 2000 Selector.

marked contact by finder action, using a control relay set. This results in a repeater being switched in, at the correct gain, within ordinary line-finding time, i.e., less than 0.5 second. This scheme has capacity for a total of 200 connecting circuits and is, of course, extensible in regard to the total number of repeaters.

Fig. 12 shows a Type 2000 selector fitted with ten contact banks.

The advent of this selector has considerably simplified the routiner problem, since with ten banks and ten pairs of wipers as many as twenty testing leads can be distributed successively to 100 pieces of apparatus for test by means of only one selector. It removes all limitations without introducing fresh difficulties and effects substantial economies in routiner equipment when employed for access purposes in place of uniselectors, which were formerly used.

MOUNTING ARRANGEMENTS.

Type 2000 selectors are arranged for mounting on single-sided racks, the shelves of which have capacity for ten selectors. The shelf itself consists simply of a suitable channel iron, on to which the cradles for mounting the individual selectors are cushioned with rubber and secured by a single screw.

The contact banks are rigidly fixed to the cradles and the multiple wiring does not project beyond the rear of the apparatus, and is thus well protected, besides being quite accessible for inspection purposes.

In cases where the number of relays per selector exceeds sixteen, an auxiliary shelf is employed to provide a second supporting point.

This method of mounting enables the selectors to be removed and replaced with the utmost despatch, since it merely involves lifting them from or placing them in position.

Relay groups, without selector mechanisms, are mounted in a similar manner, the cradles for these, however, being different from those used for selectors.

The permanent wiring and cabling are accommodated at the rear of the shelves, being supported on brackets which also serve as jumper rings. The brackets also support the moulded bakelite single-sided connection strips, which terminate the circuits in a manner suitable for grading or cross-connecting as required.

Fig. 13 is a view of the rear of a portion of a typical rack and shows the wiring terminations and cabling.

The mounting racks are available in three standard heights, namely, 8 ft. 6½ ins., 10 ft.

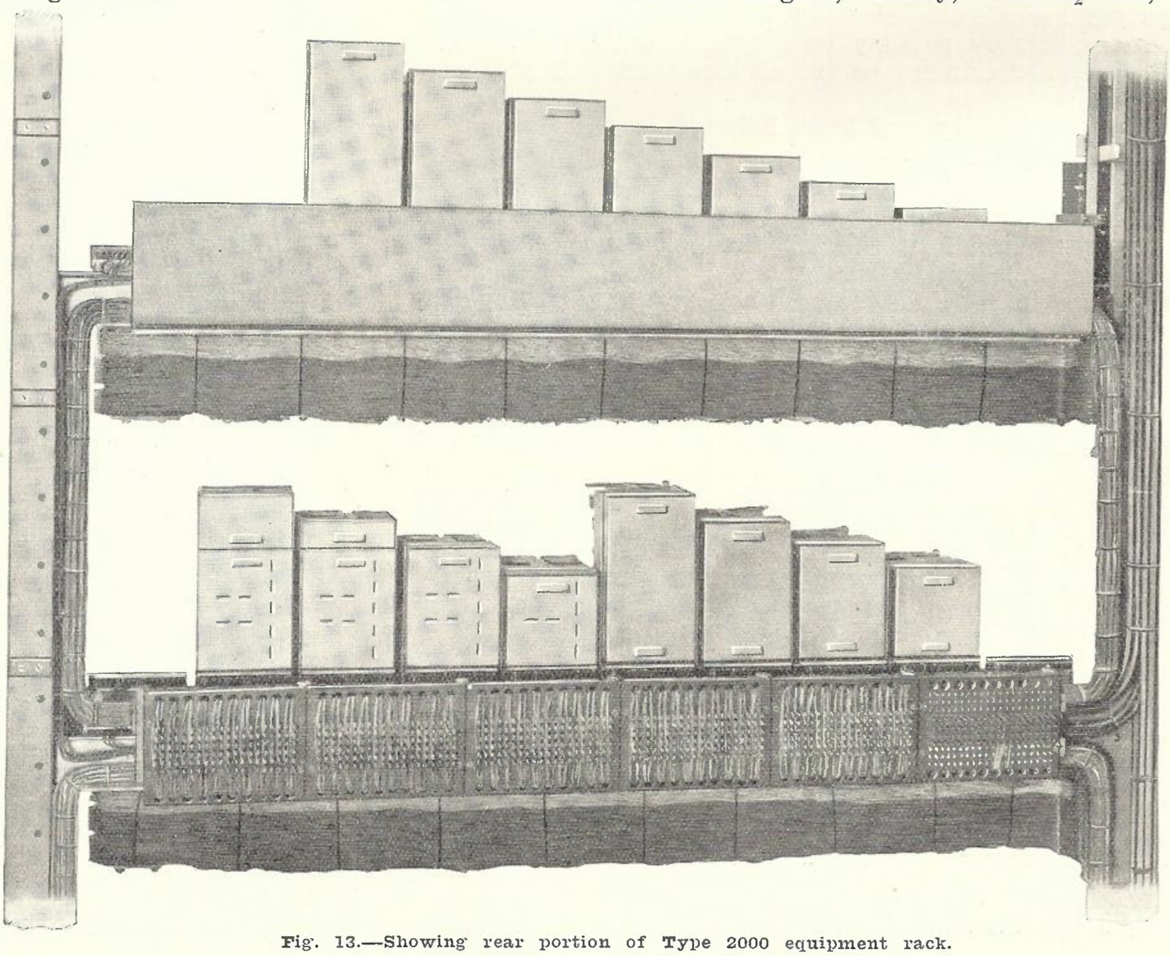


Fig. 13.—Showing rear portion of Type 2000 equipment rack.

6½ ins., and 11 ft. 9½ ins., thus providing for exchange buildings of various ceiling heights and eliminating wastage of space. The following table shows the capacity of typical racks, the standard width of which is 4 ft. 6 ins. in all cases:—

RACK CAPACITIES.

Type of equipment	Height of Racks		
	8ft. 6½in.	10ft. 6½in.	11ft. 9½in.
Line Finders 200 lines	See page 144	See page 144	*
10/10 Selectors	70	90	
10/20 Selectors	60	80	
20/10/10 Selectors	60	80	
10/10 D.S.R.	40	40	
10/20 D.S.R.	30	40	
100 Line Final Selrs.	50 } 12-relay bases	70 } 12-relay bases	
200 Do., Do.	[illegible] } 12-relay bases	60 } 12-relay bases	

*As it is unlikely that the 11 ft. 9½ in. racks will be used in Australia, the capacities have not been included in the table.

In addition to the above standard racks, composite or special racks can readily be made up, since the horizontal mounting centres of the individual selectors and relay groups and the front and rear projection are the same. This feature is of practical importance, since it enables composite racks to be of the utmost compactness. The inherent flexibility of the apparatus components is thus accompanied by corresponding flexibility in the mounting arrangements, with resultant economy in exchange building accommodation required. On an average exchange, the Type 2000 selector effects a reduction of from 15 per cent. to 20 per cent. in rack-mounting space.

CONCLUDING REMARKS IN REGARD TO THE TYPE 2000 SELECTOR.

At every stage of the development work full advantage was taken of life testing to prove features of design and the materials employed, whilst the trials under actual service conditions were made possible by the co-operation of the British Post Office. In 1933, two shelves of ten Type 2000 selectors each were cut-in to service on one of the busiest London exchanges and from the outset gave eminently satisfactory results. A year later, four more complete shelves were similarly placed in service, with similar good results. Also in 1934, the Ashton-in-Makerfield satellite finder exchange of 300/500 lines was completely equipped with Type 2000 selectors, and from the outset has continued to operate with complete satisfaction. At the present time, Rugby Exchange, England, of 1,300 lines initial capacity, has been provided with this equipment and is on the point of being cut-in to service. The Johannesburg automatic trunk exchange is also on the point of being opened and comprises a large quantity of these selectors, including cord circuit finders, each fitted with nine contact banks, for the purpose rapidly switching-in speech amplifiers.

CIRCUIT ARRANGEMENTS.

It may be said that the radical advances in mechanical design and operational characteristics of the Type 2000 selector mechanism itself have been accompanied by corresponding advances in circuit design technique. Whilst in the following descriptions of the circuit arrangements the line-finder circuit is first dealt with in detail, the circuit descriptions of the group and final selectors have been limited to an outline of important advances in the circuit features.

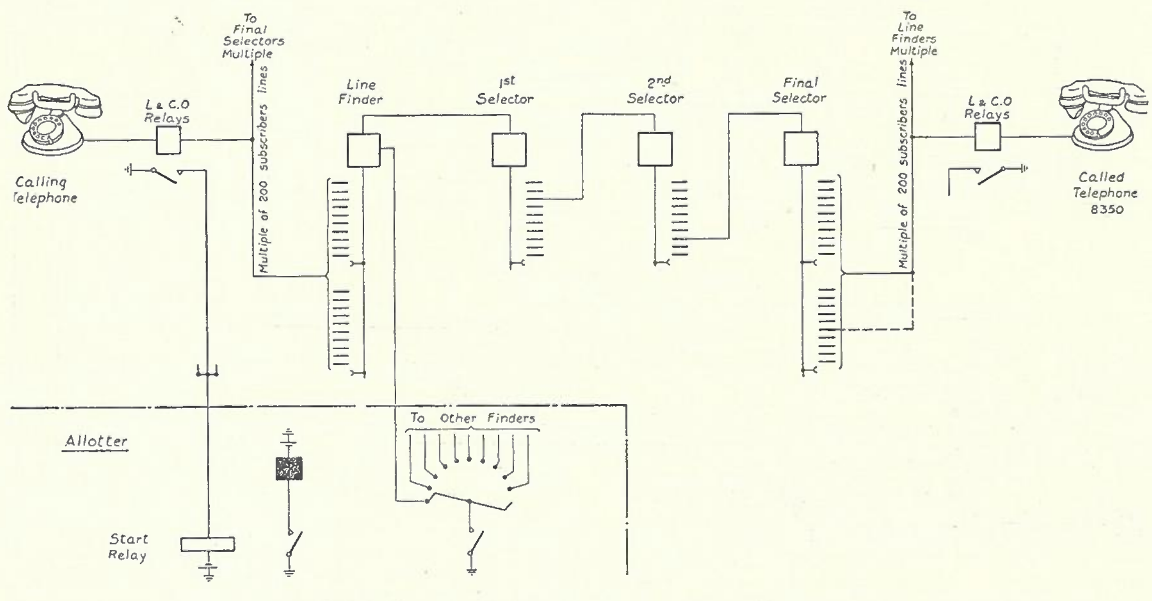


Fig. 14.—Fundamental arrangement of Type 2000 Line Finder System.

Fundamental Arrangement of the System.

Fig. 14 shows the fundamental arrangement of a four-digit system. The subscribers' lines are arranged in groups of 200 and each group is served by from 15 to 50 line finders, depending upon circumstances. When a subscriber lifts his receiver to initiate a call, a pre-selected line finder in the particular group is immediately caused to hunt both vertically and horizontally for the purpose of switching the calling line through to the associated 1st selector, from which dialling tone is received. This non-numerical or line-finder action is accomplished in less than half a second and upon its completion the allotter steps automatically to pre-select another line finder in readiness to serve the next call.

Upon the required digits being dialled, the first train of impulses raises the wipers of the first group selector to the corresponding level, where the wipers are then rotated automatically to seize a second group selector. The latter is similarly operated by the second train of impulses, the automatic hunting action in this case seizing a final selector. The third and fourth train of impulses serve respectively to control the vertical and horizontal stepping actions of the final selector, thus completing the chain of connections between the calling line and the terminals of the particular called line. When the calling party replaces his receiver, the group and final selectors, together with the line finder, are automatically released to normal.

Circuit Operation of the 200 Line Finder.

The accompanying Plates 1 and 2 show the circuits of the 200-line finder, the operation of which can best be gathered by the consideration of certain important features and the basic principles underlying the circuit design.

These include the following:—

(1) Partial secondary trunking arrangements.
(2) Plurality hunting of line finders.
(3) Self-interrupted drive of line finders.
(4) Magnet locking.
(5) Immediate change-over to secondary finders.
(6) Direct secondary test.
(7) Congestion supervision—thermionic valve scheme.
(8) Automatic locking-out of faulty apparatus and diversion of call to alternative apparatus. Time-delay feature.
(9) Secondary throw-out.
(10) Routining of line finders and testing facilities.

Partial Secondary Trunking Arrangements.

The fundamental principle of the line-finder system is that the subscribers' lines are arranged in groups of 200, each group being served by a relatively small, yet ample, number of line finders. The function of the line finders is to seek out each calling line and to switch them through as quickly as possible to selectors in the first rank of the switching train in readiness for dialling. After switching-through, the line finder is held for the duration of the call. The line finders are used in succession and, in gene-

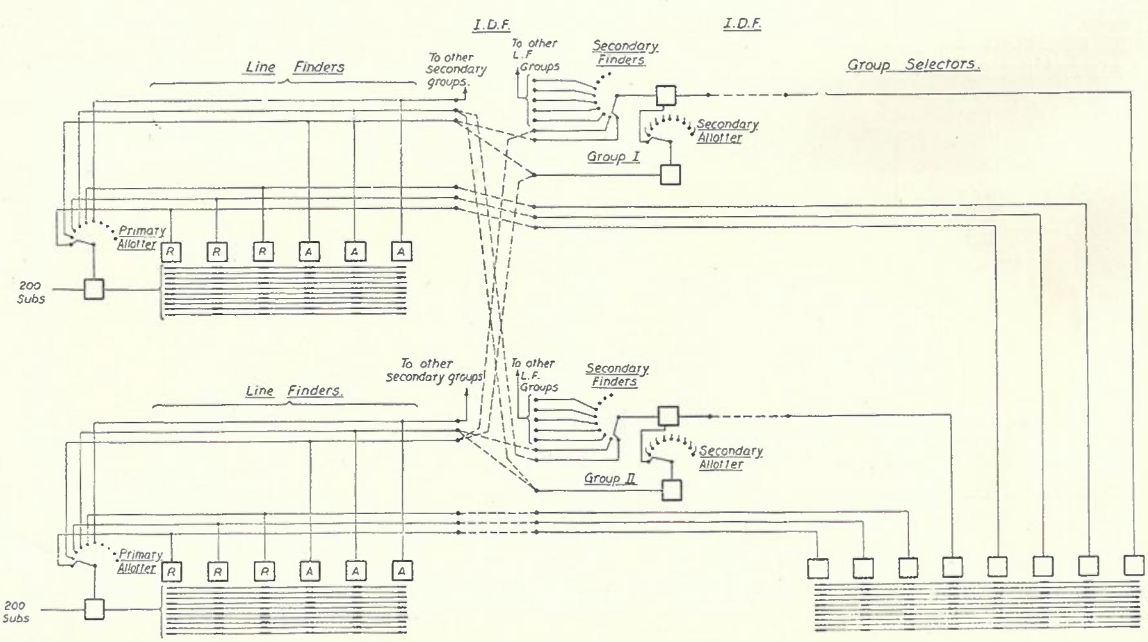


Fig. 15.—Schematic of partial secondary system.

ral, they are fully pre-selected, i.e., a line finder is always waiting in readiness to find and switch through any line on which a new call is initiated. This pre-selection of the line finders is accomplished by means of an allotter, of the uniselector type, which steps automatically to find a disengaged line finder immediately each call is switched through.

On the partial secondary line-finder system, each group of line finders is sub-divided into regular (direct) finders and auxiliary (indirect) finders. The former are each directly associated with an individual selector in the first switching rank, whereas the latter gain access to first rank selectors by means of secondary finders and a system of partial secondary trunking. This ensures maximum traffic-carrying efficiency of the first rank of selectors and a minimum amount of secondary apparatus, hence economising considerably in switch quantities. The following considerations will make this clear:—

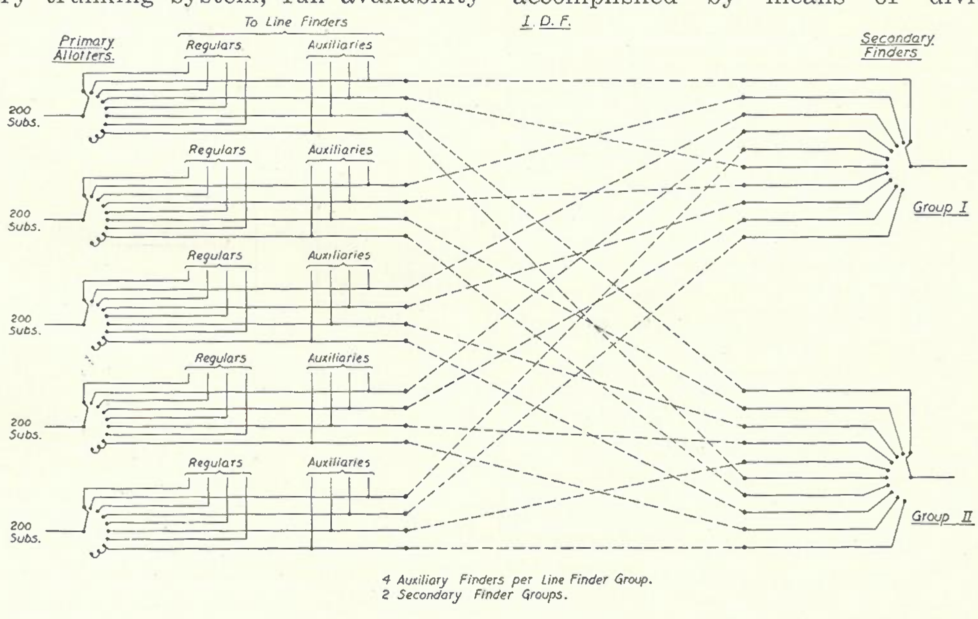
The minimum number of first selectors occurs when all subscribers' lines have access, directly or indirectly, to all first selectors, i.e., under the condition of full availability. Now, whilst this condition can only be absolutely provided by a full secondary trunking system, full availability

selectors, whereas the auxiliary finders are connected to the contact banks of secondary finders, the wipers of which are each directly connected to a first selector. In practice, the auxiliary finders are automatically busied out until all the regular finders are simultaneously engaged, whereupon the auxiliary finders are made available and are pre-selected in turn.

The general arrangement of the partial secondary trunking scheme and typical cross-connections between the auxiliary and secondary finders are shown in Figs. 15 and 16 respectively.

Plurality Hunting of Line Finders.

An adverse feature of the earlier finder systems was that only a single line finder could hunt at a time in each group. This was considered to be a somewhat serious disadvantage, despite the fact that ordinarily any single call would normally be switched through in less than about half a second. Hence the Strowger partial secondary line-finder system incorporates the "plurality" hunting feature, whereby one, two or three line finders are enabled to hunt simultaneously in the same group. This is accomplished by means of divided starting



Typical Cross Connections between Line Finders & Secondary Finder Banks – Partial Secondary Trunking Scheme.

Fig. 16.

conditions can be practically attained and a very considerable saving in secondary apparatus effected by means of partial secondary trunking.

Whilst on the partial secondary trunking scheme the line finders are not taken into use in a definite order, an equivalent effect is obtained by dividing the line finders of each 200 lines group into two sections, regular and auxiliary. The former are directly connected to first

arrangements, in conjunction with two or more control relay sets and allotters, which are provided for each group of 200 subscribers' lines. The arrangement for three control sets is shown schematically in Fig. 17.

Five triple-wound relays, SA to SE, are provided. Only two windings of each relay are normally in use, the third winding being for a special purpose, when routining, as explained later. One "make" contact of each line relay of the twenty subscribers associated with each level is commoned and connected from battery through a resistance to earth via one winding of one or other of the relays as shown. Hence each relay is controlled by the contacts of the

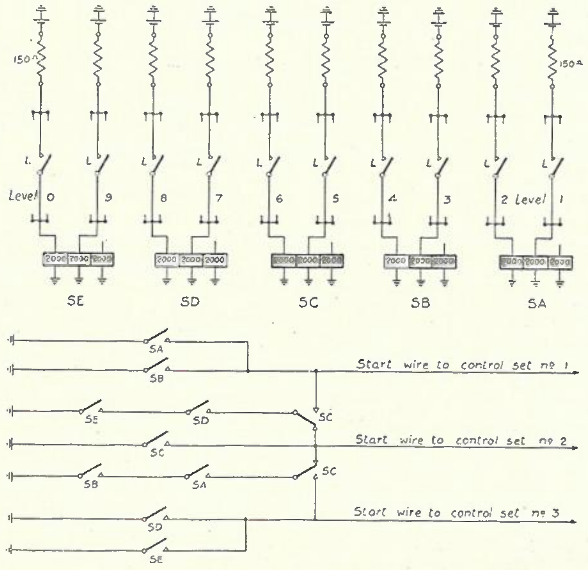


Fig. 17.—Schematic of divided start arrangements.

line relays of forty subscribers, arranged on two adjacent levels. A little consideration will show that a call initiated in any one of the five forty-line groups will earth the start wire of one or other of the three control sets; also that calls initiated simultaneously in any two groups will introduce two control sets, whilst calls initiated simultaneously in any three groups will introduce three control sets.

An allotter is associated with each control set, so that immediately the start wire of the latter is earthed a pre-selected line finder functions to switch the line through, whereupon the particular line relay is released and the allotter steps to pre-select another free line finder.

It will be appreciated that this principle could be extended to provide for the simultaneous hunting of more than three line finders. In practice, however, it is found that not more than three control sets need be provided. Indeed, whilst provision is usually made for a maximum of three control sets only two sets may be actually fitted. In this case, certain simple strapping changes have to be made. The third control set may, of course, be introduced at any time by reverting to the original strappings.

Self-interrupted Drive of Line Finders.

Fig. 18 shows the elements of the circuit arrangements of the line-finding action, both vertical and rotary motions of which are performed on the self-interrupted principle. The operation is as follows:—

Upon a line finder being seized, VR & SF relays operate by means not shown. Relay HA then operates over the following circuit; battery on rotary magnet R, normal contacts HA 8 & 6, off-normal contacts N 2 & 3, 2000 ohms winding of HA, normal contact of vertical bank and vertical wiper 2, winding of relay VT & operated contacts VR 22 & 21 to earth. Due to the high resistance of relay HA, the rotary armature is not operated under this condition. The operation of relay HA completes the self-interrupted drive circuit for the vertical magnet as follows:—Battery on vertical magnet V, vertical interrupter contacts, normal contacts of rotary off-normal contacts NR 1 & 2, operated contacts HA 28 & 27, normal contacts RS 22 & 21, normal contacts VT 1 & 2, and operated contacts SF 2 & 1 to earth.

It will be observed that at the first vertical step the original operating circuit for relay HA is broken at the vertical wiper 2. Relay HA is, however, held operated via normal rotary off-normal contacts NR 4 & 5, cam springs S, metal rectifier MR, operated contacts HA 28 & 27, etc., and operated contacts SF 2 & 1 to earth.

The vertical action, therefore, proceeds step

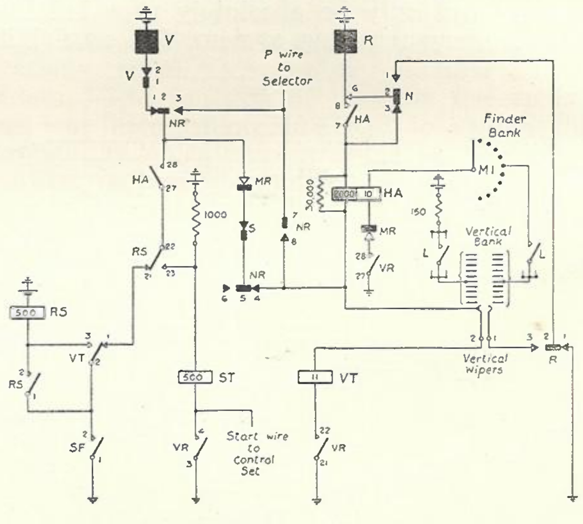


Fig. 18.—Schematic of self-interrupted drive.

by step until the level marked by the calling line is reached, whereupon relay VT operates over the following circuit:—Battery on the common 150 ohms resistance, operated L contacts of line relay, "marked" contact of vertical bank, vertical wiper 2, winding of relay VT and operated contacts VR 21 & 22 to earth. The operation of relay VT opens the vertical magnet circuit at operated contacts VT 1 & 2, and also releases relay HA and operates and locks up relay RS.

The rotary action now follows and commences immediately relay HA releases, via battery on rotary magnet, normal contacts HA 8 & 6, operated off-normal contacts N 2 & 1 and rotary interrupter contacts R 2 & 1 to earth. The wipers are, therefore, rotated step by step until the particular "marked" contact is reached, whereupon a circuit for the 10 ohms winding of relay HA is completed as follows:—Battery on rotary magnet, normal contacts HA 8 & 6, operated off-normal contacts N 2 & 1, operated rotary interrupter contacts R 2 & 3, vertical wiper 1 on calling level, contact of vertical bank, operated L contact of calling subscriber's line relay, the particular "marked" contact of the line-finder bank, line-finder wiper M1, 10 ohms winding of relay HA, metallic rectifier MR and operated contacts VR 27 & 28 to earth. Relay HA, therefore, operates and locks up on its 2000 ohms winding via operated contacts HA 8 & 7, operated contacts NR 7 & 8 to the full earth fed back from the associated group selector over the P wire.

It should be observed that this particular method of self-interrupted drive is a new departure and is a great improvement upon earlier practice. The high hunting speed of forty to fifty steps per second is attained, and this is due to the particularly improved interrupter contacts and magnets embodied in the Type 2000 selector previously described. These features, in conjunction with the two-motion principle of the mechanism, ensure that the average finding time is not only a minimum, but is also accomplished with an absolute minimum of individual mechanical operations.

Fig. 19 is an oscillograph record of the line-finder action, in this case the fourth contact on the fourth level. The vertical timing lines are at intervals of 10 milli-seconds.

Magnet Locking.

Referring to the oscillogram, Fig. 19, it will be observed that the normal operating impulse of the last rotary step is immediately followed by an additional pulse of lower amplitude. This additional pulse is known as the "magnet lock" and ensures a perfectly clean arresting of the rotary stepping action. The explanation is as follows:—When the line-finder wipers reach the "marked" contact, the rotary interrupter contacts 1 & 2 first disconnect the magnet circuit and then almost simultaneously complete the circuit for the low resistance winding of HA in series with the magnet. As the transit time of the interrupter springs is extremely short, the magnet remains locked in the operated position until relay HA operates to disconnect the low resistance circuit via HA 8 & 6 and introduces its own high resistance winding via operated contacts HA 8 & 7.

Immediate Change-over to Secondary Finders.

As previously mentioned, the auxiliary finders are not introduced until the regular finders are all engaged simultaneously, whereupon the change-over is automatically and immediately accomplished in the following manner:—The regular and auxiliary finders associated with each 200 line group are connected in different ways to the allotter banks, as shown in Figs. 20 and 21. Referring to Fig. 20, it will be seen that the regular finders are shown connected to the first series of contacts of banks R2, R1 & R6 of the allotter, also that a lead is taken from each regular finder via a metal type rectifier and that these leads are all commoned and connected to earth through the relay RFB. Now, as each finder becomes engaged, thus operating its off-normal contacts N, and "earth" connection is extended to the corresponding contacts on the allotter bank R2 and also to one side of the associated rectifier. The latter, however, is non-conducting in this direction, so that, as long as

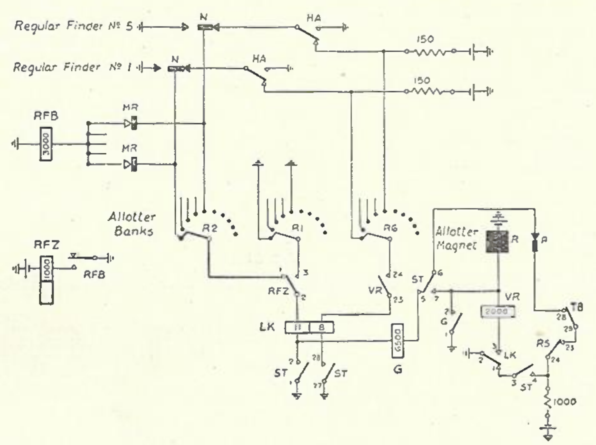


Fig 20
Schematic showing arrangement of the regular line finders.

one regular finder remains disengaged, relay RFB is steadily operated via earth on relay RFB, the particular metal rectifier and normal contacts N & HA, to battery via the particular 150 ohms resistance.

When now the last regular finder becomes engaged, relay RFB releases, thus operating relay RFZ and so changing over the circuit for

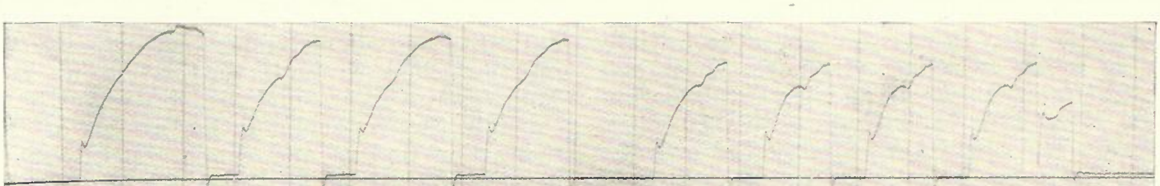


Fig. 19.—Oscillogram of self-interrupted drive.

relay LK from bank R2 of the allotter to bank R1.

Fig. 21 shows the method of connecting the auxiliary finders and is generally similar to that employed for the regular finders, except that the auxiliaries are connected to the later series of contacts on the allotter banks and are commoned to a thermionic valve; also that the testing battery is derived from the associated secondary finder apparatus. The function of the valve and the operation of the secondary apparatus is described later.

In the comparatively rare cases in which the

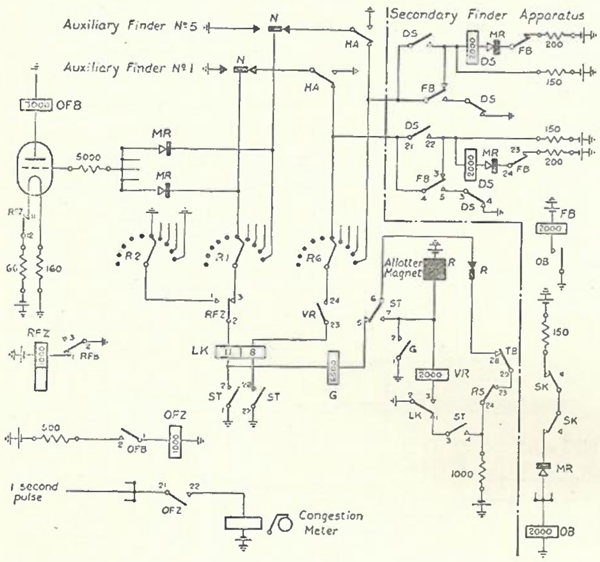


Fig. 21

Schematic showing arrangement of the auxiliary line finders.

actual traffic requirements demand more than twenty-five line finders per 200 lines group, an auxiliary allotter is introduced. In these cases the regular finders are connected to the bank contacts of one allotter and the auxiliary finders are connected to the other allotter, the change-over being automatically effected in a similar manner to that employed in the more usual cases in which fewer line finders are employed per group.

Direct Secondary Test.

Before considering this feature, it is desirable to describe the circuit operations involved when a regular finder is taken into use. Relay ST, the contacts only of which are shown in Figs. 20 and 21, is first operated and in turn operates relays LK & VR. Relay LK operates initially on its 11 ohms winding via normal contacts RFZ 2 & 1, allotter wiper and bank R2, normal contacts N & HA to battery with 150 ohms resistance. The operation of relay LK operates the high resistance relay VR in series with the allotter magnet, so that relay LK remains locked on its 8 ohms winding via operated contacts VR 23 & 24, allotter wiper and bank R6 to battery via 150 ohms resistance, when the particular finder has moved off-normal and so opened its N & HA contacts.

Upon the finder switching through, relay ST is released, thus in turn releasing relays LK & VR. A circuit is then completed for relay G from earth at operated N contacts, allotter bank and wiper R2, normal contacts RFZ 1 & 2, 11 ohms winding of relay LK, winding of relay G, normal contacts ST 5 & 6, allotter interrupter contacts R, normal contacts TB and RS, 1000 ohms resistance to battery. Relay G, therefore, operates (but not relay LK) and fully energises the allotter magnet R via operated contacts G 2 & 1. The allotter armature and pawl are thus operated and the interrupter contacts open to release relay G, whereupon the allotter wipers step to the next set of contacts. This interaction between relay G and the allotter continues until the wipers come to rest on the contacts associated with a disengaged line finder.

Considering now the auxiliary finders, the purpose of the "direct secondary test" features is to ensure that, unless there is a disengaged secondary finder available in the particular secondary group the auxiliary finder is not permitted to function and the call is accordingly routed via some other secondary group. This is accomplished in the following manner:—

Referring to Fig. 21, it will be seen that the initial operating circuit for relay LK is via operated contacts RFZ 2 & 3, allotter wiper and contact R1, normal contacts N & HA of the auxiliary finder (in the primary group) and normal contacts FB and to battery in the secondary group. Relay LK is likewise held on its 8 ohms winding via allotter wiper and bank R6 after the auxiliary finder has moved off-normal.

Now certain contacts of the switching relays, SK, of the secondary finders in each group are commoned, as shown, and connected to relay OB, which remains operated so long as one secondary finder in the group is free to pass a call. When, however, all the secondary finders in the group are simultaneously engaged, the circuit for relay OB is broken. Relay OB, therefore, releases and thus operates relay FB and busies the associated contact of the primary allotter bank R1 via operated contacts FB 4 & 5 and normal contacts DS 3 & 4. The particular line finder, although free itself, is thus passed over.

A further operational feature of the auxiliary finders is that they do not commence to hunt until the secondary finder has actually "found" and switched through to the group selector. This feature is accomplished by relay SF, which controls the vertical hunting circuit of the primary line finders and cannot operate until the circuit of the SM lead—see Plates 1 and 2—is completed. In the case of the auxiliary finders, the SM leads are connected together and when an auxiliary finder is taken into use the SM lead circuit is not completed until the secondary finder becomes positioned on the particular marked contact. Relay SF then operates and completes the vertical stepping circuit of the finder as shown schematically in Fig. 18. It will thus be clear that when an auxiliary finder switches through, current is supplied to the calling loop from the group selector before the line relay of the calling line is cleared down. This method of operation is necessary on calls initiated from series holding P.A.B.X.'s, since, if an auxiliary finder was permitted to switch through before the secondary finder had completed the loop to the group selector, there would be a momentary break in the line current and the call would be cleared down at the P.A.B.X.

Congestion Supervision, Thermionic Valve Scheme.

Referring to Fig. 21, it will be seen that when the auxiliary finders are introduced, relay RFZ is operated and the circuit for the filament of the valve is closed. So long as at least one auxiliary finder is disengaged and at least one secondary finder also, the grid of the valve is at full negative 50 volt potential and is, therefore, negative to the filament, which is at approximately negative 35 volts potential. Hence relay OFB in the plate circuit is practically without current under this condition and therefore remains inoperative. When, however, all the auxiliary finders are simultaneously engaged or no secondary finders are available for the particular group, the grid potential is changed from full negative 50 volts to earth potential. Hence the current in the plate circuit of the valve is considerably increased and relay OFB operates. The operation of relay OFB operates relay OFZ, which in turn completes the pulsing circuit of the congestion meter. The latter, therefore, operates once per second during the time that the congestion condition prevails.

Automatic Locking-out of Faulty Apparatus and Diversion of Call to Alternative Apparatus. Time-delay Feature.

The elements of the time-delay circuit are shown in Fig. 22. As each call is initiated the start wire to a control group is earthed to operate relay ST, which remains operated until the call has been switched through. If for any reason the call is not switched through within a few seconds, the call is diverted to alternative apparatus and the particular control set is locked out, and under certain circumstances the particular line finder also, and an alarm given, the operation being as follows:—When relay ST operates, a circuit is completed at ST 21 & 22 to the delay set and a circuit is also prepared for relay TA at operated contacts ST 23 & 24 via the S lead, besides completing the circuit to the line finder.

The function of the delay set is to provide a short impulse on each of the two wires, S & Z, at regular intervals of six seconds, the S pulse occurring a few milli-seconds after the completion of the Z pulse. Hence, when the S pulse is received, relay TA operates and locks up on its other winding via operated contacts TA 1 & 2

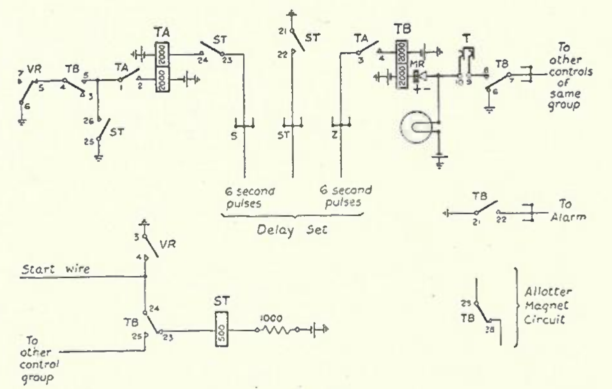


Fig 22
Schematic of time delay circuit.

and ST 26 & 25. The operation of relay TA prepares a circuit for relay TB via operated contacts TA 3 & 4, so that, should the call not be switched through by the time the Z pulse occurs six seconds later, relay TB operates and locks up through its own contacts TB 8 & 7. The locking up of relay TB disconnects the start relay ST by opening contacts TB 24 & 23 and diverts the start wire to another control group at operated contacts TB 24 & 25. The allotter magnet circuit is also disconnected at operated contacts TB 28 & 29 and both visual and audible alarm signals are given. In such circumstances, therefore, the call is given an opportunity of being completed by alternative apparatus and possible abnormal apparatus is locked out.

The following additional features of the delay circuit should be observed. It will be appreciated that the failure of a call to be switched through in normal line-finding time may be due to (1) a defective line finder, or (2) a defective control set. The delay circuit is arranged to discriminate between (1) and (2) as follows:—

In the normal case, immediately the start wire of a control set is earthed, relays LK & VR operate to initiate the finding action of a preselected line finder. If now for any reason the line finder fails to function properly within the six seconds' delay period, the particular line finder is "busied" out of service, as well as the particular control set, when relay TB operates and locks up. This is brought about because, whilst relay TB operates to disconnect relay ST, the latter releases before relays LK and VR and thus ensures the release of relay TA. A holding circuit for relay HA—see Plate 1—is therefore established from earth on 500 ohms resistance YB, operated contacts TB 2 & 1, normal contacts TA 24 & 23, winding of relay VT, allotter wiper and bank R5, vertical wiper on normal contact, 2000 ohms winding of relay HA, normal contacts N 3 & 2, HA 6 & 8, and HB 3 & 5 to rotary magnet and battery. Relay HA is thus locked up and "busies" the finder on the allotter bank R2 or R1 via normal contacts N 5 & 6, and operated contacts HA 4 & 5 to earth.

If, on the other hand, due to a defect in the control set, relays LK and VR do not operate when the start wire is earthed, relay TA remains locked up when relay TB operates and thus disconnects at operated contacts TA 23 & 24, the above holding circuit for relay HA. Consequently only the control set is busied out and the line finder is left free to be taken into service by another control set.

Secondary Throw-out.

In order to appreciate this feature, the following two important principles of the system should be understood:—Firstly, the automatic locking-out and time-delay feature, explained in the previous section, has been designed to be effective on faulty apparatus only and to be independent of traffic congestion, the latter being recorded on the congestion meter. Secondly, when an auxiliary finder is taken into use, a start signal is given to two secondary control sets and normally causes two secondary finders to hunt simultaneously for the purpose of reducing the line-finding time to a minimum. The secondary control sets have each their own start lead and a signal on either normally operates relays in both control sets to start their respective secondary finders.

Assume now the extreme borderline case in which two separate calls are initiated simultaneously, one on each start lead, and that only one secondary line finder is available. In this case, immediately one of the calls is found and switched through, not only is the particular control set cleared down, but the second control set is cleared down also. It should be understood that if the second control set were not cleared down under these circumstances, the time-delay feature would eventually function and would cause the faulty apparatus alarm signal to be given in error.

The circuit operations of the secondary throw-out feature are described later.

Routining of Line Finders and Testing Facilities.

The routining and testing facilities incorporated on Strowger line-finder equipment are important and particularly convenient features, which enable the entire equipment to be effectively and rapidly tested at any time without interference with the service.

Routining and Testing of Primary Finder Equipment.

Referring to Plate 1, it will be seen that, in the primary start relay set there are five two-way locking type routining keys, KRT, together with one two-way KTI and KVT. The latter key is locking on the KTI side and non-locking on the KVT side. The locking KTI side, in conjunction with the KRT keys, provides for the routining of the finders, whilst the non-locking KVT side is for testing the functioning of the thermionic valve. Test jacks are also provided for each control relay set, allotter and line finder. Two test jacks are also associated with the primary start relay set, but are mounted on the rack for convenience when routining.

Use of KRT Keys.

By means of these keys, in conjunction with key KTI, it is possible to exercise the line finders, both regular and auxiliary, on any desired levels to test all the control relay sets and to prove the entire finder equipment. The sequence of circuit operations in a typical case is as follows:—

Key KRT-2 Operated.

Assuming KRT-2 to be actuated, this causes relay SA to be operated from battery on the 150 ohms resistance, operated contacts 2 & 1 of Key KRT-2, one winding of relay SA to earth at normal contacts 25 & 24 of key KRT-1. The operation of relay SA in turn operates relay ST from battery on 1000 ohms resistance YD, winding of relay ST, normal contacts TB 23 & 24 and OFZ 23 & 24 to earth at operated contacts SA 2 & 1. Assuming a regular finder to be available, relay LK then operates from earth at operated contacts ST 1 & 2, 11 ohms winding of relay LK, test link across T 5 & 6, normal contacts RFZ 2 & 1, allotter wiper and bank R2, off-normal contacts N 5 & 6, normal contacts HA 4 & 3 to battery on 150 ohms resistance YA. Relay VR thus operates from battery on allotter magnet and earth at operated contacts LK 3 & 2, whilst relay HA is then operated from battery on the finder's rotary magnet R, normal contacts HB 5 & 3 and HA 8 & 6, N contacts 2 & 3, 2000 ohms winding of relay HA, normal level contact of vertical bank, wiper 2, allotter bank and wiper R5, winding of relay VT (inoperative in this case) and operated contacts VR 22 & 21 to earth.

Relay HA also locks up on its 2000 ohms winding via normal contacts NR 4 & 5, S 2 & 1, metal rectifier MRA, operated contacts HA 28 & 27, allotter bank and wiper R3, normal contacts RS 22 & 21, VT 1 & 2 and operated contacts SF 2 & 1.

It will be observed that, since a regular finder is being routined, relay SF operates via the SM lead, which in the case of regular finders is connected to the + lead, the circuit being completed to earth via one coil of the A relay of the selector.

With the operation of relay HA, the vertical hunting circuit is completed as follows:—Battery on vertical magnet, vertical interrupter contacts V 2 & 1, normal contacts NR 1 & 2, operated contacts HA 28 & 27, allotter bank and wiper R3, normal contacts RS 22 & 21 and VT 1 & 2 to earth at operated contacts SF 2 & 1. The vertical motion, therefore, takes place step by step by self-interrupted drive until the marked level, in this case the second, is reached, whereupon relay VT operates via the vertical wiper 2 on the second level and operated contacts 1 & 2 of KRT-2 to battery via 150 ohms resistance.

The operation of relay VT first releases relay HA and then operates and locks up relay RS. The release of relay HA completes the rotary magnet hunting circuit from battery on rotary magnet, normal contacts HB 5 & 3 and HA 8 & 6, operated contacts N 2 & 1, rotary interrupter contacts R 2 & 1, test link T 11 & 12 to earth. The wipers of the finder are thus rotated step by step over the bank contacts, in this case on the second level. Immediately upon reaching the 11th rotary position, the circuit for relay HB is completed as follows:—Battery on rotary magnet, normal contacts HB 5 & 3 and HA 8 & 6, operated contacts N 2 & 1 and R 3 & 2, vertical wiper 1 on second level, tapping to 11th contact of finder bank M2, contact wiper M2, 10 ohms winding of relay HB, allotter bank and wiper R8, metal rectifier MRB and operated contacts VR 28 & 27, RS 2 & 1, and SF 2 & 1 to earth. Relay HB therefore operates, the rotary magnet being meanwhile magnetically locked as previously described, and relay HB locks up on its high resistance winding via operated contacts HB 5 & 4, operated contacts NR 8 & 7 to earth on the P wire fed back from the selector. The latter was pre-energised, when relay VR operated, via battery on 150 ohms resistance YA, operated contacts VR 26 & 25, allotter wiper and bank R4 and the lead SM, which is cross-connected on the I.D.F. to the positive wire of the selector. Hence, with the operation of relay HB, relay ST is shunted down and released, being followed in turn by the release of relays LK, VR, SF and RS. Release of relay VR causes the earth connection to be removed from the P wire, whereupon relay HB releases and completes the release circuit of the finder, which therefore restores to normal.

With the release of relay RS, the allotter is caused to step to select another line finder for routining and also causes the finder just routined to be restored to normal. The stepping of the allotter is accomplished as follows:—Battery on 1000 ohms resistance YE, normal contacts RS and TB, allotter interrupter contacts, test clip T 8 & 7, normal contacts ST 6 & 5 and OFZ 2 & 1, 6500 ohms winding of relay G, 11 ohms winding of relay LK, test clip 5 & 6, RFZ 2 & 1, allotter wiper and bank R2, to earth at the operated off-normal contacts N 5 & 4. Relay G therefore operates, but not relay LK, and at operated contacts G 2 & 1 the allotter magnet circuit is completed, thus attracting its armature and opening its interrupter contacts. Relay G therefore releases and the allotter wipers are stepped to the next set of contacts. If the latter are earthed, relay G again operates and causes the allotter wipers to be again stepped, this interaction continuing until a disengaged line finder is found. The routining of the newly seized line finder then immediately commences.

The release action of the finder previously routined occurs about a quarter of a second after relay VR is released. This brief delay is due to the earth connection of the P wire being maintained during the slow release period of the B relay of the selector. Relay HB releases when this earth is removed and thus completes the release circuit of the line finder, via normal contacts HB 5 & 3, etc.

Use of Other KRT Keys.

It should be noted that in the foregoing typical case of KRT-2 being operated, all the line finders can be rapidly routined in succession, but only on the second level, switching with the HB relays; also that the control relay set No. 1 would alone be used for each line finder. By means of the full set of keys, however, the line finders can be routined on any level, both the HA and HB relays can be checked and all the control relay sets can be exercised, as indicated in the following table:—

KRT Key No.	Control Relay Set used	Level routined	Switching Relay operated
1	1	1	HA
2	1	2	HB
3	1	3	HA or HB
4	1	4	HA or HB
5	2	5	HA
6	2	6	HB
7	3	7	HA
8	3	8	HB
9	3	9	HB
10	3	10	HA or HB

Varied and comprehensive as the above tests may be, they are supplemented by certain special facilities. These include:—

(a) Dial tone tests on levels 7 & 9.
(b) Test for local guarding earth on banks P1 & P2.
(c) Continuous routining of any single line finder.
(d) Routining of auxiliary line finders.
(e) Test for operation of thermionic valve.

(a) Dial Tone Tests on Levels 7 & 9.

These tests are accomplished by plugging a telephone into the test jacks 1 & 2 for the 7th or 9th level and by operating the appropriate key KRT7 or KRT9. In either case the loop should hold the selector and dial tone should be heard. By momentarily breaking the loop circuit upon the completion of each routine the line finders can be subjected to this test in rapid succession.

(b) Tests for Local Guarding Earths on Banks P1 & P2.

This routine is accomplished at the same time as the foregoing, the relay RT being operated and the lamp LPB glowing steadily in both the level 7 and level 9 tests if satisfactory. Referring to the above table, it will be seen that relay HA switches on level 7 and relay HB switches on level 9. If during the holding period of this particular routine test another line finder hunts over this particular level and fails to switch through in the normal manner, the second finder will rotate to the 11th step, where it must be caused to switch in order to prevent possible continuous attempts to find. This is accomplished by means of the operated contacts RT 22 & 23, or RT 25 & 26, which prepare a switching circuit at the 11th step for the alternative switching relay. The particular control set will, therefore, be shunted down to release the second finder and the call routed via another line finder.

(c) Continuous Routining of Any Single Line Finder.

The continuous routining of any particular regular line finder is made possible by merely opening the allotter magnet circuit, stepping the wipers by hand to the appropriate position and actuating the desired KRT key. The opening of the allotter magnet circuit is accomplished by merely removing the test link from T 7 & 8.

Any auxiliary line finder can be continuously routined by first transferring the test link from T 6 & 5 to T 5 & 4 and then proceeding as above for the continuous routining of a regular line finder.

(d) Routining of Auxiliary Line Finders.

The auxiliary line finders can be routined in succession by merely actuating the locking type key KTI. This operates relay RFZ via operated contacts KTI 32 & 31 and thus changes over at operated contacts RFZ 2 & 1 from the regular finders on allotter bank R2 to the auxiliary finders on allotter bank R1. It should be observed that in the event of all the auxiliary finders becoming simultaneously engaged under this condition, the regular finders are automatically re-introduced to deal with any calls that may be initiated as follows:—

Relay RFB remains energised so long as any regular finders are disengaged. Hence, when the auxiliary finders are being routined, and in the event of all of these being simultaneously engaged, the thermionic valve functions to operate relay OFB. Relay RFZ is thus shunted down via operated contacts OFB 2 & 1 and RFB 3 & 2. Relay RFZ therefore releases and reintroduces the regular finders.

(e) Test for Operation of Thermionic Valve.

This test is quite simply performed whilst the regular finders are in use by merely operating and holding the non-locking key KVT. This has the effect of changing the potential of the grid from full negative 50 volts to earth potential, at operated contacts KVT 21 & 22. Under this condition, relay OFB in the plate circuit should operate and light the lamp LPA via operated contacts KVT 25 & 24, OFB 2 & 1, and RFB contacts 3 & 2 to earth.

Non-interference with Service whilst Routining Line Finders.

It will be observed that the third winding, ce, on each of the five primary start relays SA to SE is normally short-circuited by the normal contacts of an odd-numbered routining key. When routining, however, on an odd level the corresponding ab winding is short-circuited by the actuated key and the ce winding of the next relay is unshorted. For example, when routining on the fifth level, the ab winding of relay SC is short-circuited and the ce winding of relay SD is unshorted.

This arrangement ensures that, when routining is proceeding on any odd level, any calls initiated on the companion even level are not delayed, but are immediately put through via another control set and finder. It will be appreciated that without some such arrangement calls initiated on the companion even level could not otherwise be put through when routining on the odd level.

There is, of course, no delay in switching through calls initiated on any odd level that is being routined, since the particular finder in use will stop on any marked contact and switch through any waiting call encountered on its normal passage to the 11th routining contact.

Special facilities are provided to prevent any interference with the service to subscribers on the 7th and 9th levels, when the finders are being routined on these levels, since in these cases the finders are held to listen for dialling tone. Interference is prevented by means of relay RT. This relay operates on both the 7th and 9th levels when the finder being routined reaches the 11th contact and thus clears down relay SD or SE by opening contacts RT 4 & 3 or RT 5 & 6 upon switching through. Hence any calls initiated whilst holding a routined finder on either of these levels are immediately put through via other finders.

The function of the contacts of relay RT associated with the 7th and 9th levels calls for special comment. It will be remembered that certain routine tests on these particular levels are loop tests, and that the operation of relay HA is tested on level 7, whilst relay HB is tested on level 9. If now, for example, during the holding period of relay HA on bank M1 a second finder is caused to hunt for a call marked on the same level and fails to find, then the second finder will rotate to the 11th step and relay HB will operate via level M2, and operated contacts RT 22 & 23. The operation of relay HB ensures that the control set is shunted down and the allotter is stepped before the finder restores to normal. A further finder is thus introduced and caused to hunt for the call on level M1.

Similarly if whilst holding relay HB via level M2 on the 9th level a second finder fails to find a call marked on the same level, relay HA of the second finder operates at the 11th step via operated contacts RT 25 & 26 and the call is diverted to another line finder and a further attempt made.

It will be appreciated that it is imperative to ensure the clearing down of the control set in this manner. Normally, of course, the control set is released upon switching through. If for any reason, however, any finder fails to switch through, then the control set must be cleared down at the 11th step for the purpose of ensuring that the allotter is stepped and another finder obtained. Otherwise the particular finder might possibly hunt continuously and fail to switch the call through.

Use of Test Jacks of Primary Finder Equipment.

In regard to the test jacks associated with the primary start relay set, a telephone is arranged to be plugged into either of the jacks for the purpose of routining the finders, both regular and auxiliary, on the 7th and 9th levels and listening to dial tone. The switching of relays HA & HB are tested on levels 7 & 9 respectively. On these tests the glowing of the lamp LPB proves the HA & HB contacts connected to wipers P1 & P2 which guard the calling subscriber's line.

Lamp LPA is for checking the functioning of the thermionic valve.

In the primary control relay, test U-links are normally inserted to bridge 5 & 6, 7 & 8, and 9 & 10. By merely transferring the U-link from 5 & 6 to 4 & 5, the auxiliary finders are introduced, whilst by moving U-links 7 & 8 to bridge 1 & 2 the running of the allotter can be tested by short-circuiting the allotter test jack. Finally, should the delayed alarm feature function and thus lock-up relay TB, this may be cleared down by momentarily withdrawing the U-link from points 9 & 10.

The test jack of the primary finder has normally two U-links inserted, one in points 11 & 12 and the other in points 13 & 14. By transferring the latter to points 7 & 8, the particular line finder is "busied" out of service as follows:—(See Plate 1.) Earth via the bridged points 7 & 8, normal contacts N 7 & 8, 2000 ohms winding of relay HA, normal contacts N 3 & 2, HA 6 & 8, and HB 3 & 5 to battery on rotary magnet. Relay HA operates and locks up via operated contacts HA 8 & 7 and at operated contacts HA 4 & 5 connects earth to the allotter bank R2 in the case of a regular finder and to bank R1 in the case of an auxiliary finder.

The finders can also each be busied by merely plugging a telephone into jack points 3 & 4.

The test U link in points 11 & 12 normally completes the finder release circuit, so that by merely withdrawing this link the finder can be operated mechanically for inspection purposes.

The test jack points 9 & 10 are for rapidly determining which of the two relays, HA or HB, on engaged finders, has switched through. The test buzzer operates when points 9 & 10 are bridged if relay HB has switched through, but remains silent if relay HA has switched.

In England, cases occur where regular subscribers and coin-box lines are served as a mixed group by the same line finders, a relay group is associated with wire D for the purpose of giving a discriminating signal to the operator on certain calls from the coin-box subscribers. By earthing test jack point 6, the functioning of this relay group can be checked conveniently.

Operation of Secondary Finder Equipment.

In order to ensure minimum secondary finder hunting time, it is arranged that, whenever an auxiliary finder is taken into use, two secondary finders are caused to hunt simultaneously. The circuit operation is as follows:—Referring to Plate 2, it should be observed that so long as a secondary finder is available relay OB remains operated. With the operation of relay ST in the primary control relay set, the auxiliary finders being in use, a circuit is completed for the SS wire in Plate 1 from operated contacts ST 1 & 2, 11 ohms winding of relay LK, operated contacts RFZ 2 & 3, allotter wiper and bank R1, normal contacts N 5 & 6 and HA 4 & 3. Turning now to Plate 2, the foregoing earth connection on the SS wire energises relay DS in the secondary control relay set via normal contact FB 4 & 3, winding of relay DS, metal rectifier, normal contacts FB 24 & 23, 200 ohms resistance YA to battery. Relay DS operates and in turn operates relay DR via operated contacts DS 1 & 2, normal contacts FB 2 & 1 and FR 26 & 25. Relay DR locks up on its own contacts DR 22 & 21. Relay DK operates via operated contacts DR 24 & 25, secondary allotter wiper and bank SA1, normal contacts SK 7 & 6 to battery on 150 ohms resistance YA. The operation of DK completes the hunting circuit of the finder via interrupter contacts SFdm, normal contacts SK 26 & 27, allotter bank and wiper SA3, operated contacts DK 3 & 2 and normal contacts FK 1 & 2 to earth.

The operation of relays DR & DK cause relay FR to operate from battery on allotter magnet, operated contacts DR 2 & 1, allotter interrupter contacts SAdm, operated contacts DR 6 & 7 and winding of relay FR to earth. Relay FR locks up on its own contacts FR 7 & 6. Upon the "marked" set of contacts on bank SF4 being reached, relay FK operates to arrest the hunting action and also operates relay SK via allotter bank and wiper SA2. Relay SK locks up via operated contacts SK 25 & 24 and earth fed back on the P wire of the selector. The call is thus switched through and the earth on the P wire is extended to the primary control relay set, which is thus cleared down and in turn releases relays DS & DR in the secondary control relay set.

The secondary allotter then steps to pre-select another secondary finder by the interaction of relay GG and the allotter magnet, as follows:—Battery on 1000 ohms resistance YD, normal contacts DR 5 & 6, allotter interrupter contacts SAdm, winding of relay GG, normal contacts FB 25 & 26, test link 8 & 7, normal contacts DR 23 and 24, allotter wiper and bank SA1 and operated contacts SK 7 & 8 to earth. Relay GG operates and at operated contacts GG 2 & 1 fully energises the allotter magnet, which attracts its armature and then opens the interrupter contacts to release relay GG. The wipers are thus stepped to the next contacts and the interaction continues until another finder is preselected.

Considering now the operation of the companion secondary finder, it will be seen that with the initial operation of relays DS & DR in the secondary control set, an earth connection is extended from operated contacts DS 1 & 2 and DR 3 & 4 via the normal contacts of key KST 5 & 4 of the secondary start relay set to lead 19 of the other secondary control relay set. Relay DR in the latter thus operates and causes a companion secondary finder to commence hunting. Upon one or other of the two secondary finders switching through, the primary and both secondary finder control relay sets are cleared down.

It should be observed that if for any reason a secondary control relay set is removed, jack points 3 & 1 make contact, thus commoning up to the two SS wires so that the companion finder serves both.

Operation of the Secondary Throw-out Feature.

As previously mentioned, important features of the system are not only that each auxiliary finder is prevented from being taken into use unless at least one secondary finder is available, but a secondary finder must actually "find" and operate its SK relay to complete the loop to the group selector before the auxiliary finder is permitted to commence hunting. The latter feature is secured by relay SF—see Plate 1—which cannot operate, when the auxiliary finders are being used, unless the circuit of the SM leads in both the primary and secondary apparatus is completed.

Referring to Plate 2, it will be seen that the SM lead in the secondary apparatus is not completed until the secondary finder becomes positioned on the "marked" contact. Relays FK & SK then operate in the secondary apparatus and relay SF operates in the primary apparatus to permit the auxiliary finder to commence hunting. This method of operation ensures that the loop to the group selector is completed before the auxiliary finder "finds" and thus prevents the possible opening of the loop to the calling line. If this precaution were not taken, calls initiated by series-holding P.A.B.X.'s might sometimes be cleared down.

A further feature of the system is that the locking-out time delay alarm signal is given by faulty apparatus only and not by traffic congestion. It will be clear that in the event of a call being signalled simultaneously on each start wire of the two secondary control relay sets, and assuming that only one secondary finder is available, then only one of the calls can be switched through. In the event of the congestion continuing, the delayed alarm signal would eventually be given in error. This, however, is prevented as follows:—

Under the particular conditions assumed, the two DS relays, one in each secondary control set, operate and lock up and the last remaining secondary finder continues to hunt. Upon the secondary finder switching one of the calls through, the particular control set is cleared down and relay OB also releases. The release of relay OB causes relay FB to operate and at operated contacts FB 1 & 2 or FB 21 & 22 causes relay DR, in the other control set, to release. The release of relay DR also releases relay DK, which in turn shunts down relay FR. The holding circuit for relay DS is thus broken at restored contacts FR 22 & 21 (contacts FB 24 & 23 being already operated) and relay DS therefore releases. An earth connection is thus applied to the secondary start wire at operated contacts FB 4 & 5 or FB 7 & 8 and restored contacts DS 3 & 4. The primary control set is, therefore, cleared down and the faulty apparatus delayed alarm signal is prevented from being given.

Routining and Testing Facilities of Secondary Equipment.

A two-way non-locking test key KST is provided for each secondary start relay set. This key, in conjunction with a telephone plugged in test jack points 1 & 2, enables the secondary equipment to be functioned on test calls on each of the two secondary start wires separately and dial tone from the selector to be listened to. In these cases only one secondary finder is brought in and switches through on the 25th contacts, which are reserved for this test, the lamp LP glowing if the test is satisfactory.

The hunting action of the allotter is arranged to be conveniently tested by simply transferring the test link from points 7 & 8 to points 1 & 2 on the control relay set and by bridging the allotter test jack, 1 & 2.

Since the secondary finders are of the non-homing type a convenient test is provided for determining whether or not any particular finder is engaged. This test is performed by simply bridging the test jack springs 1 & 2 of the finder, a buzzer being heard if the finder is engaged.

Complete Schedule of Facilities of the Line Finder Equipment.

It will be appreciated from the foregoing detailed description of various features of the line-finder circuit that the facilities provided by the line-finder equipment as a whole are not only wide and varied, but are also extremely convenient and facilitate both operation and maintenance procedures. The full schedule is as follows:—

(1) Automatically connects a calling line to a 1st selector in the switching train, with minimum line-finding time.

(2) Employs an improved form of self-interrupted drive, hence eliminating a relay and operating at a higher speed.

(3) Incorporates magnet-locking feature at the conclusion of the rotary motion.

(4) The line finders are in two groups, regular and auxiliaries.

(5) During periods of light and normal traffic the regular finders only are employed and each call is switched through direct to a selector.

(6) During periods of peak traffic the auxiliary finders are automatically introduced and each call in excess of those which can be dealt with by the regular finders is then routed via a secondary finder to its associated selector. The secondary arrangement approach full availability conditions and increase the average occupancy of the selectors.

(7) The change-over from regular to auxiliary line finders is automatic and immediate.

(8) When the auxiliary line finders are in use, a direct secondary test feature becomes operative and prevents the seizure of any auxiliary finder unless the outlet from it can be switched by a secondary line finder.

(9) In the event of any auxiliary finder being unable to be used as in (8), the call is automatically diverted via another channel and an alarm signal is given.

(10) Normally, when an auxiliary line finder is taken into use, two secondary line finders are caused to hunt simultaneously for the purpose of reducing finding time to a minimum.

(11) By means of simple strapping facilities provided, the regular and auxiliary finders can be connected conveniently in any desired order to the banks of the allotters.

(12) By means of divided starting arrangements and a plurality of primary control sets, two or more line finders may hunt simultaneously in each group.

(13) Any number of control sets and consequently any number of line finders may be arranged to hunt simultaneously in each group.

(14) Ensures uniform loads on the control sets.

(15) An alarm signal is given if for any reason a control set or line finder fails to switch through and the particular control set is then busied and locked out.

(16) Both primary and secondary line finders are fully pre-selected.

(17) Provides congestion metering when all finders in a group are simultaneously engaged.

(18) Prevents continuous rotation of allotters when all finders in a group are simultaneously engaged.

(19) Reduces line "stealing" to a minimum by preventing double searching on any particular level of line finders.

(20) Provides full line-finder-1st selector I.D.F. facilities enabling any line finder or secondary finder to be jumpered to any 1st selector for load distribution.

(21) Provides test bell facilities to readily determine the "odd" and "even" switching of the line finders.

(22) Provides for the individual release of each line finder.

(23) Gives release alarm signal in the event of any line finder failing to restore.

(24) Provides divided fusing of line finders to prevent traffic dislocation.

(25) A subscriber's faulty line or equipment has no adverse influence on the service to other subscribers on the same finder level.

(26) Provides for busying any line finder or secondary line finder from the associated selectors and also for the busying of any line finder by inserting a busy marker in the test jack of the line finder or associated selector.

(27) Provides extremely comprehensive automatic routining and convenient testing facilities for both the regular and auxiliary line finders and also the secondary finder equipment. The arrangements ensure that the routining can proceed at any time without interfering in any way with the service to subscribers.

(28) Provides for the manual routining of any line finder by merely transferring a test U-link from one position to another.

(29) Suitable for use with any standard 3-wire positive battery metering system.

(30) Provides for single or multi-fee metering.

(31) Prevents false switching to an engaged subscriber's line, i.e., the line finder is prevented from switching when testing an engaged subscriber's line coincident with the application of booster battery for metering purposes.

(32) Employs battery testing principles throughout.

Some Circuit Features of Group and Final Selectors.

Whilst the circuit arrangements of group and final selectors embodying the Type 2000 mechanism are in general conformity with the well-known Strowger principles, important advances in circuit design features have been incorporated and may be summarised as follows:—

(1) Self-interrupted drive of high speed.
(2) Minimum unguarded period on switching through.
(3) Effective re-guard during release action.
(4) Direct guard on private contact.
(5) Balanced transmission of tones.
(6) All "x" and "y" contacts avoided.
(7) All marginal adjustments avoided.

(1) Self-interrupted Drive of High Speed.

The sectionalised diagram Fig. 23 shows the simple self-interrupted drive circuit, which, as in the case of the line finder, operates at approximately fifty steps per second. The contacts are shown in the diagram in their actual positions at the commencement of the rotary stepping action, i.e., relay C normal, relays H & B operated and the off-normal contacts N closed. Owing to the improved design of the interrupter contacts, previously referred to, these contacts do not open until near the end of the forward stepping stroke of the armature, by which time the wipers are almost central on the bank contacts. This form of self-interrupted drive provides a degree of reliability much superior to that previously attained by the so-called "relay drive" and, of course, accomplishes this without the relay.

(2) Minimum Unguarded Period on Switching Through.

In order to appreciate this feature, it is necessary to point out that on earlier group selectors the private wiper, upon reaching a contact associated with a free outlet, did not receive its guarding earth in less than about 15 milli-seconds, which is the approximate time required for the switching relay to operate.

This unguarded period, although of very brief duration, occasionally led to dual switching, i.e., the switching of a second selector on to the same set of contacts. In the new circuits this unguarded period is reduced to between one and two milli-seconds and functions in the following manner:—

Referring to Fig. 23, it will be seen that so long as the stepping P wiper continues to encounter engaged (earthed) contacts, relay H remains held on its 2000 ohms winding. Immediately, however, the P wiper is stepped to a

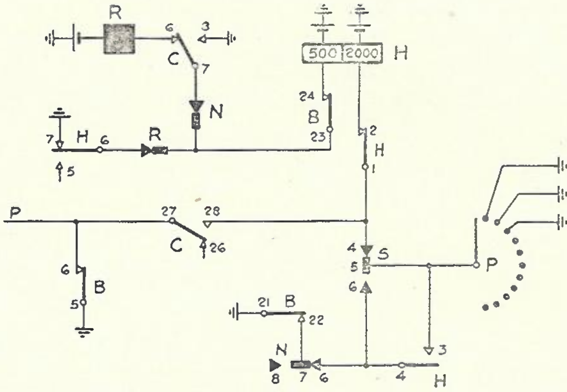


FIG. 23
Schematic of direct drive of group selectors.

disengaged contact, which is denoted by the absence of an "earth" connection, not only is the 2000 ohms holding circuit of relay H opened, but its 500 ohms winding receives a reverse inductive kick from the rotary magnet. Relay H is thus caused to release very rapidly and immediately guards the private wire via operated contacts B 21 & 22 and N 6 & 7 and restored contacts H 4 & 5. Subsequently, relays C & H operate in turn, so that an overlapping guarding earth is maintained from operated contacts B 5 & 6 and C 27 & 28 until "earth" is fed back via the P wiper.

It will be appreciated that the above feature effectively minimizes the possibility for the occurrence of dual connections.

(3) Effective Guard During Release Action.

The release "unguard" is approximately of 25 milli-seconds' duration and the seizure of the selector during this period does not interfere with its complete release action. Moreover, the release unguard period is achieved by means of relay release time alone and has the advantage of being less variable than the unguard periods provided by the previous method dependent upon the characteristics of the release magnets.

Fig. 24 is a sectionalised diagram showing the holding condition of the circuit when switched through. It will be seen that the earth connection on the P wiper holds relay H, which in turn holds relay C to maintain the through connection of the line wires. When now at the commencement of release the holding earth is removed, relay H releases in about 10 milli-seconds and is followed by the release of relay C in about 15 milli-seconds. It is during this total

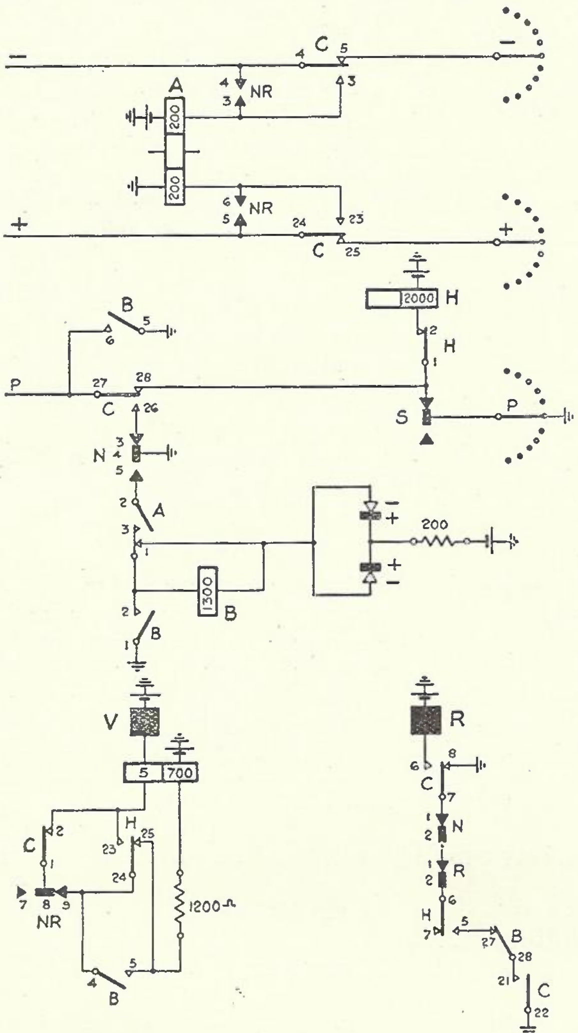


FIG. 24.
Schematic showing effective guarding of Type 32A Selectors during release action.

period of 25 milli-seconds that the P wire is unguarded to release any selectors in the previous ranks, and it will be appreciated that the selector may be again seized during the period. However, as previously mentioned, such re-seizure will not affect the completion of the release action. The circuit operation is as follows:—

Relays H & C having released, the release circuit is completed from battery on the rotary magnet, restored contacts C 6 & 7, operated contacts N 1 & 2, normal contacts R 1 & 2, restored contacts H 6 & 5, normal contacts B 27 & 28 and restored contacts C 21 & 22 to earth. Meanwhile the circuit for relay A is completed at restored contacts C 24 & 23 and C 4 & 3, whilst the circuit for relay B is disconnected at opened off-normal contacts N 5 & 4. It will therefore be seen that, although relay A would operate if the selector has been re-seized, relay B is prevented from operating until the off-normal contacts restore upon the wiper carriage returning to the normal or start position. The release action therefore continues without interruption and, upon its completion, the rotary magnet circuit is first disconnected at opened contacts N 2 & 1, whilst at restored contacts N 4 & 5 the circuit for relay B is completed. Relay B therefore operates and in turn operates relay C via operated contacts B 5 & 4 and restored contacts H 24 & 23. The rotary off-normal contacts having also been restored, the circuit for relay A is maintained via restored contacts NR 5 & 6 and NR 3 & 4, whilst the operated contacts B 5 & 6 maintain the guarding earth on the P wire.

The above method of ensuring absolute non-interference with the release action of the selector is an undoubted improvement on earlier practices and ensures higher operating efficiency in service by eliminating the possibility of dual connections, however remote these may be.

(4) Direct Guard on Private Contact.

This feature effectively eliminates any flicking or buzzing of the switching relays of selectors which formerly tended to occur when the P wiper made contact with engaged P wire coincident with the brief application of the positive metering impulse. Fig. 25 is a schematic dia-

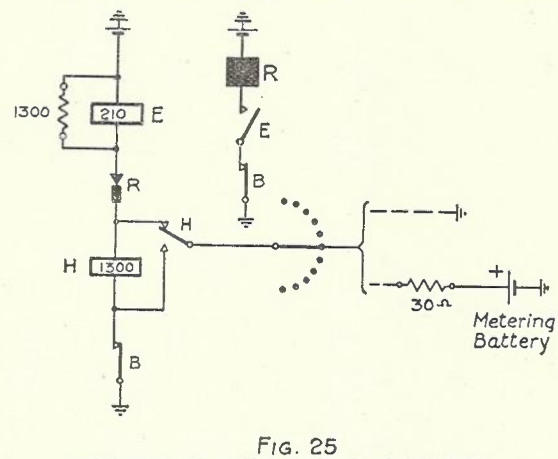


FIG. 25
Schematic of earlier method of guarding.

gram showing the elements of the earlier arrangement, from which it will be seen that the rotary stepping action is controlled by relay E. Relay H is the wiper switching relay and is normally prevented from operating when the P wiper encounters the earth of engaged contacts, which then re-energise relay E to again step the wipers. If, however, instead of earth it should happen that the short metering pulse is on the P wire at the time, both relay H and relay E tend to operate via the normal break contacts of

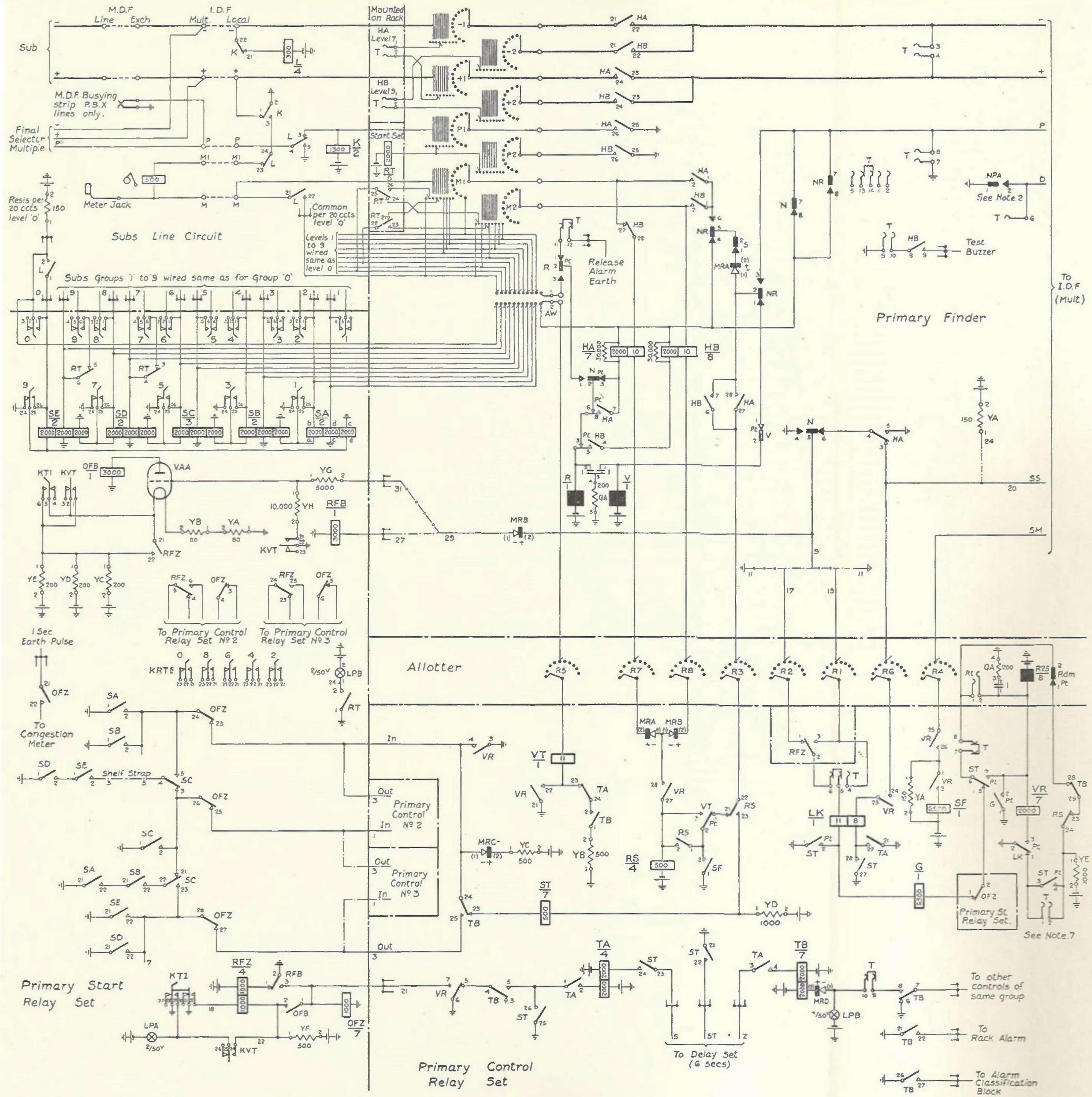


PLATE 1.

NOTES.

(1) When line finder is directly connected, strap U9-U17, U11-U19, U20-U24 and U27-U29. When line finder is indirectly connected, strap U9-U19, U11-U17 and U29-U31.

(2) In cases where the group of line finders is arranged to serve mixed coin-box and ordinary subscribers' lines, normal springs will be fitted and adjusted to operate on those levels serving coin-box lines. These finders must be directly connected.

(3) Five KRT keys provide level test facilities, in conjunction with key KTI, for changing over to indirect line finders, when desired. Key KVT tests the operation of the valve, in which case lamp LPA should glow. This test should only be employed when directly connected line finders are actually available.

(4) The jack points U1 & U3 are adjusted to make contact when the control relay set is removed.

(5) Any spare positions on the allotters are multipled; for example, 13 to 1, 14 to 2, etc.

(6) In cases where only two control relay sets are required, the shelf wiring shown in broken lines is omitted and jack points U1-U3 and U5-U7 require to be strapped.

(7) To test the running of the allotter uniselector from the test jack, transfer U-link from T7 and T8 to T1 and T2 on the associated control relay set.

(8) To routine continuously any particular directly connected line finder, transfer U-link from T7 and T8 to T1 and T2, set the allotter by hand and operate the appropriate KRT key.
To routine continuously any particular indirectly connected line finder, transfer U-link from T5 and T6 to T4 and T5 and proceed as for a directly connected line finder.

(9) For line-finder groups having directly connected line finders only, strap U31 to earth.

(10) For dial tone tests on levels 7 and 9, insert a telephone in the appropriate test jack associated with the primary start relay set and operate the appropriate KRT key. The telephone loop should hold the connection and lamp LPB should glow.

(11) For directly connected finders, connect SM lead to +. SS lead not connected. For indirectly connected finders, connect (a) SS lead to S1 or S2, and (b) connect SM lead to SM lead of secondary apparatus.

relay H. This tends to cause flicking or buzzing of both relays and although of short duration is an undesirable feature which is entirely eliminated by the new circuit arrangements.

Reverting now to Fig. 23, which shows the elements of the new circuit, it will be seen that relay H remains steadily operated if the P wire encounters full earth or the positive metering battery impulse and thus ensures the steady maintenance of the rotary magnet circuit.

(5) Balanced Transmission of Tones.

Figs. 26 and 27 show the earlier and new methods of applying tones to the line. It will be appreciated that the new method has the advantages of maintaining the purity of the tones unimpaired under all conditions and also of reducing mutual interference between lines, since the series impedance to earth of both line wires are balanced.

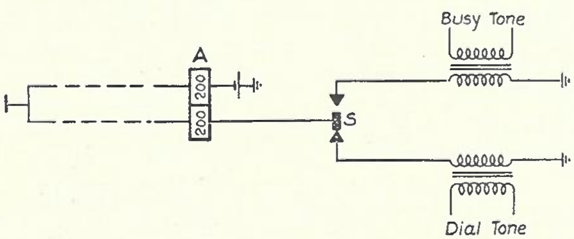


FIG. 26
Earlier Method
Schematic of earlier method of applying tones.

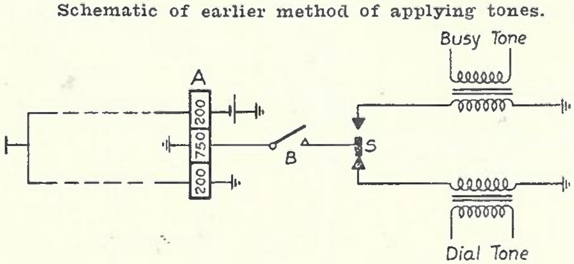


FIG 27
New Method
Schematic of Type 2000 method of applying tones.

(6) All "X" and "Y" Contacts Avoided.

It was an occasional feature of earlier circuits to employ relays, the contacts of which were adjusted to operate in a definite sequence. For example, "x" contacts were those adjusted to be operated before all other contacts, whilst "y" contacts were adjusted to be operated last of all. Whilst in these cases the performance and stability in service was generally quite satisfactory, it was always appreciated that in the event of accidental damage the readjustments necessary would be more difficult than if the sequence of operations were avoided. It is for this reason that the new circuits have been designed so as to eliminate almost entirely the necessity for any "x" and "y" contacts. The maintenance of the new circuits should, therefore, prove to be more simple.

(7) All Marginal Adjustments Avoided.

In the earlier circuits it was occasionally found economical to employ relays adjusted within certain margins, and in general this practice was likewise found to be reasonably satisfactory. At the same time it was realised that a factor in obtaining the highest all-round operating efficiency in service centred around the elimination of all marginal adjustments. The new circuits have therefore been designed from this point of view, all marginal adjustments having been eliminated.

SOME GENERAL NOTES ON STROWGER LINE-FINDER EQUIPMENT.

In order that some idea may be formed of the extent to which Strowger line-finder equipment approaches to the ideal of "one mechanism-one relay" installations, the following selector quantities are given of a typical main exchange having an initial capacity for 8,800 lines.

Two-motion Selectors.

Line finders, 200 lines	767
Digit absorbing selectors, 20/10	512
Group selectors, 10/10	338
Group selectors, 10/20	669
Final selectors, 200 lines, regular	560
Final selectors, 200 lines, regular and PBX	128
Final selectors, test and trunk offering	88
Trunk offering selectors	9
Test selectors	6
Total two-motion selectors	= 3075

Uniselectors.

Allotters	87
Secondary line finders	56
Total uniselectors	= 143

Lower Maintenance Costs.

From the above selector quantities it will be appreciated that in comparison with the earlier preselector installations the line equipment must obviously have important advantages from the maintenance point of view. In the case of a comparable preselector installation the total number of selecting mechanisms would be 11,000 as against only 3,218, the latter, however, being practically all of the two-motion type. This fact, coupled with particularly comprehensive and convenient routining facilities provided on line-finder equipment, definitely implies reduced maintenance costs in case of line-finder installations and has been amply demonstrated by actual results on line-finder installations introduced in England within the last few years.

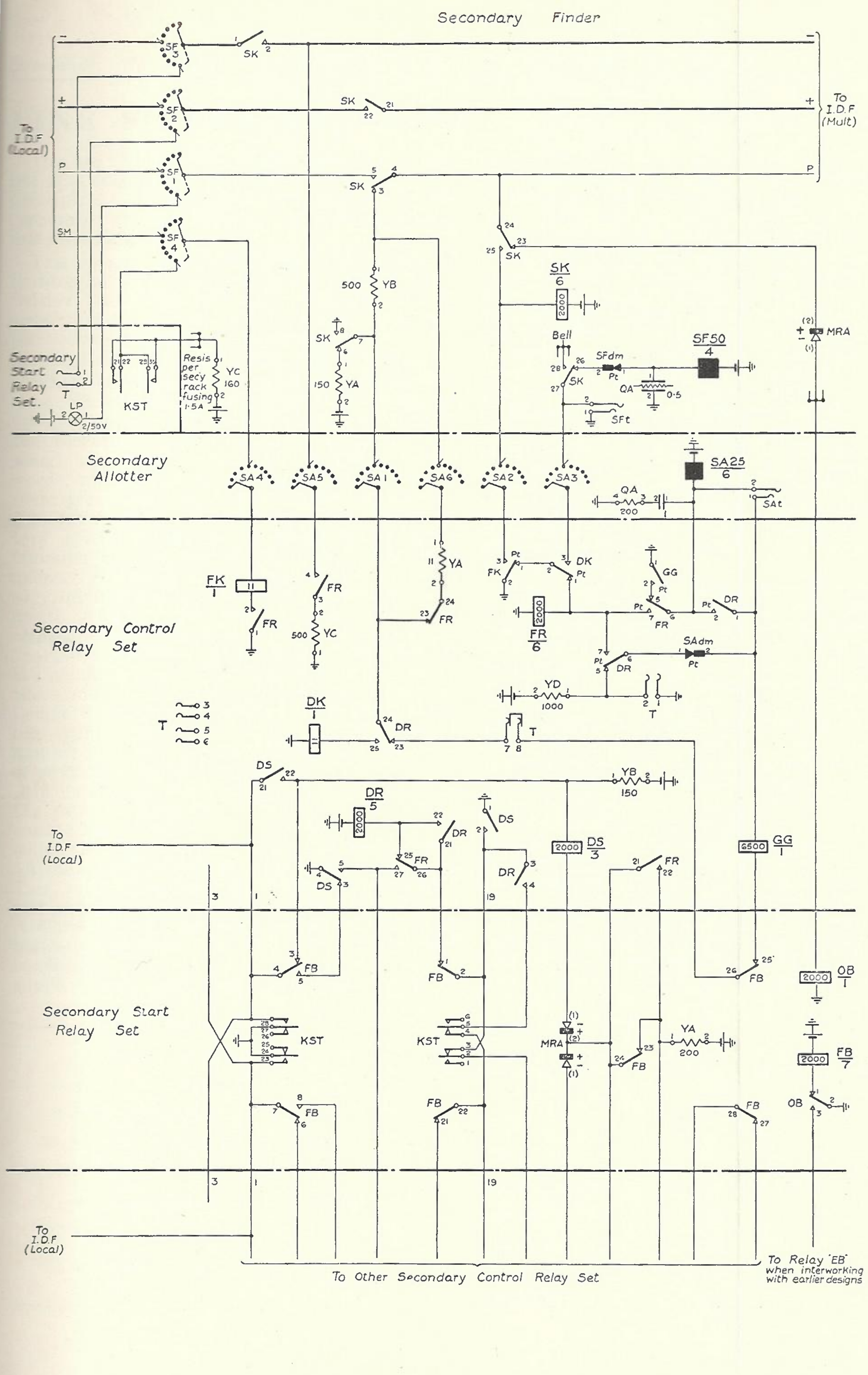


PLATE II.

NOTES.

(1) Any spare positions on the secondary allotters to be multipled; for example, 13 to 1, 14 to 2, etc.

(2) Shelf jack points 1 and 3 to "make" contact when a relay set is removed.

(3) One KST key is provided for each secondary start relay set and is two-way, non-locking.

(4) To test the running of the allotter uniselector from the test jack, transfer the test U-link from T7 and 8 to T2 and 1 on the associated control relay set.

LINE FINDER TRUNKING

C. McHenry, A.M.I.E. Aust.

The use of line finders in trunking is not new, but it is only within recent years that the finder principle of trunking has been successfully incorporated in the design of step-by-step automatic exchanges.

The present article deals with the trunking features of the finder system incorporated in the British Post Office 2000-type equipment, and in order that these features may be seen in proper perspective certain matters associated with the practical side of trunking will be discussed.

When telephone calls arrive at random the most efficient form of restricted access is the "simple" group, that is, a trunk group wherein the essential characteristic is that of "full search" or "full availability," which, in other words, means that a call cannot be lost unless it arrives when all trunks in the group are simultaneously in use. Economic and other factors govern the extent to which simple group trunking can be applied practically, and consequently variations of the simple group are necessary, giving rise to what may be termed "composite groups." The main characteristic of a composite group is that of "partial search" or "partial availability" and a call is lost when all the trunks accessible thereto are in use. although there may be other free trunks in the group. Composite groups are typified by grading, interconnecting, subdivision of the trunking into a number of simple groups, and the various forms of secondary and tertiary access.

In expressing the efficiency of a trunk group, the ratio of occupied time to total time can be used. For example, a group of 15 trunks in which the traffic carried during the busy hour is 5A, has an efficiency of 5/15 or 33.3 per cent. This ratio is termed the "absolute efficiency," and although useful is not the best criterion, as it disregards the grade of service and gives no indication of what is to be expected under ideal conditions. As the ideal arrangement is the simple group, more useful information is to be gained therefore by a knowledge of how closely any composite group approaches a simple group of the same size for the same grade of service. This factor will be termed the "relative efficiency" and is defined as the ratio of the actual traffic carried to that which could be carried with the same loss by a simple group of the same size. In the group cited above, assume that the loss, or grade of service, is 0.001 (1 lost call per 1000). For this loss a simple group of 15 trunks would carry 6.2A and the relative efficiency of the actual group is therefore 5/6.2, or just on 81 per cent. If the grade of service were equal to 0.0005 (5 lost calls per 10,000) the traffic carried under simple group conditions would be 5.7A, and the relative efficiency would then be 5/5.7, or just on 88 per cent. The figures of 81 per cent. and 88 per cent. convey all the essential information as to how the group is functioning, and for this reason the relative efficiency is a better criterion than the absolute efficiency.

The failure of the earlier finder arrangements is accounted for by their low traffic efficiency, caused by the subdivision of the trunking into a relatively large number of simple groups. To make this point clear, an example will be taken which will show this prominently. Assume an exchange of 1000 lines in which the busy hour originated traffic is 40A: the following statement shows the number of first selectors required for various trunking arrangements and the relative efficiencies for three different grades of service:

No practical telephone engineer would be happy with arrangements (3), (4) or (5). From the standpoint of trunking efficiency, (2) is the best practical compromise, but from the standpoint of cost (6) would need to be considered, and, as will be seen later, the traffic efficiency of (6) can be improved. There is a fundamental difference between the trunking principle utilised in (2) as compared with (3) to (6) inclusive. In (2) the underlying principle is that

Trunking arrangement	Loss = 0.010		Loss = 0.005		Loss = 0.001	
	First Selectors	Relative Efficiency	First Selectors	Relative Efficiency	First Selectors	Relative Efficiency
(1) Large simple group—ideal—but impracticable	52	100%	54	100%	58	100%
(2) 24-point homing first uniselectors—graded access	60	84.2%	63	89%	70	80%
(3) 40 simple groups of 25-point line finders	200	22.2%	200	23%	240	19.6%
(4) 20 simple groups of 50-point line finders	120	38.5%	140	40%	160	31%
(5) 10 simple groups of 100-point line finders	90	53.4%	100	49.2%	120	42.6%
(6) 5 simple groups of 200-point line finders	75	65%	80	63.5%	90	59.3%

of forward search, that is, the calling line searches for a free selector and the availability is 24 out of the total first selectors provided; on the other hand, in (3) to (6) the underlying principle is that of inverse search, that is, the calling line is searched for, and the availability varies from 5 to 18.

In any inverse trunking arrangement such as line finders in association with first selectors the finders must be subdivided into distinct and independent groups, but this restriction does not apply to the first selectors, as by interposing a concentrating stage between the finders and the selectors the availability of the selectors can be increased, resulting in greater traffic efficiency and an appreciable reduction in the number of first selectors; unfortunately, in practice this is not so simple as it may appear because the saving in first selectors must be balanced against the cost of concentrating the traffic via the additional selecting stage.

One of the characteristics of a simple group is that the traffic carried by the group considered as a whole is independent of the order in which the trunks are tested or assigned; on the other hand, the traffic carried by each individual member of a simple group depends solely upon the order in which the search or assignment is arranged. Assume a group of 20 finders serving 200 lines in which the total traffic offered is 10A and let the finders be assigned in an invariable order, say, 1 to 20. Under these conditions the second finder will be assigned only when the first finder is in use; the third only when the first and the second are in use; and so on. The average traffic carried per finder for the group as a whole will be 0.496A, but the traffic actually carried by each of the individual finders will be as shown in the following table:—

Finder number	Traffic carried	Finder number	Traffic carried
1	0.91	11	0.51
2	0.89	12	0.44
3	0.87	13	0.36
4	0.85	14	0.28
5	0.82	15	0.21
6	0.79	16	0.15
7	0.75	17	0.10
8	0.70	18	0.06
9	0.65	19	0.04
10	0.58	20	0.02

Traffic carried	= 9.98A
Traffic lost	= 0.02A
Traffic offered	= 10.00A

Examination of the foregoing table discloses that the earlier choice finders carry a very much greater amount of traffic than the later choice outlets. Assume now that the 20 finders are subdivided into two groups, the first group comprising x finders and the second group taking the remaining (20-x) finders, and let it be arranged that finders in the second group are assigned only when all x finders in the first group are in use. The traffic carried by each group and the average traffic per finder in each group, as determined from the preceding table, are then:—

GROUP 1
(First choice)

Finders in Group	Total traffic carried by Group	Percentage of total traffic carried	Average traffic per Finder
7	5.88	58.8	0.840
8	6.58	65.8	0.824
9	7.23	72.3	0.803
10	7.81	78.1	0.781
11	8.32	83.2	0.757
12	8.76	87.6	0.730
13	9.12	91.2	0.701

GROUP 2
(Second choice)

Finders in Group	Total traffic carried by Group	Percentage of total traffic carried	Average traffic per Finder
13	4.10	41.0	0.315
12	3.40	34.0	0.283
11	2.75	27.5	0.250
10	2.17	21.7	0.217
9	1.66	16.6	0.184
8	1.22	12.2	0.152
7	0.86	8.6	0.123

From the foregoing table it can be seen that the traffic efficiency of the first group of finders is very high, the concentration in this group being so great that further improvement cannot be expected, and therefore as a practicable proposition the size of this group can be suitably proportioned and the finders therein terminated directly on first selectors (or equivalent switches). The efficiency of the second group of finders is very low, and keeping in mind that the total number of finders is determined by the grade of service, a low traffic efficiency in the second group must be tolerated, but as already stated this does not apply to the associated first selectors, as will now be proved. If an exchange consisted of 200 lines offering 10A, a total of 20 200-point line finders would be required to give a grade of service of 0.002, and since simple group conditions would prevail a total of 20 first selectors would be required also. If, however, the exchange consisted of 400 lines, two groups each of 20 line finders would be required, but less than 40 first selectors would be needed with proper trunking arrangements because advantage could be taken of the fact that a demand for 20 finders in one group would not always coincide with a similar demand in the other group; therefore if, for example, the finders in each group were arranged as 10 first choice and

10 second choice with the first choice finders connected directly to first selectors, this would give 20 first selectors, carrying 15.62A, or approximately 78 per cent. of the total traffic offered. The second choice finders in each group would carry 2.17A, or a total of 4.34A, and if this traffic were concentrated on a common group of second choice first selectors, the number required would be appreciably less than 20, thereby giving a saving in first selectors, which saving, however, would be reduced by the cost of concentrating the second choice traffic. The concentration of the second choice traffic is effected by means of secondary finders interposed between the second choice finders and their associated first selectors, and since the concentration only applies to the second choice traffic this form of trunking is termed "Partial Secondary Access." In concentrating the second choice traffic it is not possible to deal with each primary group separately; the arrangement depends essentially on the second choice traffic from a number of groups being merged in a common group of selectors. Let N be the number of finder groups; x the total number of finders per group; X the number of first selectors actually provided and X_s the number of first selectors which would be required to trunk the exchange as a simple group. For N simple groups a total of Nx first selectors would be needed and, therefore, partial secondary trunking results in the number of first selectors being intermediate between Nx and X_s, the arrangement being better than subdivision into a number of simple groups, but never better than the ideal of one large simple group. Thus within reasonable limits, partial secondary trunking can be applied to counteract the inefficiency resulting from the division of the primary finders into distinct and closed groups, and for all practical purposes is almost as efficient as full secondary trunking with the advantage of lower cost.

For a given grade of service, the number of first selectors is a maximum when no secondary access is employed, and a minimum when full secondary access is provided. With partial secondary working the most economical arrangement is the one for which the saving in first selectors less the cost of the secondary finders is greatest. This difference is governed by various factors, and particular factors may not operate to the same extent in all cases. As a broad guiding principle, however, it can be taken that the most economical arrangement is obtained when the numbers of first and second finders in each primary group are approximately equal.

In the B.P.O. system the subscribers' lines are connected to the banks of 200-point bimotional switches known as primary finders. Each group of primary finders is divided into two sections: the finders in the first section carry the first choice traffic and are each connected directly to first selectors (or equivalent switches): the finders in the second section carry the overflow traffic from the first section and are connected to the banks of 50-point uniselectors, termed secondary finders, and the latter switches are connected to first selectors. The primary finders in the first section are known as "direct" finders whilst those in the second section are known as "indirect" or "auxiliary" finders. Where more than one group of secondary finders is necessary, the auxiliary finders in each 200-line group are distributed as uniformly as possible over the secondary groups in order to increase the availability, and to secure a more uniform distribution of traffic. Sufficient secondary finders are provided in each secondary group to handle the traffic received from the primary finders accessible thereto.

Tables for the determination of primary and secondary finder quantities have been available for some time. As it is the intention to discuss several examples to demonstrate the method of dealing with practical cases, the writer has taken the liberty of rearranging the data referred to and has embodied it in one table and two sets of curves which accompany this article. The table gives the traffic capacity of 200-point primary finders and also shows the amount of traffic per 200-line group which is passed via the secondary finders. The primary traffic is divided into two sections designated A and B. The curves give the traffic capacity of 50-point secondary finders, one set of curves designated "A" and the other set of curves designated "B" being consulted for section A and section B primary traffic respectively. The upper figure in each square of the table gives the traffic originated by each 200-line group expressed to the second decimal place, and it will be seen that the traffic interval is uniformly 0.05A: the lower figure in each square gives the amount of secondary traffic per 200-line group, and for purposes of distinction, and also to avoid confusion, this latter figure has been uniformly expressed to the third decimal place, in which connection it is desired to stress that where the third figure is "0" it is no criterion of the accuracy. The tables covers a range of calling rates from 0.01A to 0.102A per line. The curves are limited to seven groups, and when this number of secondary groups is reached it is termed a "division." The number of lines per division depends on the traffic. When extensions are made, only incomplete divisions therefore need be disturbed: otherwise the amount of rejumpering would be considerable and there would be a greater risk of interfering with the service. It may some-

TRAFFIC CAPACITY OF 200-POINT PRIMARY LINE FINDERS.
WITH PARTIAL SECONDARY ACCESS.

NOTES.
1. UPPER FIGURE IN EACH SQUARE = TRAFFIC UNITS (A) ORIGINATED PER 200-LINE GROUP.
2. LOWER " " " " - TRAFFIC UNITS PER 200-LINE GROUP VIA SECONDARY FINDERS.
3. FOR SECTION A AND B SECONDARY TRAFFIC, REFER TO RESPECTIVE SECONDARY FINDER CURVES.

SECTION A TRAFFIC								SECTION B TRAFFIC.								PRIMARY FINDERS.		
																DIRECT.	VIA SECOND. FINDERS	TOTAL.
2·00 0·420	2·05 0·450	2·10 0·475	2·15 0·500	2·20 0·525				2·25 0·555	2·30 0·585	2·35 0·615	2·40 0·645	2·45 0·675				3	6	9
2·50 0·705	2·55 0·745	2·60 0·775	2·65 0·810	2·70 0·845	2·75 0·875			2·80 0·910	2·85 0·945	2·90 0·970	2·95 1·005	3·00 1·035	3·05 1·070			3	7	10
3·10 0·668	3·15 0·695	3·20 0·720	3·25 0·752	3·30 0·782	3·35 0·815			3·40 0·845	3·45 0·878	3·50 0·910	3·55 0·945	3·60 0·980	3·65 1·010.			4	7	11
3·70 1·040	3·75 1·070	3·80 1·100	3·85 1·030	3·90 1·160				3·95 1·200	4·00 1·230	4·05 1·270	4·10 1·310	4·15 1·350				4	8	12
4·20 0·910	4·25 0·940	4·30 0·970	4·35 1·000	4·40 1·030	4·45 1·060			4·50 1·090	4·55 1·120	4·60 1·160	4·65 1·190	4·70 1·220	4·75 1·260			5	8	13
4·80 1·290	4·85 1·320	4·90 1·360	4·95 1·400	5·00 1·430	5·05 1·470			5·10 1·500	5·15 1·530	5·20 1·570	5·25 1·610	5·30 1·650	5·35 1·680			5	9	14
5·40 1·200	5·45 1·230	5·50 1·260	5·55 1·290	5·60 1·320	5·65 1·350	5·70 1·380		5·75 1·420	5·80 1·460	5·85 1·490	5·90 1·520	5·95 1·560	6·00 1·590	6·05 1·620		6	9	15
6·10 1·660	6·15 1·700	6·20 1·730	6·25 1·770	6·30 1·800	6·35 1·830			6·40 1·870	6·45 1·910	6·50 1·950	6·55 1·980	6·60 2·020	6·65 2·050			6	10	16
6·70 1·540	6·75 1·570	6·80 1·610	6·85 1·640	6·90 1·670	6·95 1·700	7·00 1·740		7·05 1·770	7·10 1·810	7·15 1·850	7·20 1·880	7·25 1·920	7·30 1·950	7·35 1·980		7	10	17
7·40 2·020	7·45 2·050	7·50 2·080	7·55 2·120	7·60 2·160	7·65 2·200			7·70 2·230	7·75 2·270	7·80 2·310	7·85 2·350	7·90 2·380	7·95 2·420			7	11	18
8·00 1·890	8·05 1·920	8·10 1·960	8·15 1·990	8·20 2·020	8·25 2·060	8·30 2·090		8·35 2·130	8·40 2·170	8·45 2·200	8·50 2·230	8·55 2·270	8·60 2·310	8·65 2·350		8	11	19
8·70 1·830	8·75 1·860	8·80 1·890	8·85 1·920	8·90 1·960	8·95 1·990	9·00 2·020		9·05 2·060	9·10 2·100	9·15 2·130	9·20 2·160	9·25 2·200	9·30 2·230	9·35 2·270		9	11	20
9·40 2·300	9·45 2·340	9·50 2·370	9·55 2·410	9·60 2·450	9·65 2·480	9·70 2·570		9·75 2·550	9·80 2·580	9·85 2·620	9·90 2·660	9·95 2·690	10·00 2·730	10·05 2·770		9	12	21
10·10 2·220	10·15 2·250	10·20 2·280	10·25 2·320	10·30 2·350	10·35 2·380	10·40 2·420		10·45 2·450	10·50 2·490	10·55 2·520	10·60 2·560	10·65 2·600	10·70 2·630	10·75 2·660		10	12	22
10·80 2·700	10·85 2·730	10·90 2·770	10·95 2·810	11·00 2·850	11·05 2·890	11·10 2·930		11·15 2·970	11·20 3·000	11·25 3·040	11·30 3·080	11·35 3·110	11·40 3·150	11·45 3·190		10	13	23
11·50 2·600	11·55 2·630	11·60 2·670	11·65 2·710	11·70 2·750	11·75 2·780	11·80 2·820		11·85 2·860	11·90 2·900	11·95 2·930	12·00 2·970	12·05 3·010	12·10 3·050	12·15 3·080		11	13	24
12·20 3·120	12·25 3·160	12·30 3·200	12·35 3·230	12·40 3·270	12·45 3·310	12·50 3·350	12·55 3·380	12·60 3·420	12·65 3·460	12·70 3·500	12·75 3·540	12·80 3·580	12·85 3·620	12·90 3·660	12·95 3·700	11	14	25
13·00 3·080	13·05 3·120	13·10 3·160	13·15 3·200	13·20 3·230	13·25 3·270	13·30 3·300		13·35 3·340	13·40 3·380	13·45 3·420	13·50 3·460	13·55 3·500	13·60 3·530	13·65 3·570		12	14	26
13·70 3·610	13·75 3·650	13·80 3·680	13·85 3·720	13·90 3·760	13·95 3·800	14·00 3·840		14·05 3·880	14·10 3·920	14·15 3·960	14·20 4·000	14·25 4·040	14·30 4·080	14·35 4·120		12	15	27
14·40 3·490	14·45 3·520	14·50 3·560	14·55 3·600	14·60 3·640	14·65 3·680	14·70 3·720	14·75 3·760	14·80 3·800	14·85 3·830	14·90 3·870	14·95 3·910	15·00 3·950	15·05 3·990	15·10 4·030	15·15 4·070	13	15	28
15·20 4·120	15·25 4·160	15·30 4·200	15·35 4·240	15·40 4·280	15·45 4·320	15·50 4·350		15·55 4·390	15·60 4·430	15·65 4·470	15·70 4·510	15·75 4·550	15·80 4·580	15·85 4·620		13	16	29
15·90 3·970	15·95 4·010	16·00 4·050	16·05 4·090	16·10 4·130	16·15 4·170	16·20 4·210	16·25 4·240	16·30 4·280	16·35 4·320	16·40 4·360	16·45 4·400	16·50 4·440	16·55 4·480	16·60 4·510	16·65 4·550	14	16	30
16·70 3·920	16·75 3·960	16·80 3·990	16·85 4·030	16·90 4·070	16·95 4·110	17·00 4·150	17·05 4·190	17·10 4·220	17·15 4·260	17·20 4·300	17·25 4·340	17·30 4·380	17·35 4·420			15	16	31
17·40 4·460	17·45 4·500	17·50 4·530	17·55 4·570	17·60 4·610	17·65 4·650	17·70 4·690	17·75 4·730	17·80 4·770	17·85 4·810	17·90 4·850	17·95 4·890	18·00 4·930	18·05 4·970	18·10 5·020	18·15 5·060	15	17	32
18·20 4·390	18·25 4·430	18·30 4·470	18·35 4·510	18·40 4·540	18·45 4·580	18·50 4·670		18·55 4·660	18·60 4·700	18·65 4·740	18·70 4·770	18·75 4·810	18·80 4·850	18·85 4·890		16	17	33
18·90 4·930	18·95 4·970	19·00 5·010	19·05 5·060	19·10 5·100	19·15 5·140	19·20 5·180	19·25 5·220	19·30 5·260	19·35 5·300	19·40 5·340	19·45 5·380	19·50 5·420	19·55 5·470	19·60 5·510	19·65 5·550	16	18	34
19·70 4·870	19·75 4·910	19·80 4·950	19·85 4·990	19·90 5·020	19·95 5·060	20·00 5·100	20·05 5·140	20·10 5·180	20·15 5·220	20·20 5·260	20·25 5·310	20·30 5·350	20·35 5·390	20·40 5·430	20·45 5·470	17	18	35

times be convenient to arrange each division with less than seven secondary groups.

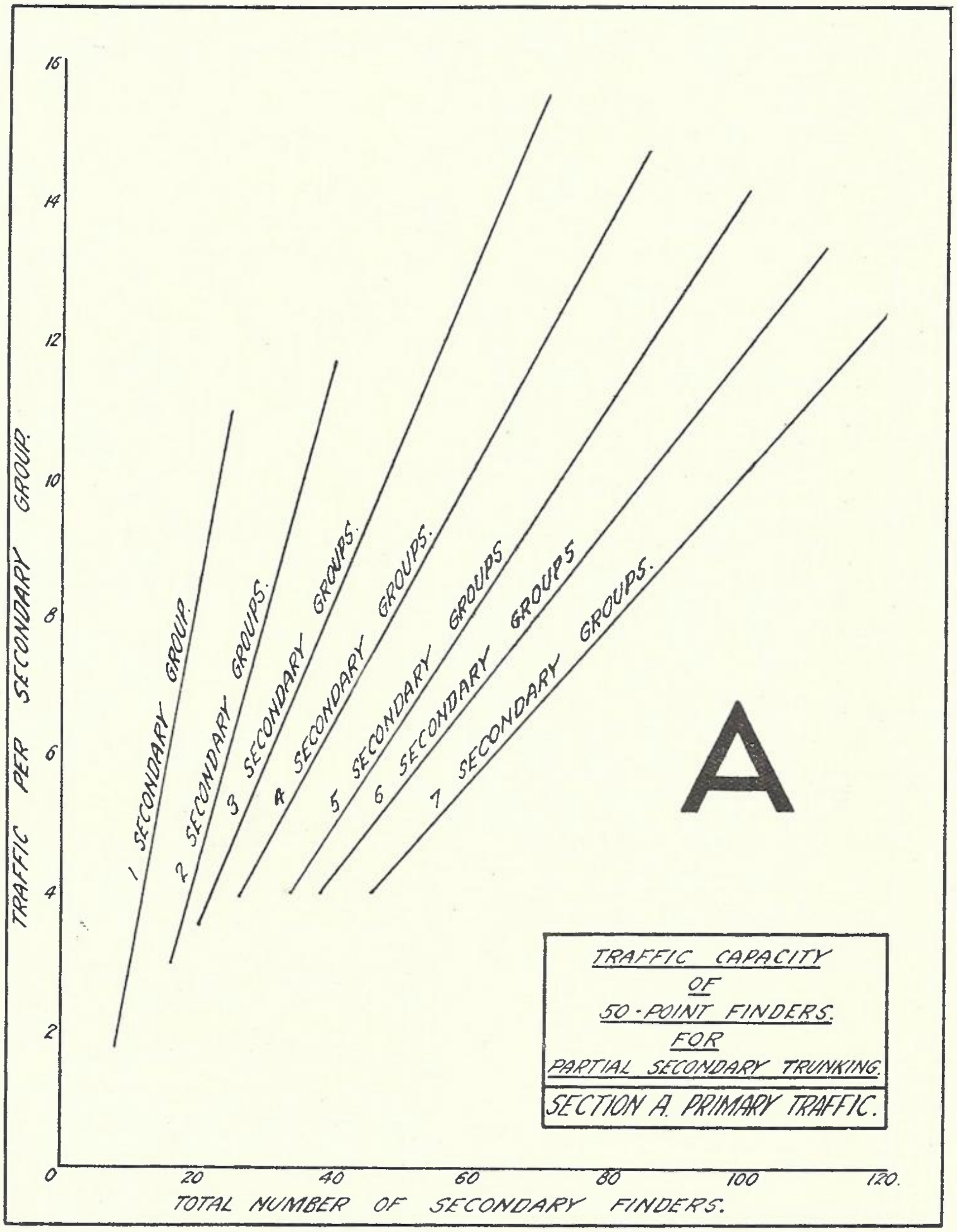
The following details relative to the equipment arrangements are given as a matter of interest and are complete only in so far as they are of assistance from a trunking standpoint. The equipment racks are in two heights, 10 ft. 6½ ins. and 8 ft. 6½ ins.; the widths are 3 ft. 6 ins. for the L and K relays, and 4 ft. 6 ins. for primary and secondary finders. The rack capacities are:—

(a) **L and K Relays:** Sets for 900 and 700 lines respectively for each of the rack heights stated.

(b) **Primary Line Finders:**

Finders per 200-line group	Number of finders per rack	
	10 ft. 6½ ins. (Standard height for racks)	8 ft. 6½ ins. (Used where ceiling height is low)
15	.... 60	.... 45 ....
20	.... 60	50 + 50: racks in suites of 2.
25	70 + 60 + 70: racks in suites of 3	.... 50 ....
30	.... 60	50 + 50 + 50: racks in suites of 3
35	.... 70	50 + 45 + 45: racks in suites of 3

The nominal capacities for single racks may, therefore, be taken as 60 and 50 respectively. Up to 50 finders per 200-line group can be accommodated. When the rack capacity is not a multiple of the number of finders per 200-line group, one group of finders at least must be spread over two racks. Space must be available on the racks for the start and control circuits, and this is another factor affecting the capacity. Under average conditions 25 finders per 200-line group will frequently occur, and as will be seen from the above statement, this is met by arranging the finders in eight groups—total 200 finders —distributed over three racks, the first, second, and third racks accommodating 70, 60, and 70 finders respectively. Some of the control gear for racks 1 and 3 is mounted on rack 2, with the result that the last-mentioned rack can accommodate only 60 finders. The banks are in basic sets of five and ten from which any size group can be built up.



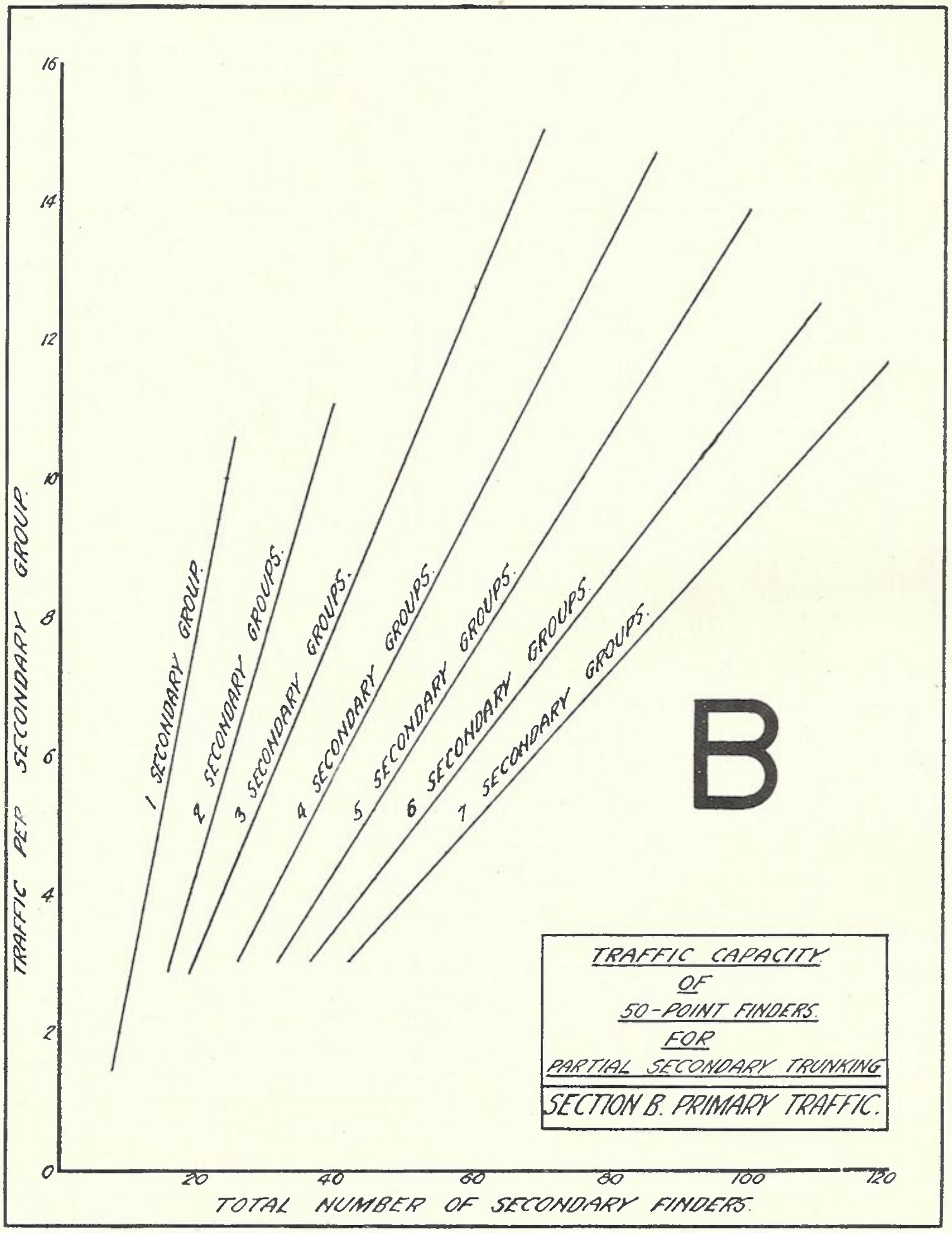
(c) **Secondary Finders:**

Secondary line finders per 200-line group	Number of finders per rack	
	10 ft. 6½ ins.	**8 ft. 6½ ins.**
15	105 in 7 groups	75 in 5 groups
20	100 in 5 groups	80 in 4 groups
25	100 in 4 groups	75 in 3 groups

The banks are in sets of 15, 20 and 25.

(d) **I.D.F.:** In all 2000-type exchanges a central I.D.F. will be provided. Jumpering fields will be available to provide full flexibility. The general arrangements will be seen by reference to Figures 15 and 16 on pages 126 and 127.

(e) Other equipment details of interest are



contained in the companion article in this issue.

When a new exchange is cut-over, (a) complete reserve equipment must be available to meet the normal development over some predetermined period; and (b) partial reserve equipment over and above this must be available in situ as a safeguard against any unforeseen increase in the development or the traffic and so that major extensions can be designed and installed to merge in with the existing installation without risk of a hold-up in service. The practice in the Commonwealth is to install banks, shelves, racks and cabling for the 5-year requirements: whilst switches are provided to meet the 2-year requirements; thus between the 2- and 5-year dates development can be met by the addition of switches. It should be remarked that the building and certain other matters are based on the 20-year data, but these are not apposite to the present discussion. For the determination of primary and secondary finders and the associated first selectors (or equivalent switches) the only data of immediate concern are, therefore, the number of subscribers' lines and the busy hour originated traffic at periods of two and five years from the date of cut-over. In the following examples, the 2- and 5-year figures will be separated by a bar, thus 10/15 indicates 10 and 15 respectively at each date.

Example 1. An exchange in which the estimated development is 4000/6000 lines and the busy hour traffic per 200-line group is 8A/9A.

(a) Number of 200-line groups: (lines/200)	= 20/30	
(b) Primary finders/200 lines (refer to table) —direct	= 8/9	= 19/20 in Section A.
—auxiliary	= 11/11	
(c) Total primary finders— direct (20x8)/(30x9)	= 160/270	= 380/600
—auxiliary (20x11)/(30x11)	= 220/330	
(d) Secondary groups (5 year auxiliary finders/50)	= 7/7 (330/50)	
(e) Total secondary traffic (secondary traffic per 200-line group x number of primary groups. From the table the secondary traffic per group is 1.890A/2.020A. Multiply this traffic by 20/30)	= 37.8A/60.6A	
(f) Traffic per secondary group	= 5.4A/8.7A.	
(g) Secondary finders (refer to A set of curves and take 5.4A/8.7A for 7 groups)	=58/87 say 63/91 (see comments)	
(h) Secondary finders/group	= 9/13	
(i) Banks/primary group (to provide 20 banks would allow no spares if the traffic were to increase. Therefore to be on the safe side the provision should be 25)	= 25/25	
(j) Banks/secondary group	= 15/15	
(k) First selectors (160 + 63)/(270 + 91)	= 223/361 on 380 banks.	

The next point is to examine the foregoing quantities from the standpoints of adding additional switches from time to time and the factor of safety they give. In each 200-line group a maximum of 25 primary finders can be provided and this number will meet an increase in the calling rate of approximately 40 per cent., which over the period considered is not very likely. The maximum number of secondary finders which can be accommodated is 15 per group, or 105 for the seven groups, and each group can serve 50 auxiliary primary finders, or a total of 350 for the seven groups, giving 350/30, or just on 12 auxiliary finders per 200-line group, 12 auxiliary finders in association with 10 direct finders per 200-line group will handle 10.55A and therefore by the addition of primary and secondary finders an increase of approximately 30 per cent. in the calling rate can be met, without increasing the number of secondary groups whilst space is still available for a further three direct finders per 200-line group.

The 6000 lines would form a division.

For the 2-year figures, five secondary groups would suffice, this giving a capacity of 5 x 50, or 250 auxiliary finders, but as 220 auxiliary finders are required at the 2-year date the spare contacts would be 250-220 or 30, and as there are 11 auxiliary finders per primary group it would be necessary to add another secondary group involving, inter alia, considerable re-jumpering on the I.D.F. when the exchange had grown to 4200 lines, which at the outside would be about four months after the 2-year date. Therefore points like this must be avoided and the 5-year framework established to the greatest extent possible. For this reason seven secondary groups should be established initially, and as this will give a division much of the initial jumpering would not need to be disturbed, as the exchange grew.

As the auxiliary finders must be distributed as evenly as possible over the secondary groups, it is necessary that each secondary group accommodate an equal number of secondary finders: therefore since the curves give 58 and 87 total secondary finders, which is incommensurable with seven (the number of secondary groups), it is necessary to take the nearest multiple of the number of groups above the figure given by the curves, namely, 63 and 91.

Example 2. An exchange of 7000/10,000 lines with busy hour traffic per 200-line group of 10A/11A. This is a case where more than one division is required and to keep the divisions symmetrical two will be taken. (Note: To find the most convenient number of divisions may be a matter of working out several arrangements and taking the most suitable.) Thus division 1 will take 5000 lines and should not require any extensive alterations after being established; division 2 will commence with 2000 lines with provision for extension to 5000 lines. Practically all development will be met by extending division 2. Dealing first with division 1, which as stated will form a closed group, the position is:

(a) Number of 200-line groups	= 25/25	
(b) Primary finders/200-lines— —direct	= 9/10	= 21/23 in Sections B/A respectively.
—auxiliary	= 12/13	
(c) Total primary finders— —direct	= 225/250	= 525/575 for 25 groups.
—auxiliary	= 300/325	
(d) Secondary groups=325/50	= 7/7	
(e) Total secondary traffic (2.730A/2.850A/200-line group)	= 68.25A/71.25A.	
(f) Traffic per secondary group	= 9.75A/10.18A.	
(g) Secondary finders (from curves for 7 groups)	= 96/100 say 98/105	
(h) Secondary finders/group	= 14/15	
(i) Banks/primary group	= 25	
(j) Banks/secondary group	= 15	
(k) Total first selectors (225 + 98)	= 323 on 360 banks.	

For division 2, the 5-year quantities will be the same as for division 1, so that it is a matter of ascertaining the switches for 2000 lines, and therefore:—

(a) Number of 200-line groups	= 10	
(b) Primary finders/200 lines	= 9 as for (b) above.	
(c) Total primary finders—		
—direct	= 90	= 210
—auxiliary	= 120	
(d) Secondary groups	as for (d) above.	
(e) Total secondary traffic	= 2.73A.	
(f) Traffic/secondary group	= 3.9A.	
(g) Secondary finders	= 50 (curve B for 7 groups), say 56.	
(h) Secondary finders/group	= 8	
(k) Total first selectors (90 + 56)	= 146	

In this example the 5-year quantities are a tighter fit than in the first example, but nevertheless two additional direct finders can be accommodated in each primary group, and after making due allowance for unavailable spares due to disconnections, etc., which will be somewhere between 1 per cent. and 3 per cent. at least, and probably more if P.B.X. groups are present, the factor of safety is reasonable in view of the cost of being still safer.

Example 3. For the final example, assume an exchange of 8000/12,000 lines with a busy hour traffic per 200-line group of 12A/14A. Two divisions of 6000 lines each would be too heavy and therefore it will be necessary to provide for three divisions each of 4000 lines, but it would be foolish to leave the third division without switches and therefore as a compromise each division could accommodate roughly 2700 lines or division 1 could be filled and the remaining 4000 lines distributed over divisions 2 and 3 initially. It will be better to fill division 2 rather more fully than division 3 and, therefore, without further detailed examination it will be assumed that divisions 2 and 3 will take 3000 and 1000 lines respectively. Dealing first with division 1, the position will be:—

(a) Number of 200-line groups	= 20/20 for 4000 lines.	
(b) Primary finders/200-lines—		
—direct	= 11/12	= 24/27 in Sections B/A
—auxiliary	= 13/15	
(c) Total primary finders—		
—direct	= 220/240	= 480/540
—auxiliary	= 260/300	
(d) Secondary groups = 300/50	= 6/6	
(e) Total secondary traffic (2.970A/3.840A per primary group)	= 59.4A/76.8A.	
(f) Traffic/secondary group	= 9.9A/12.8A.	
(g) Secondary finders	= 90/107 (curves B/A for 6 groups).	
(h) Secondary finders/group	= 15/18 giving 90/108.	
(i) Banks/primary group	= 30/30	
(j) Banks/secondary group	= 20/20	
(k) Total first selectors (220 + 90)	= 310 on 360 banks.	

The above figures provide ample safety and somewhat the same remarks apply as for example 1. In divisions 2 and 3 the bank, shelf and rack capacities will be the same as for division 1, so it is only necessary to ascertain the switches required for 3000 and 1000 lines. Dealing next with division 2, the figures are:—

(a) Number of 200-line groups	= 15 for 3000 lines.	
(b) Primary finders/200 lines	= 11 as for (b) above.	
(c) Total primary finders—		
—direct	= 165	= 360 Section B.
—auxiliary	= 195	
(d) Secondary groups	= 6 as for (d) above.	
(e) Total secondary traffic	= 44.55A.	
(f) Traffic/secondary group	= 7.43A.	
(g) Secondary finders	= 72	
(h) Secondary finders/group	= 12	
(k) Total first selectors (165 + 72)	= 237	

Whilst for division 3, which takes 1000 lines, the figures are:—

(a) Number of 200-line groups	= 5 for 1000 lines.	
(b) Primary finders/200 lines	= 11 as for (b) above.	
(c) Total primary finders—		
—direct	= 55	= 120 (Section B)
—auxiliary	= 65	
(d) Secondary groups	= 6 as for (d) above.	
(e) Total secondary traffic	= 14.85A.	
(f) Traffic/secondary group	= 2.48A.	
(g) Secondary finders	= 33, say, 36.	
(h) Secondary finders/group	= 6	
(k) Total first selectors (55 + 36)	= 91	

The three foregoing examples demonstrate that a fair amount of discretion is called for since no two exchanges are alike. Other things being equal, preference should be given to the scheme which enables the growth of the exchange to be most easily dealt with. It must be remembered that installation charges are high and, therefore, the 5-year framework should be as rigid as possible.

The table and the curves are easy to use and the calculations are simple and straightforward.

Concluding Remarks. It is now desired to comment on a particular phase which, by intention, has not been referred to earlier. The tables, on which 2000-type finder quantities are at present based, have been compiled on the basis of giving a grade of service of 0.002 (1 in 500) up to and including the first selectors. The main basis of the tables is a loss function, and this is the feature which calls for comment.

It is not generally appreciated that in any telephone system the different trunk groups do not all work under identical conditions. These differences may be slight or they may be fundamental, but wherever trunk groups function differently from each other the effects on the service will vary, and in groups of the same size the traffic capacities will not be equal. The effects on the service can be covered by the generalised statement that calls which do not succeed when originated are either "delayed" or "lost."

In calculating the traffic capacity of step-by-step (Strowger) systems it has been generally assumed up to the present that calls are lost if a free outlet is not immediately available, but this assumption is wrong and delays as well as loss can occur in these systems.

Whether delay or loss can occur depends on the trunking arrangements of a group. Delay or loss can occur only when all trunks accessible to a call are simultaneously busy. If calls which arrive during periods of congestion can obtain service by waiting until a trunk becomes available, then delay is experienced; but if service cannot be obtained by waiting the calls are lost and must be repeated when free trunks are available.

Between the subscribers' lines and the first selectors calls cannot be lost in the sense as defined, because if a finder is not available when a subscriber removes the receiver to make a call, he is at liberty to stand by until one does become available: consequently a loss formula should not be applied here.

By using a loss formula for finders the service is better than intended because delays are ignored; and it follows that if the service is better than intended then too much switching equipment has been installed.

In any system delays are inevitable at some point or other, and they should be dealt with by means of delay formulæ.

For step-by-step systems this matter has been investigated by the writer and the results accompanied by curves will be published in a later issue.

TRANSMISSION PRACTICE

PART 1 TRANSMISSION MEASUREMENTS AND CROSSTALK.

S. Jones

Measurement of Line Impedance at Audio Frequencies.

When measuring the impedance of an open-wire trunk line for the purpose, for instance, of designing a voice frequency repeater balance-network, the theoretically correct method is to measure and calculate the characteristic impedance of the line at each of the frequencies stated below, and to terminate the line in its characteristic impedance for each subsequent measurement. In practice, however, it has been found that sufficiently accurate results are obtained by making measurements with the distant end of the line terminated in a 600 ohm

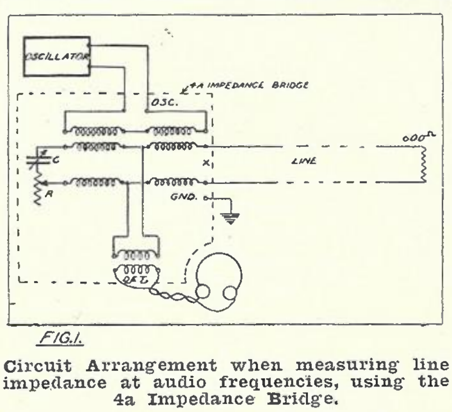


FIG.I.

Circuit Arrangement when measuring line impedance at audio frequencies, using the 4a Impedance Bridge.

non-inductive resistance. The distant end of the line is therefore terminated in 600 ohms, the 4A bridge is connected as shown in Figure 1 and the oscillator is adjusted to the frequency at which the measurement is required to be made. (Impedance v. frequency measurements are made on voice frequency circuits commencing at 200 cycles and proceeding in steps of 100 to 2,800 cycles.) A pair of headphones is connected across the terminals of the 4A bridge designated "DET." The resistance dials and capacity dials are then adjusted until no tone is heard in the headphones, the absence of tone indicating that the bridge is balanced, i.e., indi-

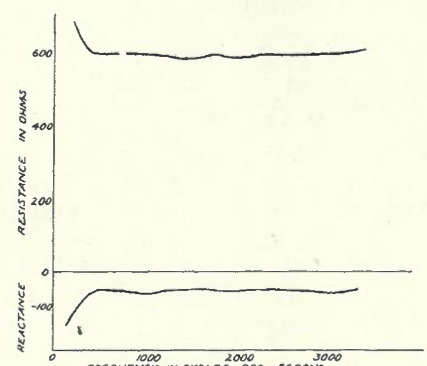


Fig. 2.—Typical Resistance and Reactance versus Frequency Curve of a Telephone Line.

cating that the resistance and capacity in the variable arms of the bridge are equal respectively to the resistance and capacity of the line under measurement. If the line which is being measured is inductive the capacity C in the 4A bridge is connected in series with the line by throwing a key associated with the bridge. The measurements are then continued in steps of 100 to 2,800 cycles. For each measuring frequency the resistance in ohms and the reactance in ohms are recorded in a data book, and at the completion of the run the values are plotted on a graph. The points plotted on the graph are then joined by means of curves which form the basis of the design of the balance-network.

(The reactance in ohms $= - \dfrac{1}{6.28\ f\ C}$

where f = frequency in cycles per second,
and C = capacity in **Farads.**)

A typical impedance v. frequency characteristic of a telephone trunk-line is shown in Figure 2.

Measurement of Line Impedance at Carrier Frequencies.

The measurement of the impedance of a line at carrier frequencies requires certain precautions that are not necessary at audio frequencies. A 10A or 8A oscillator, a 4A impedance bridge, 1A detector amplifier, a variable attenuator, and two 600/600 ohm accurately matched carrier transformers are required. The variable attenuator is for the purpose of varying the current output from the oscillator. One carrier transformer is for insertion between the line and the hybrid coils of the bridge, while the other transformer is for insertion between the hybrid coils and the variable resistance and capacity of the bridge. The inner terminal R is bridged to the inner terminal "C," and the outer terminal "R" and outer terminal "C" are connected through one of the carrier transformers to the terminals "B" of the bridge. The equipment is then arranged as shown schematically in Figure 3.

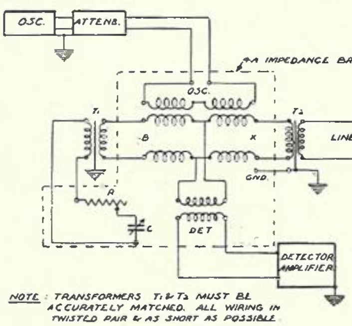


Fig. 3.—Circuit Arrangements for measuring Line Impedance at Carrier Frequencies with 4a Impedance Bridge.

All connections should be made in twisted pair wire, but shielded wire should not be used because this type of wire usually possesses unbalanced capacities to ground. The shields of all the items of equipment in use should be earthed and the wiring kept as short as is possible.

When making an impedance v. frequency measurement over trunk lines at carrier frequencies, it is necessary to have the line terminated in its characteristic impedance, and this value is determined by making impedance measurements at 3 kilocycles, 8 kilocycles, 16 kilocycles, and 30 kilocycles, first with the distant end of the line open-circuited, and then with the distant end short-circuited. The mean value of the four readings taken with the line open-circuited is then regarded as the open-circuit impedance, i.e., Z_{oc}, and the mean of the four readings taken with the line short-circuited is regarded as the short-circuit impedance, i.e., Z_{sc}.

These measurements are made by balancing the bridge as described for audio-frequency measurements.

$$Z_{oc} = \sqrt{R^2_{oc} + \left(\frac{1}{-2\pi f C_{oc}}\right)^2}$$ when the line is open-circuit;

$$Z_{sc} = \sqrt{R^2_{sc} + \left(\frac{1}{-2\pi f C_{sc}}\right)^2}$$ when the line is short-circuited;

where R_{oc} and R_{sc} = resistance indicated in the bridge rheostat at balance with the line open circuited and short circuited respectively.

f = measuring frequency in cycles per second.

C_{oc} and C_{sc} = capacity in farads in the bridge at balance with the line open circuited and short circuited respectively.

The characteristic impedance of the line is then the square root of the product of the open-circuit impedance and closed-circuit impedance, i.e., $Z_o = \sqrt{Z_{oc}\ Z_{sc}}$.

With the distant end of the line then terminated in a non-inductive resistance equal to Z_o ohms, the impedance measurements are carried out, commencing at 3 kilocycles and proceeding in steps of .5 kilocycle to 30 kilocycles, the oscillator of course being adjusted for each individual measuring frequency, and also the detector amplifier being accurately tuned to each measuring frequency. The resistance and reactance in ohms are then recorded in a data book. On completion of the run the values are plotted on a graph and the points are joined up by means of curves, the curves indicating the variation of the resistance and reactance with frequency.

On a line which is entirely free from irregularities, the curve so plotted will be smooth and free from peaks, but on a line which has one or more intermediate irregularities such as intermediate lengths of cable, the curve drawn will exhibit peaks, and where a peak recurs at regular intervals, the distance between the testing station and the irregularity which causes the peak can be determined from the formula:—

$$d = \frac{186000}{2S}$$

where d = the distance from the testing station to the irregularity in miles,

186000 = the velocity of an electromagnetic wave in miles per second, and

S = the separation between two adjacent recurring peaks in cycles per second.

This method of locating the position of the irregularities is not an accurate one, but it is useful in determining whether there are irregularities in the line not due to the normal composition of it.

Thermocouple Method of Measuring Attenuation.

When it is required to measure the attenuation of a line of 600 ohms characteristic impedance between Stations "A" and "B" at neither of which a transmission measuring set is available, or where the measurement is required to be made at carrier-frequencies, thermocouples, meters, isolating transformers and variable attenuators may be used to take the place of the transmission measuring set. When measuring in the direction "A" to "B," the equipment required at "A" is an oscillator having a possible output into 600 ohms of approximately 40 milliamps, a variable balanced attenuator of 600 ohms impedance having a range of at least 0 to 20 decibels, a 600 ohm non-inductive resistance variable in steps of 1 ohm, a low impedance thermocouple (N type), a Rawson multimeter

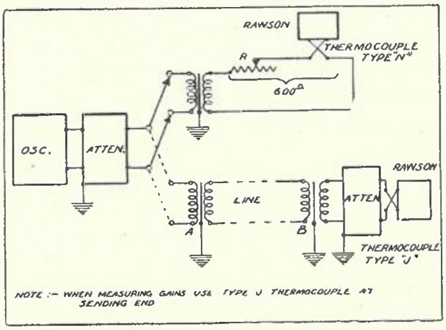


Fig. 4.—Measurement of Transmission Equivalents—Thermocouple Method.

which has previously been calibrated with the thermocouple in use so that the Rawson meter will indicate to fractions of a milliamp, the amount of current passing through the heater of the thermocouple, two 600/600 ohm matched transformers, and a double pole changeover switch. At station "B," the equipment required is a variable balanced attenuator of 600 ohms impedance having a range of at least 0 to approximately 20 decibels, a 600/600 ohm transformer, and a 600 ohm thermocouple (J type) and Rawson multimeter which have also been calibrated together so that the Rawson meter will indicate in fractions of a milliamp the amount of current which is passing through the heater of the thermocouple.

The equipment is arranged as shown in Figure 4.

The attenuator at Station "A" provides a means of adjusting the amount of current which is sent into the line. The attenuator at "B" is for the purpose of protecting the heater of the thermocouple from excess current in the event of the line under measurement having a high overall gain. The transformers are for the purpose of minimising the effect of longitudinal currents.

In making the measurement the oscillator is adjusted to the frequency at which the measurement is to be made. The changeover switch is thrown to the position where the output of the oscillator through the sending attenuator is connected through the transformer to the rheostat "R" and thermocouple in series, the rheostat "R" being adjusted to a value such that the sum of its resistance and that of the thermocouple is 600 ohms. (The resistance of a type N thermocouple is 46.5 ohms.) The attenuator at Station "B" is adjusted to include its full loss. The attenuator at Station "A" is then adjusted until the Rawson meter indicates that a suitable value of sending current, say, 8 milliamps, is flowing through the heater of the thermocouple, i.e., the output from the sending attenuator into the 600 ohm network is 8 milliamps. The changeover switch is then operated to the position where this current is fed into the sending end of the line, and the attenuator at Station "B" is then gradually reduced to zero loss, or until the Rawson meter at "B" indicates that a current less than 5 milliamps is flowing in the heater of the thermocouple, this value being the maximum current which the heater of the type J thermocouple can safely carry. If, however, the line has an attenuation greater than about 2 db it will be possible to reduce the receiving attenuator to zero without causing 5 milliamps to flow through the thermocouple heater. When the receiving attenuator has been adjusted, the current which is flowing through the heater of the type J thermocouple is determined by the reading on the Rawson meter, and the attenuation of the line is then calculated from the formula:

$$X + N = 20 \log \frac{I_1}{I_2}$$

where N = the attenuation in decibels,
I_1 = the value of current fed into the sending end of the line.
I_2 = the value of current received at Station "B."
X = setting of the receiving attenuator.

The value of 8 milliamps quoted as the amount of sending current is arbitrary so far as the method is concerned, but when using a type N thermocouple or when V.F. repeaters are in the line, the value should not greatly exceed this figure. The best method of determining the amount of current to send into the line is to estimate the approximate attenuation of the line by taking into account its length and class of conductor, and then sending such a value that a current of approximately 1 milliamp will be received at the distant end. When measuring a line with a very high value of attenuation it will be necessary, in order to obtain a useful reading at the receiving end, to send much more than 8 milliamps into the sending end. In such a case a type "C" (5 ohm) thermocouple would be used at the sending end. This type will pass up to 75 milliamps without damage, but it is advisable not to exceed 50 milliamps.

Thermocouple Method of Measuring Overall Gain.

For measuring gains between stations where no transmission measuring sets are available the same equipment is required as for the measurement of attenuation by the thermocouple method, with the exception that the rheostat and type "N" thermocouple at the sending end are replaced by a type "J" (600 ohm) thermocouple. The sending current into the 600 ohm thermocouple is adjusted by means of the variable attenuator at the sending end to a value of 2 milliamps into the 600 ohm network. With the full attenuation of the variable attenuator at the receiving station inserted in the line the changeover switch at the sending station is thrown to the position where this current of 2 milliamps is sent into the line, and the attenuator at the receiving station is then gradually reduced until the Rawson meter at that station indicates that a current of 2 milliamps is flowing through the heater of the type J thermocouple. When this point is reached the overall gain of the line is then equal to the amount of attenuation left in the variable attenuator. (The reason for using a type J thermocouple at the sending end in this case is that it is the only type which will give a useful reading at 2 milliamps.)

Care should be exercised when making these measurements to ensure that voice frequency repeaters in the line are not overloaded.

ATTENUATION MEASUREMENTS AT CARRIER FREQUENCIES.

For measuring the attenuation of lines at carrier frequencies the method outlined for audio-frequencies in general meets requirements. In measuring long sections of lines, however, where the attenuation at carrier frequencies reaches the order of 40 db or higher, longitudinal currents and induced currents frequently render the results obtained from this method inaccurate. In these cases, the thermocouple at the receiving end of the line should be replaced with a 1A detector amplifier and the variable attenuator should be capable of inserting a loss of at least 50 db. The object of using this detector-amplifier is that the current to be measured can be fed through its tuned circuit, thus eliminating the effect of all currents which are not of the same frequency as the measuring current.

The detector-amplifier is first calibrated so that its meter reads centre scale when a current of approximately 50 db below 10 milliamps is being fed into it. This calibration is effected by adjusting the output of a local oscillator to the required testing frequency and to an output current of 10 milliamps into 600 ohms. The 10 milliamps is then fed through a 50 decibel variable 600 ohm attenuator, a 600/600 ohm transformer to the detector-amplifier and the potentiometer of the detector amplifier is then turned to the stop at which the meter reads approximately centre scale, the tuned circuit first having been adjusted to the measuring frequency.

The receiving circuit consisting of the 50 decibel attenuator, 600/600 ohm transformer, and tuned detector-amplifier are then connected to the receiving end of the line, and at the sending end the sending circuit consisting of the oscillator tuned to the testing frequency, the attenuator and 600 ohm current measuring network, is connected as shown in Figure 4. The changeover switch at the sending end is then operated to connect the output from the oscillator through the attenuator into the 600 ohm current measuring network, and the output is adjusted to 10 milliamps. The changeover switch is then thrown so that this 10 milliamps is fed into the line, and at the receiving end the 50 decibel attenuator is varied until the detector-amplifier meter gives the same reading as it did during calibration. Now if the receiving attenuator had to be adjusted to zero loss in order to obtain this reading, it would be an indication that the line had an attenuation of 50 db at the testing frequency. Alternatively, if the attenuator at the receiving end had to be adjusted to 50 db in order to obtain the correct meter reading, it would be an indication that the line had zero loss. Consequently the attenuation of the line is the difference between 50 and the amount of loss which it is necessary to insert in the attenuator in order to cause the meter to give the same reading as it did during calibration.

In making attenuation v. frequency measurements at carrier frequencies by this method, it is essential that the detector amplifier be recalibrated and re-tuned for each separate testing frequency used, and also it must be calibrated to the same current as that which is sent into the line at the sending end.

CROSSTALK IN TELEPHONE CIRCUITS.

The term "crosstalk" is used generally to refer to inductive interference between telephone circuits, even though the interference may not actually be in the form of intelligible speech. Between voice frequency (physical) telephone lines, crosstalk is always intelligible if of sufficient level, but between carrier telephone circuits the crosstalk which results depends for its intelligibility upon the frequency of the interfering currents and the frequency of the demodulator oscillator at the receiving end of the disturbed circuit. This will be explained later.

In dealing with the magnitude of crosstalk between the two circuits, a unit of crosstalk has been defined. There is one unit of crosstalk between two circuits, at a given frequency, when the coupling is such that when a given current flows in one circuit a current equal to one millionth of the given current is induced into the other circuit; i.e., the number of crosstalk units equals

$$\frac{I_2 \times 10^6}{I_1}$$

when I_1 is the current in the disturbing circuit and I_2 is the current induced in the disturbed circuit. This assumes also that the two circuits are of the same characteristic impedance.

Crosstalk between circuits to the extent of 1000 units is not uncommon and does not cause serious interference at ordinary transmission levels.

The number of crosstalk units is another form of expression of the power transferred from one circuit to the other, and it has become more usual to express the crosstalk conditions in decibels. For instance, 1000 units represents a crosstalk value of 60 decibels, and for voice frequency telephone circuits this value is approximately the maximum which should be permitted. Crosstalk at a value of 40 decibels at ordinary levels would be readily audible and intelligible between voice frequency circuits.

Carrier Crosstalk.

The frequency range employed by the carrier telephone systems used throughout the Commonwealth lies between 3000 cycles and 45,000 cycles per second. In this range of frequencies the carrier systems are practically free from noise induced by such disturbing circuits as physical telegraph lines or adjacent power circuits, but the induction between the carrier circuits varies generally in proportion to the frequency. The conditions to be overcome, therefore, in the provision of crosstalk between carrier channels of systems on the same route are much more severe, particularly as the majority of the systems use transmitting and high gain receiving amplifiers.

The operation of multi-carrier systems requires double the usual vertical spacings between circuits on the poles, and their development has now caused an alteration in the horizontal spacings of wires on the Department's aerial trunkline routes. Instead of the spacing of 14 ins. between all wires on each side of the pole and between cross arms, which was the Commonwealth standard for many years, a new arrangement of wires involving a 9 ins. spacing between the wires of a pair with 18 ins. between pairs has been adopted. This has resulted in a substantial reduction of the coupling between pairs of wires on the same arm and between pairs on different arms.

The following features in the working of carrier systems on the same pole route have been adopted to lessen the difficulties of the crosstalk problem:—

(a) Arrangements whereby the same frequencies are only transmitted in the one direction;

(b) The equalising of transmitting levels between paralleling systems;

(c) The use of "staggered" frequency allocations for systems in the closest proximity on the pole route;

(d) The careful design of terminal impedances and attention to the line conditions to avoid reflection effects.

Frequency Direction.

In carrier systems the sending and receiving circuits are divided, the "sent" transmission being carried on one group, and the "received" on another group, and the same frequency groups are transmitted in the same direction. An examination of the frequency allocations of any standard three-channel carrier telephone system, for instance, will disclose the method of allotting the frequencies.

If there are two parallel telephone circuits employing the same frequency range, and if there is a certain amount of crosstalk between the circuits, then a transmission from system 1 leaving the sending apparatus at a high level will enter directly the sensitive receiving circuit of system 2. The crosstalk resulting is called "near-end" crosstalk. With carrier systems there are transmitting and receiving amplifiers which would considerably increase the crosstalk effect.

Assuming, however, that two carrier telephone circuits were involved using the same frequency in the same direction only, then the receiving apparatus of the second system at Terminal A is not designed to accept the sending range of frequencies, and a situation involving only "far-end" crosstalk occurs. In this case the persons transmitting and receiving are at opposite ends of the lines and, although any crosstalk will be lifted by the receiving amplifiers at Terminal B, whatever this value of crosstalk may be it has previously suffered the heavy attenuation of the line, and should appear at Terminal B at a very much lower level. There is thus a substantial advantage to be gained in lower crosstalk values in arranging separate groups of frequencies for the sending and receiving channels of a system, and in keeping the direction of transmission of the frequency groups in other parallel systems the same.

In the Commonwealth the carrier telephone systems are installed so that the low frequency directional groups of channels transmit in the direction south to north, or west to east, while the high frequency groups transmit in the reverse direction in order to achieve uniformity and better crosstalk conditions.

Level Equalisation.

Efforts are made when lining up parallel carrier systems on a pole route so that, as nearly as possible, the same transmission levels are obtained at all points on all systems. This reduces the tendency for a system working at a high level to crosstalk into another system which may be at a relatively low level. The trouble that can arise from this cause has been exemplified on several occasions by crosstalk occurring between systems that has been traced to being picked up in the loops to repeater stations when the outgoing high level transmission from a repeater crosstalks into another similar system incoming at a low level to its repeater or terminal, and then being raised in level by the amplifiers and finally appearing as a heavy interference at the terminal.

Staggering of Frequency Bands.

Greatly reduced levels of crosstalk are obtained by the staggering of the frequency allocation of three-channel systems. An examination of the frequency allocations of any two different types of three-channel systems—for instance, CN3 and CS3 (see Table 1)—will indicate how the carrier frequencies of the channels of one system are staggered with respect to those of the other system. It will be seen that the groups of frequencies of one system are located as nearly as possible between the groups of frequencies of the other system, the most sensitive portion of the band, i.e., that frequency which when demodulated will produce a product of demodulation of about 1000 cycles, always falling outside the band of the other system.

The interference between similar carrier telephone systems, although taking place at carrier frequencies, is demodulated at the carrier terminal designed to accept the particular frequencies, and in this case it appears as intelligible crosstalk. Between dissimilar systems the transmitted bands only partially overlap, and the carrier frequencies are different. Therefore the crosstalk induced into one system, after demodulation, is of an entirely different range of frequencies than those which were originally impressed upon the telephone transmitter. The crosstalk in this case is unintelligible. The advantage gained by this staggering of frequencies represents approximately an increase of 10 decibels of crosstalk at the lower frequencies to 15 decibels at the higher frequencies.

In locating the several parallel systems on a route, endeavour is made to keep the similar systems as far apart as possible. Thus two CN3 systems would never be placed alongside one another, or on the side circuits of a phantom group, or in positions immediately above one another. Always advantage is taken of the lower crosstalk levels made possible by placing a CS3 system between two CN3 systems, or vice versa.

Impedance Considerations.

Every effort is made in the layout of carrier lines to avoid abrupt impedance changes in the circuit and to avoid reflection effects. As previously stated, it is only "far-end" crosstalk that should be picked up in carrier telephone systems.

If the line circuit is irregular, however, due to intermediate sections of cable in crossing rivers or entering intermediate offices, reflection may take place at these points resulting in the "near-end" crosstalk (which it is normally not possible to pick up for the reasons stated earlier) being reflected and appearing as "far-end" crosstalk, and thus adding to the true "far-end" crosstalk. Wherever possible, therefore, the carrier line between terminal points is kept smooth and free from irregularities, and aerial wires are retained at least for the carriers, over intermediate cable sections and continued aerial as close as possible to the terminal stations. An additional reason for this is, of course, the much heavier attenuation suffered by the carrier frequency current through cable circuits. The apparatus terminal impedances are also carefully designed so that they are as close as possible equal to the impedance of the lines over which the systems operate.

		Type CN3		Type CS3	
Channel	Direction	Side Band Transmitted	Carrier Frequency	Side Band Transmitted	Carrier Frequency
1	A-B	Lower	7.7 k.c.	Upper	6.2 k.c.
2	A-B	Lower	10.7 k.c.	Upper	9.4 k.c.
3	A-B	Lower	14.0 k.c.	Upper	12.7 k.c.
1	B-A	Upper	16.1 k.c.	Lower	20.8 k.c.
2	B-A	Upper	19.5 k.c.	Lower	24.5 k.c.
3	B-A	Upper	23.5 k.c.	Lower	28.3 k.c.

Table 1.—Frequency Allocations CN3 & CS3 Carrier Systems.

THE MEASUREMENT OF CROSSTALK.

Crosstalk measurements are made on trunk lines using a 10A or 8A oscillator and a 74015A crosstalk measuring set. At audio frequencies a pair of headphones serves as a detector, but at carrier frequencies a 1A detector amplifier is necessary. With the exception of the source of testing current and the detector the crosstalk set contains all the apparatus necessary for making crosstalk measurements.

Measurement of "Near End" Crosstalk at Audio Frequencies.

In order to measure crosstalk at audio frequencies the disturbing line and the disturbed line are both terminated in 600 ohm resistances at their distant end and are connected to the crosstalk set as shown in Figure 5. The terminal marked "GND" is connected to earth, the output of the oscillator to the terminals marked "OSC." The disturbing circuit is connected to terminals 1 and 2 marked "LINE," and the disturbed circuit is connected to the "LINE" terminals Nos. 3 and 4. A pair of headphones is connected to the terminals designated "DET," and the output of the oscillator is then adjusted until a definite tone is heard in the headphones when the keys are in the "LINE" position, the frequency of the oscillator having first been adjusted to that at which the measurement is required to be made. The keys are then thrown alternately to positions "LINE" and "MET," adjusting the crosstalk meter until the magnitude of the tone in the headphones is the same for either position of the keys. The crosstalk meter is actually a variable attenuator with a scale calibrated in decibels, and the number of decibels indicated on the meter is the measure of "NEAR-END" crosstalk which exists between the two lines.

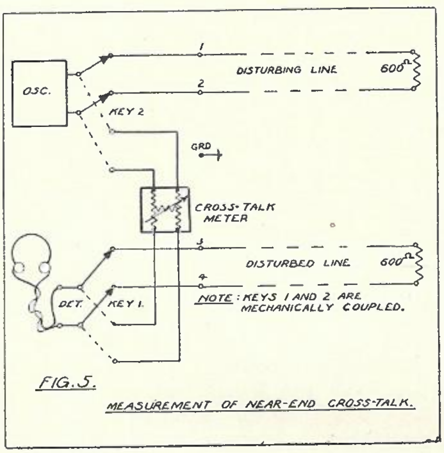


FIG. 5.
MEASUREMENT OF NEAR-END CROSS-TALK.

Measurement of "Far End" Crosstalk at Audio Frequencies.

In order to measure "far-end" crosstalk at audio frequencies, the disturbing line and the disturbed line are connected to the crosstalk set as shown in Figure 6. The terminal marked "GND" is connected to earth. The headphones are again connected across the terminals marked "DET," and in this case the oscillator is connected to the distant end of the disturbing line. Key 3 is thrown to the position marked with the impedance which is closest to that of the disturbing line under test, the characteristic impedance of the line having first been determined. For an aerial line at audio frequencies, however, the 600 ohm position is suitable. The distant end of the disturbed line is also terminated in its characteristic impedance which for an aerial line at audio frequencies is approximately 600 ohms. The output of the oscillator is then raised until a definite tone is heard in the headphones with Keys 1 and 2 in the "LINE" position. The keys are then operated alternately to the positions "LINE" and "MET" and the crosstalk meter is again adjusted until the tone heard in the headphones is the same for both positions of the keys. The number of decibels indicated on the meter scale then represents the amount of crosstalk in decibels which exists between the two lines when the disturbing current is being fed in at the distant end of the disturbing line.

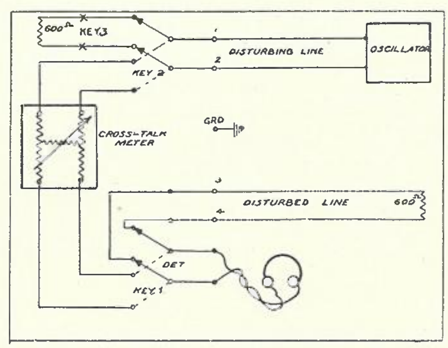


Fig. 6.—Measurement of "Far-End" Cross-Talk.

Determination of Crosstalk versus Frequency Characteristic.

In order to determine the crosstalk versus frequency characteristics of any two lines at audio frequencies, "near-end" and "far-end" crosstalk measurements are made as described over a range of frequencies beginning at 200 cycles per second, and proceeding in steps of 100 to 2800 cycles per second, first with one line as the disturbing circuit and the second line as the disturbed circuit. Each measurement is then repeated with the lines transposed, that is, the first line being the disturbed circuit and the second line the disturbing circuit. It will be found convenient to transpose the lines after each measurement so that only one series of oscillator adjustments is necessary. The results of the measurements are then recorded in a data book, and on completion of the run the results are plotted on a graph (Form TRM12) and the points are then joined by means of lines. The points plotted when the first line was the disturbed circuit are joined by a full line, and those points plotted when the second line was the disturbed circuit, are joined by a broken line. These graphs then represent the crosstalk versus frequency characteristics of the two lines concerned, one form being used for the two "near-end" characteristics, and another form for the two "far-end" characteristics. Form TRM12 is arranged so that the crosstalk in decibels can be read from one side of the graph while on the other side of the graph the ordinates can be read off in crosstalk units.

Measurement of Crosstalk at Carrier Frequencies.

For measuring "near-end" and "far-end" crosstalk at carrier frequencies, the procedure outlined for audio frequencies is followed, excepting that a pair of matched 600/600 ohm carrier transformers is required. One is inserted between the crosstalk set and the disturbed line, and the other between the crosstalk set and the disturbing line. These transformers are for the purpose of isolating the measuring equipment and minimising the effect of longitudinal currents. Also the pair of headphones is used in conjunction with a 1A detector amplifier because carrier frequencies above approximately 8000 cycles per second are not audible and the heterodyne facility of the detector amplifier is necessary. Whether for "near-end" measurements or for "far-end" measurements, the procedure is to adjust the oscillator and the tuned circuit of the detector amplifier at which the measurement is required to be made. The output of the testing oscillator is then raised until a definite beat note is heard in the headphones. Keys 1 and 2 are then thrown alternately to the positions "LINE" and "MET," and the measuring dial is tuned until the magnitude of the tone in the headphones is the same for both positions of the keys. The crosstalk in decibels between the two lines at the particular frequency is then read off the crosstalk meter.

In order to prepare a crosstalk versus frequency characteristic, crosstalk measurements, both "near end" and "far end," are made, commencing at 3 kilocycles and proceeding in steps

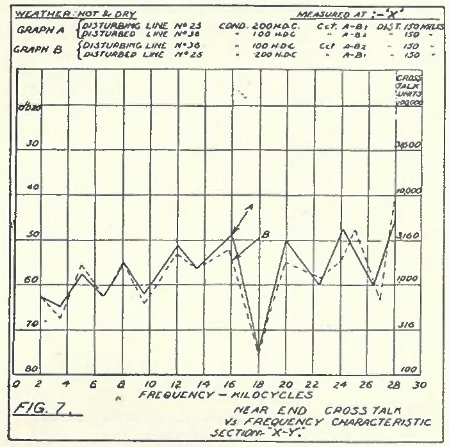


FIG. 7.

of .5 kilocycles until the maximum frequency for which the characteristic is required is reached. The results of the readings are recorded in a data book, and on completion of the run the results are plotted on Form TRM12 and the graphs are then drawn as described for the audio frequency characteristic.

Figure 7 shows a typical crosstalk versus frequency characteristic of two typical open wire lines.

EDITOR'S NOTE.

This article is the first of a series to be published in this Journal, covering Transmission Practice in Australia. In this issue the author has not described the use of the 6A Transmission Measuring set, as this has already been dealt with in the red book on Carrier Practice issued by the Australian Postal Electricians' Union some years ago.

A Pick-Up Amplifier for Moving Coil Microphones

H. W. Hyett

With the introduction of moving coil microphones on outside pick-up work, the necessity arose for pick-up amplifiers having sufficient gain to be capable of an output power of 6 m.w. to line when used with these microphones.

As the rated output of this type of microphone is of the order of 70 db below reference volume, an amplifier having a gain of about 80 to 85 db is desirable in order to provide a reasonable margin of amplification under working conditions.

Past experience has shown that four input channels are adequate for 99 per cent. of the work, multi-channel amplifiers having been in use in N.S.W. since 1931, therefore it was decided to retain this number of input circuits.

The unit method of construction using panels of standard sizes has been adopted, the number of units being three, viz., the amplifier unit, the fader unit, and the meter unit. The amplifier is mounted on a 19 ins. x 7 ins. panel and so arranged that all components and wiring are exposed by the removal of the front panel, which can be detached independent of the amplifier chassis. This feature is illustrated in

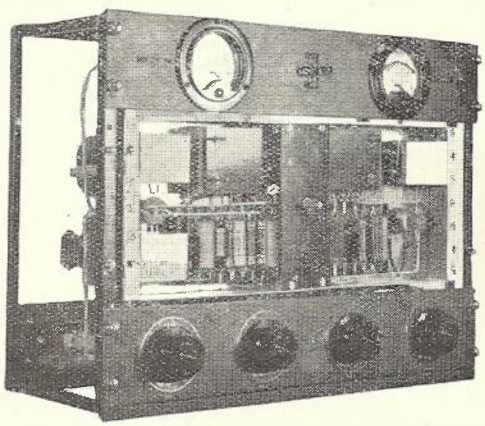


Fig. 1.—Front View with Amplifier Panel removed.

Figure 1. The four faders, which are of the General Radio type as regards mechanical construction, are mounted on a 19 ins. x $3\frac{1}{2}$ ins. panel and the two meters and the anode meter switching key on another panel of similar dimensions.

The two meters provided are one level indicator and an anode current meter, the former giving a full scale deflection at a level of 6 db above 6 m.w. and being permanently connected across the output of the amplifier, and the latter having a maximum deflection of 10 m.a. and being capable of being switched into either one of the three plate circuits, the normal position being in the plate circuit of the output tube.

A steel frame, 19 ins. x $14\frac{1}{2}$ ins. high and 7 ins. deep, was manufactured from $\frac{1}{2}$-inch angle, all joints being oxywelded, and the panels were mounted on this frame, the meter panel at the top, the amplifier panel in the centre and the fader panel at the bottom, the remaining half-inch being covered by a strip of $\frac{1}{8}$-inch aluminium. The fader panel was raised half an inch from the bottom of the frame to obviate the necessity of reducing the thickness of the lower front member of the frame to give clearance for the fader dust covers. A metal strip carrying the four microphone jacks, the battery jack, and the output and monitoring jacks was mounted on the rear face of the frame immediately behind the fader panel.

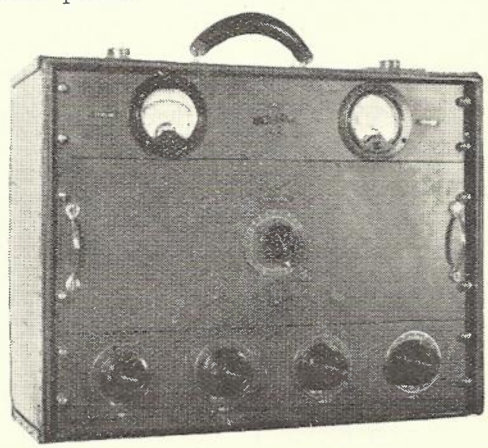


Fig. 2.—Amplifier mounted in travelling case.

The carrying case was supplied by one of the leading travelling-case manufacturers, and was made of a rigid type of ply-wood covered with black fibre with brass corner protectors and catches. A recess was provided inside the lid for the storage of the cords and headphones, and the lid was made completely detachable, as the equipment was designed to operate in a vertical position. Figure 2 shows the amplifier mounted in the case in the normal operating position, with the lid of the case detached.

An opening 1 ft. 5 ins. x $1\frac{5}{8}$ ins. was provided in the rear of the case through which access to the jacks was obtained, leaving the front panel clear of all connections.

Amplifier Unit.—The amplifier is designed to operate from 6-volt filament and 180-volt anode supplies, the total filament current being 0.9 amps and that of the plate 7 to 8 milliamps. After experimenting with several types of tubes it was found that the required amount of amplification could be obtained from three triodes using resistance-capacity type of coupling, the first two tubes being 6.F.5 type and the output tube a 6.C.5 type.

Owing to the large overall gain of the amplifier it was essential to maintain the input circuits balanced to ground in order to ensure complete stability under all conditions. For this reason it was decided to use balanced potentiometers, their centre points being connected to ground, as this method has been found more satisfactory than earthing the centre point of the input transformer, probably on account of the difficulty of maintaining a balance between the windings of a transformer of this type. This necessitated arranging the potentiometers in parallel and inserting loading resistors in order to preserve correct impedance relations, instead of using the more conventional series method. The overall gain of the amplifier was thus reduced from 93 db to 81 db, as the network so formed approximates a 25/100 ohm pad, the minimum value of which is 11.5 db. The series resistors were increased to a value of 55 ohms each, to compensate for the loss of the shunt resistance when three of the four channels are closed. The total resistance of each potentiometer is 30 ohms, and it will be seen that with any one channel open, which is the normal working condition, both the amplifier input and the microphone are correctly terminated.

Extensive field tests have proved the amplifier to be quite stable on full gain, even though not connected to earth; in fact, on no occasion has it yet been found necessary to make an earth connection to the equipment.

The impedance ratio of the input transformer is 30/50,000 ohms. It has an extremely flat characteristic from 30 to 10,000 cycles, the maximum deviation from the 1000 cycle reference axis being only a small fraction of 1 db. An additional 4 or 5 db gain could be obtained by using a transformer having a 30/150,000 ohms ratio, but these have only recently become available and were not procurable at the time the amplifier was under construction.

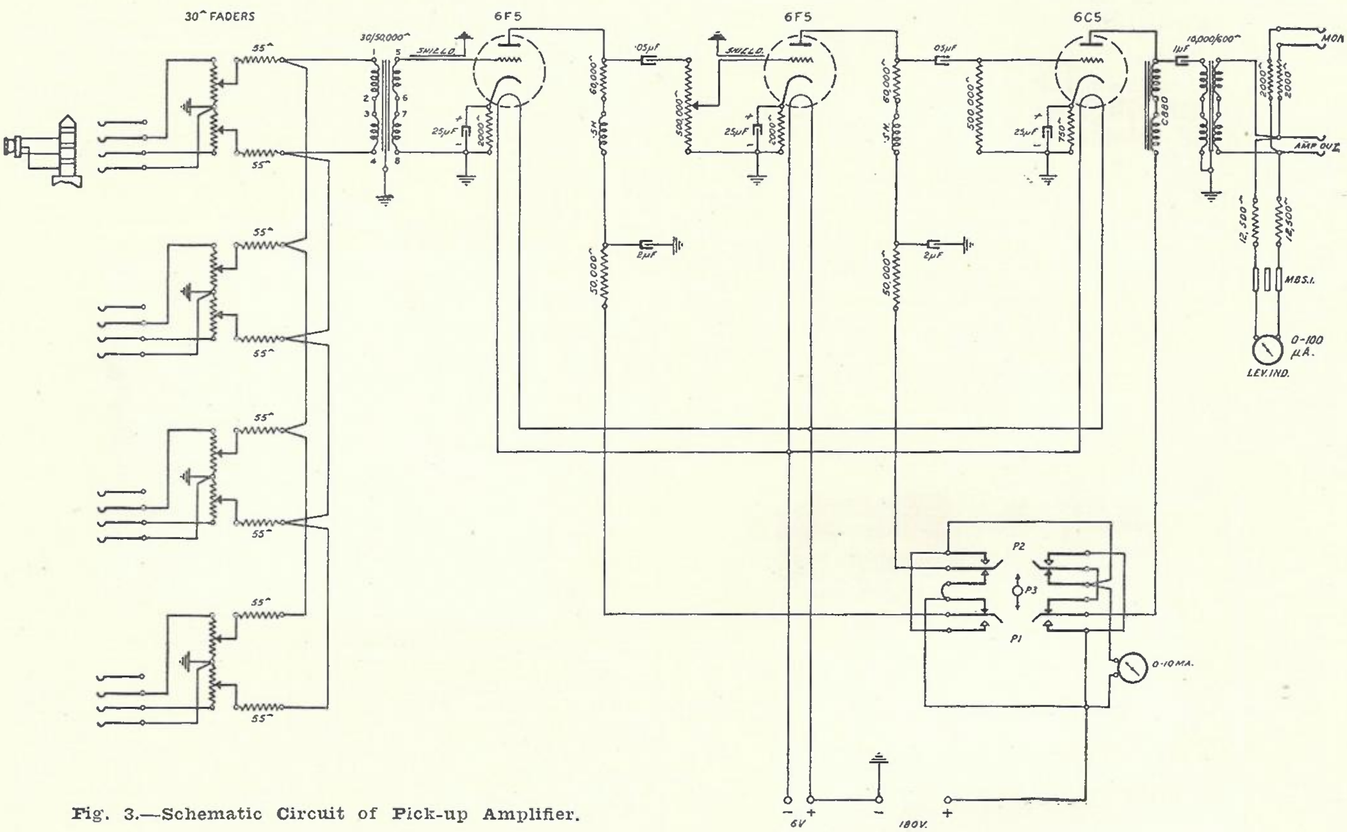


Fig. 3.—Schematic Circuit of Pick-up Amplifier.

An output transformer having an impedance ratio of 10,000/600 ohms was chosen as being the most suitable for the 6.C.5 tube, the primary being kept free from direct current by means of the conventional high impedance choke and condenser. The choke is of the pi-wound variety, and does not introduce any measurable loss at 10,000 cycles in circuits up to 15,000 ohms impedance.

The level indicator and monitoring jacks are connected across the output of the amplifier, the output jacks being connected directly to the 600 ohms winding of the output transformer, all key contacts being purposely avoided in this circuit.

The values of the components in the interstage couplings are shown on the schematic diagram (Figure 3), the gain control being connected across the grid-cathode circuit of the second tube. A 0.5 henry choke shown in Figure 3 has been connected in series with the plate coupling resistances of each of the first two tubes to provide the necessary correction at the higher frequencies and the overall characteristic is within ± 1 db of the 1000 cycle reference axis from 35 to 10,000 cycles.

Actually the measurements were made throughout the band from 20 to 14,000 cycles, the gain being 2.7 db below that at 1000 cycles at these lower and upper limits.

The 0.5 henry chokes were obtained by winding 5000 turns of 40 S.W.G. enamel wire on two "Magicores" placed end to end, the assembly being mounted by means of a brass screw through the centre of the cores. The finished chokes are small and compact and are readily mounted in the space available.

Gain control is obtained by means of a 0.5 megohm potentiometer in the grid circuit of the second tube consisting of a modified General Radio type fader on which 1/3 watt I.R.C. resistances have been mounted, giving a range of 27 steps of 3 db each. A ratchet action has also been incorporated, so that the wiper cannot take up a position between studs.

The tube sockets are mounted on a sponge rubber fitting which gives entire freedom from microphonic noise, even with the gain at the maximum. It was not found necessary to cushion-mount the input transformer.

The amplifier gives a constant gain of 80 db at 1000 cycles for all outputs between 0.6 m.w. and 90 m.w.; i.e., from 10 db below reference level (6 m.w.) to 12 db above it. An ample margin is, therefore, maintained at the normal output level of 6 m.w.

The level indicator is obtained by using a 0-100 microammeter in conjunction with an M.B.S.1 type copper-oxide rectifier and calibrating resistance. A locally manufactured meter is used and scales are obtained calibrated in db giving a range from minus 15 db to plus 6 db referred to 6 m.w., the plus 6 db reading corresponding with the point of maximum deflection. The damping in these meters is extremely light and their performance is very satisfactory.

No provision has been made for carrying space in the amplifier for microphones. It is the practice in N.S.W. for the microphones to be taken by the pickup operator when proceeding to the pick-up point to carry out the transmission, and to return them to the pick-up room when the transmission is concluded, whereas the amplifying equipment is transported to and from the point of pick-up as found convenient.

The spare valves are carried in additional sockets mounted on the sub-panel.

As previously mentioned, the amplifier has been subjected to extensive tests in the field, both in the city and the country, and the performance has been satisfactory in every way. It was first used for the opening ceremony of Station 2NR from the Saraton Theatre, Grafton, and since then has been in constant use. Two more amplifiers of this type have since been constructed.

INTERFERENCE TO TELEPHONE LINES FROM HIGH VOLTAGE TRANSMISSION LINES.

H. A. Finlay

The increasing development in the electrification of country areas throughout the Commonwealth has resulted in the erection of long extra-high and high voltage transmission lines operating from comparatively few generating sources. The creation of long parallels with adjacent communication circuits, with their severe inductive interference effect, has made the prevention of disturbance on telephone circuits an important and interesting study for Communication Engineers.

In Tasmania, progress in Rural Electrification has been considerable owing to the natural resources available. The Great Lake, located in the centre of the island at an altitude of 3,300 feet, is the chief source of electrical energy and from the Hydro-Electric generating stations located near the lake, 88 K.V. 3-phase 50-cycle Star-connected transmission lines radiate south, north-west, north and east to sub-stations, where isolated-neutral lines of 22 K.V. and 11 K.V. transformation Star-Delta YD (Delta on distribution side) distribute.

The power distribution systems are built along the highways and parallel, at small separation for the greater portion of their length, the main Interstate and Intrastate Trunk and Telegraph routes, as well as a considerable number of minor trunk and subscribers' routes.

Unfortunately, in the design, particularly of the 11 K.V. distribution system, many long single-phase (two-wire) branching circuits metallically connected to two wires of the three-phase distribution systems have been erected. This practice creates severe unbalances in the distribution system, causing high voltages on, and consequently considerable disturbance to, the neighbouring telephone circuits.

In what follows, it is proposed to indicate some of the more important underlying principles that have been established in dealing with the interference problem and to give some actual examples of their application in practice.

Inductive interference in communication systems due to power lines is directly proportional to the product of three simultaneously existing factors:—

"A"—**The Inductive Coupling** between the Power and Telegraph systems due to Mutual Capacitance and Inductance between the two systems.

"B"—**The Disturbing Influence** of High Voltage or Heavy Current Power systems.

"C"—**The Susceptibility** of Telephone lines.

To eliminate the interference it is necessary to reduce one of these factors to zero and conversely the increase of any factor results in a corresponding increase in the inductive effects. To secure complete freedom, the power transmission and telephone lines should be built on widely separated routes, but in Tasmania, where the conditions do not permit of a high degree of separation, consideration has had to be given to the reduction of all three factors. The principal components determining the magnitude of these factors are given hereunder in the order of their importance:—

"A"—**The Inductive Coupling** (Electrostatic and Electromagnetic) between Power and Telephone Systems depends on:

1. **Horizontal separation between the lines,** the inductance decreasing approximately as the cube of the separation or more accurately—

$$E \text{ (Induction) } \propto H^{-n}$$

where H is the horizontal separation and the exponent "n" depends on the power circuit configuration.

The lowest value of "n" is 2.3 for an isosceles triangle with altitude equal to 1.25 times the base; for equilateral triangle 2.6; vertical wires 2.9, and horizontal symmetrical 3.5. As doubling the separation will generally reduce induction to 1/8th, the importance of building routes with the greatest possible separation is evident.

2. **Length of Parallel,** the induction increasing in direct proportion to increase in the length of parallel.

3. **Spacing of Disturbing Power Conductors.** Increase of spacing tends to make the effect of the nearest power wire of a three-phase system more predominant, partly by decreasing its relative distance to the telephone wires and by increasing that of the other power wires and thereby reducing the neutralising effects of the latter. Induction generally increases proportionately to the spacing of the power wires.

4. **Spacing of the disturbed telephone wires.** Induction is directly proportional to the spacing between the two conductors of a metallic circuit. The 9 ins. spacing now adopted as standard for wires used for superposed carrier working results in a reduction of noise in lines exposed to inductive influence. In phantom circuits the noise produced in an untransposed section is three times that of the side circuit with the normal 14 ins. spacing.

5. **Height of Conductors.** As the voltage that is induced on a telephone wire from a neighbouring Power wire depends on the ratio of the Mutual Capacitance and the Capacitance to

ground of the telephone wire, increasing the height of both conductors tends to increase the induced potential and consequently the amount of interference.

"B"—The Disturbing Influence or Telephone Influence Factor of the Power System depends on:

1. **The Magnitude of the operating Voltages and Currents (balanced components),** the induction increasing directly with the voltage and currents.

2. **The Magnitude of the Residual Components of the operating Voltages and Currents.** The residual voltage or current of a power system is the vector sum of voltages or currents to ground of the conductors comprising the circuit, and is equivalent to a single-phase voltage impressed on, or current flowing in, a circuit consisting of the several power conductors in parallel and an earth return. Obviously, when the vector sums are zero the residuals are zero and a condition of Balanced Voltages and Currents exist.

The magnitude of the residual voltage depends on the unbalanced mutual and earth capacitances of the wires forming the power system and is particularly severe where long single-phase (two-wire) circuits are directly connected to the three-phase system, the phase wire which is not extended having, of course, a much lower capacity to ground. This practice results in the setting up of high residual voltages, both in the single-phase and three-phase portions of the power systems.

To overcome the severe residual effect due to this cause, it is necessary to—

(a) Electrically isolate the single-phase tap by means of an isolating transformer, thus eliminating the unbalanced capacitance to ground of the three-phase system and permitting the single-phase portion to become a balanced circuit with 180 deg. phase shift between wires, or

(b) To convert the single-phase tap to three-phase by erecting the third wire.

Where the power system is wholly three-phase, inequalities in the distances (capacitances) between power lines are of more importance than small inequalities in the distances (capacitances) to ground, and consequently various configurations or poling diagrams adopted for power lines have widely different characteristic residual voltage. For example, the horizontal configuration with unequal spacing of adjacent conductors gives rise to a much larger residual voltage than the equilateral triangular configuration.

Calculation of Residual Voltage.

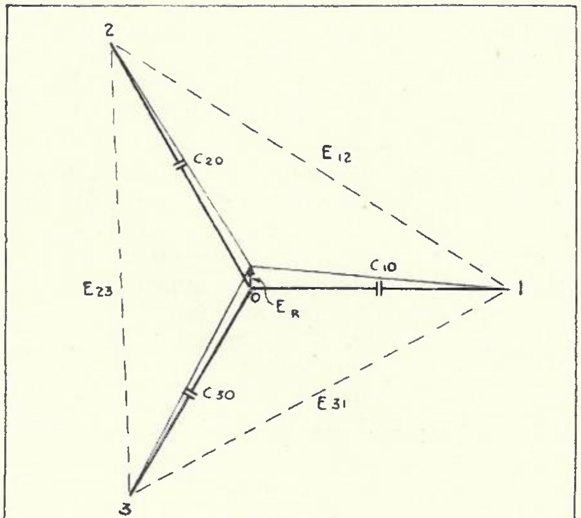


FIG. 1.

Figure 1 represents a three-phase system with unbalanced capacitances to ground and the formula for the calculation of the residual voltage is:—

$$E_R = -3E \frac{C_{10} + C_{20}\angle 120^\circ + C_{30}\angle 240^\circ}{C_{10} + C_{20} + C_{30}}$$

where E_R = Characteristic Residual Voltage.

$$E = \frac{E_{12}}{1.732}$$ (Voltage of each phase wire to ground)

C_{10}, C_{20}, etc., is the effective capacitance (Self and Mutual) of each phase wire to ground (O).

3. **Wave Form.** If a pure sine wave of fundamental frequency 50 cycles per second is propagated over power lines no noise would be heard in exposed telephone lines, owing to the high motional impedance of the telephone receiver and ear drum (together with the high capacitance reactance to this low frequency). Noise interference is due almost entirely to the odd multiples (harmonics) of the fundamental frequency into which the irregularities of the voltage and current waves may be analysed. The irregular wave forms may be caused by—

(a) Faulty design and construction of generators and motors.

(b) Distortion of voltage and current wave forms by faulty design and operation of transformers.

(c) Load unbalances of the power system.

The disturbing harmonics are divided into two groups—

(i) The odd triple series—3rd, 9th, 15th, etc.

(ii) The odd non-triple series—5th, 7th, 11th, etc.

In a balanced symmetrical three-phase system the voltage and current curves are separated by an angle of 120 deg. and their vector sum is zero, but if upon the fundamental the 3rd harmonic or any of its odd multiples is imposed, these harmonics will be coincident in phase and their effects will be additive and appear in the residual voltage.

On the other hand, the fundamental and odd non-triple harmonics can only appear in the residual voltage when they are unbalanced or unequal in magnitude. See Figure 2, which shows the magnitude of the residual 5th harmonic component of the voltage waves of the 11 K.V. power system radiating from the Bridgewater Sub-station.

It is essential that the two sides of a telephone circuit be balanced both in series impedance and impedance to ground. The inductive susceptibility of a telephone circuit increases with—

1. **Insulation Resistance Unbalance** of each leg to earth. Circuits exposed to inductive influence and normally silent will become quite unworkable when a cracked insulator, wire contacting with a stay-wire or tree or contact by wet hands or oilskins of linemen causes localised insulation resistance unbalance.

On the other hand, humid and wet weather conditions bringing **uniformly distributed** leakage on the wires of each system does not increase the induction as is popularly supposed, and theoretically the reduction in capacitance and consequential longitudinally-induced potentials under such conditions should reduce inductive effects.

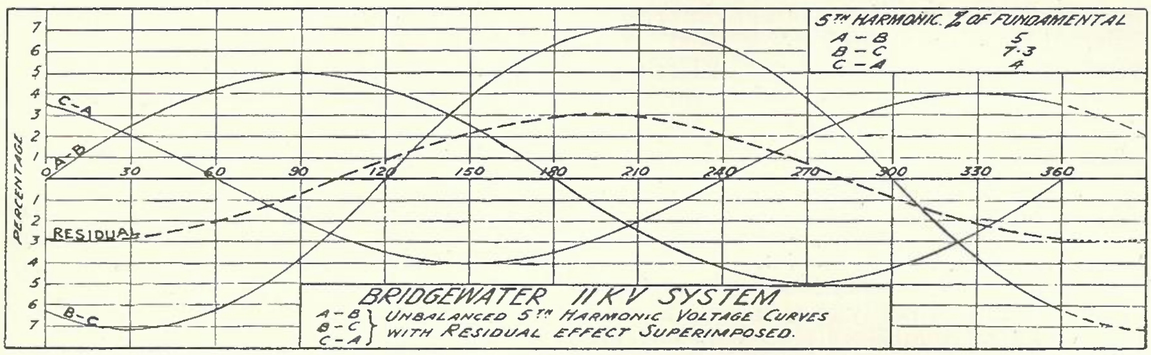


FIG. 2

2. **Conductor Resistance Unbalance.** High resistance joints and different gauges or classes of wire will increase the intensity of disturbance. The permissible limit of conductor resistance unbalance is 2 ohms per 150 miles of circuit.

These two causes of unbalance can only be remedied by a high standard of telephone line construction, and a high grade of plant maintenance. Regular routine inspections to remove likely causes of unbalance are essential, and in this connection the principles for ensuring a high standard of maintenance of Trunk and Telegraph lines and the regular routine tests to determine such maintenance are laid down in General Engineering Circulars Nos. 8 and 17 respectively.

As harmonics are responsible for the disturbance created in telephone circuits, special attention is given to their reduction by the improvement in generator and other power apparatus design by manufacturers, and modern specifications usually contain a clause limiting the maximum deviation from the sine curve to not more than 5 per cent.

The transformer connections can be used to suppress the 3rd harmonic and its multiples, a delta connection providing a closed path for the third harmonic current and its odd multiples, and so eliminating the corresponding harmonics from the flux and induced voltage wave.

For the suppression of a particularly troublesome harmonic, an anti-resonant circuit or wave trap can be designed for insertion in the generator earth.

"C"—The Susceptibility of the Telephone Line to Inductive Effects arises from the electrical unbalances in the two conductors forming the circuit or in the terminal apparatus connected to the line.

As earth circuit lines are wholly unbalanced with respect to earth, this type of telephone circuit cannot be retained when, due to development of Rural Electrification, portions of such circuits are brought within the sphere of influence of a High Voltage power system.

3. **Capacity Unbalance of telephone lines to ground.** In aerial transposed wires this component is comparatively unimportant, but in underground cables which are likely to be paralleled by extra high pressure lines, the balancing of the earth capacitances to the sheath of each wire is desirable to eliminate the interference due to electromagnetically induced currents flowing in the lead sheath.

4. **Terminal Apparatus.** It is essential that every unit of apparatus connected to a telephone

circuit be balanced within itself. When it is necessary to connect unbalanced apparatus or circuits (e.g., Earth circuit lines) to balanced circuits subjected to Inductive influence, a transformer to isolate the balanced from the unbalanced portion is always necessary.

CO-ORDINATION OF POWER AND TELEPHONE SYSTEMS—TRANSPOSITIONS.

Having dealt with the fundamental factors and their components in the causation of inductive interference, it is now proposed to discuss the fundamental principles underlying the inductive co-ordination of power and telephone systems.

Besides implying the adoption of proper maintenance and operating methods by both Power and Telephone administrations, so that the Inductive Influence of Power circuits on the one hand and the Inductive Susceptibility of the Telephone circuits on the other are reduced to the minimum possible, the term Inductive Co-ordination also refers to the best relative arrangement and location of transpositions in both circuits in order to diminish the inductive coupling and consequently the inductive interference.

Balanced Components of Voltage and Currents—the Effects of Transpositions.

In Figure 3, which represents a telephone line exposed to an untransposed three-phase power circuit for a distance of three miles, the effect of the nearest power wire is predominant and induces "longitudinal" voltages to ground along the wires of the telephone circuit. The voltage on each wire differs in magnitude, the larger, of course, being on the telephone wire nearest to the power lines, and this differential effect is known as "transverse" induction. The effect of inserting a transposition in the telephone circuit is to balance the induced potentials on each leg, neglecting phase change and attenuation, and if the series impedance and admittance to ground of each leg of the telephone circuit are equal, i.e., perfectly balanced, no circulating currents or noise will occur. Any imperfection in the balanced condition due, say, to unequal leakance in each leg or a high resistance joint will permit the longitudinally induced potential to cause current to flow through receivers and consequently generate noise.

In Figure 4, the effect of cutting in one barrel, i.e., a section wherein each power conductor occupies each of the conductor positions for the same distance—by means of two power transpositions (arranged right over left in this instance) and leaving the telephone circuit untransposed can be clearly seen. Here we see that over the section the induced voltage to

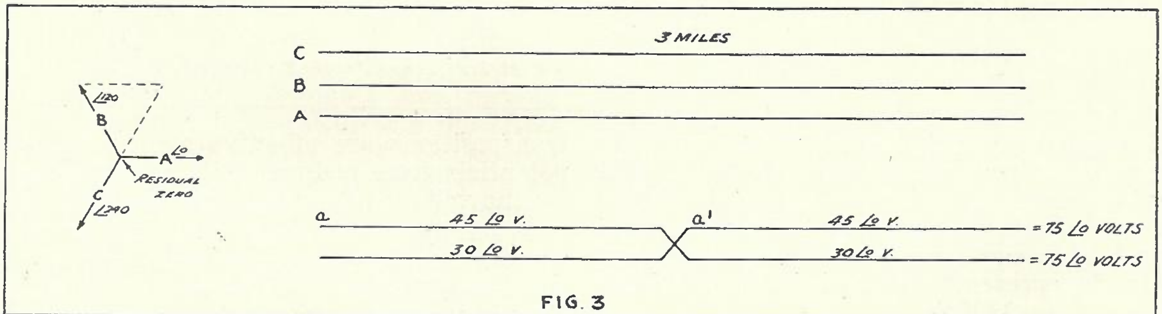


FIG. 3

BALANCED VOLTAGE COMPONENTS EFFECT OF TELEPHONE TRANSPOSITIONS.

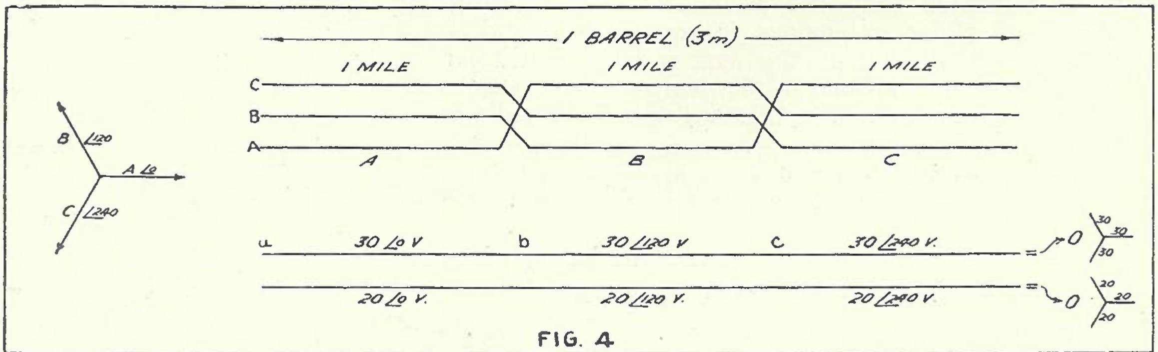


FIG. 4

BALANCED VOLTAGE COMPONENTS EFFECT OF POWER TRANSPOSITIONS.

ground is, by the neutralising effects of the three sections, reduced to zero on each leg, and also the difference of voltage between the two wires is zero.

In co-ordinated Power and Telephone transposition sections the telephone transpositions are located to balance the transverse induction from the nearest phase wire for each section of a barrel, and the power transpositions are used to reduce to zero in any one barrel the inductive effects from the balanced components of the power system.

Residual Components of Voltage and Current—the Effects of Transpositions.

The effect of residual voltage component of 11 K.V. three-phase system with two single-phase extensions is shown in Figure 5.

wholly residual, i.e., totally unbalanced with respect to the neutral point, the insertion of a single-phase power transposition in such an unbalanced system will have no effect on parallelled circuits.

Figure 6 indicates the effect of the residual components of the power system illustrated in Figure 5 on a parallelled telephone circuit.

The residual voltage on the three-phase portion of the system is equal to 1350 volts and the approximate induced potentials on relative sections of the parallelled telephone wires are indicated.

The power transpositions in the three-phase portion neutralises the induced voltage to ground from the balanced components only, but cannot reduce the effect of the residuals. Telephone

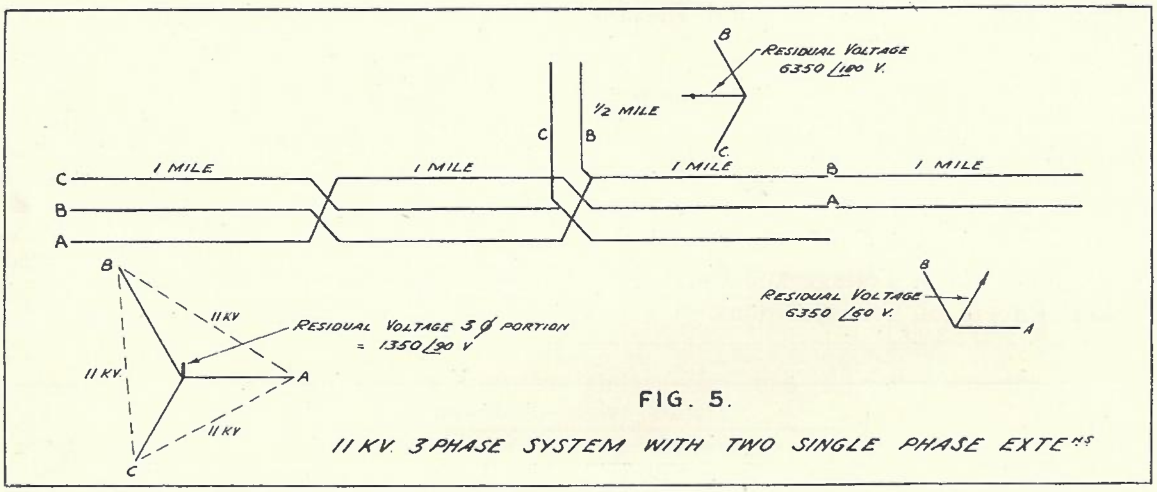


FIG. 5.

11 KV 3 PHASE SYSTEM WITH TWO SINGLE PHASE EXTE^NS

transpositions are effective against the induced potentials from residual voltages, but only equalise the voltages on each leg to ground.

The residual or unbalanced portion of the voltage persists throughout the three-phase and single-phase sections, and its effect can be represented by a single-wire ground-return power line with an E.M.F. equal to the residual voltage.

Figure 5 represents an 11 K.V. line (phase voltage to earth $\frac{11 \text{ K.V.}}{1.732} = 6{,}350$ volts) with two single-phase extensions, and is a typical example of an unbalanced power system. The vector diagram to the right indicates that the residual voltage on the single-phase extensions is equal to the phase to earth voltage of the system and located + 60 deg. from "A" and — 60 deg. from "B," i.e., midway between. As this voltage is

Generally to obtain a high degree of transverse balance, it is of advantage to have numerous transpositions inserted in circuits erected on the pin positions located at each end of the telephone crossarms. Such well-transposed circuits would tend to shield adjacent circuits and also to reduce the secondary induction from themselves.

Owing to the effects of phase-shift and attenuation the necessity for more numerous transpositions increases with the increase of the frequency of the harmonics to be counteracted. By dividing the exposed circuit into smaller sections

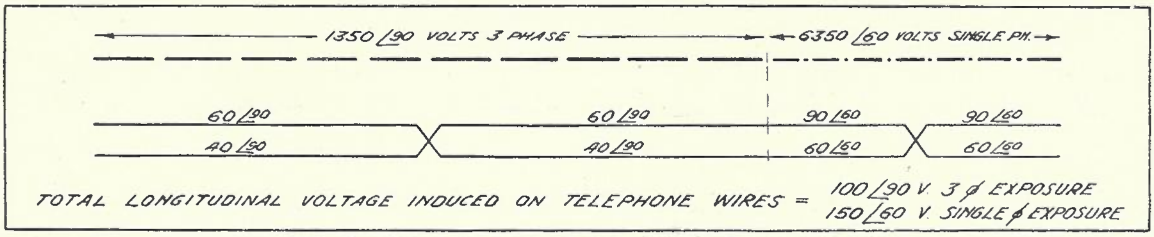


Fig. 6.—Effect of residual components of power system.

by transpositions, the induced voltages and currents in adjacent sections will have approximately the same phase and magnitude and accordingly will be more fully neutralised.

Unbalanced Exposures. A calculation of the unbalanced exposure or equivalent untransposed length by the formula hereunder for any given parallel gives a ready means of estimating the amount of induction to be expected and serves as a basis for computing the relative effects of any alterations to an existing power and telephone transpositions scheme:—

Type of Induction	Power Component	Length of Untransposed Exposure
Longitudinal	Residual	$a + b + c + a' + b' + c'$
	Balanced	$(a + a')\angle 0° + (b + b')\angle 120° + (c + c')\angle 240°$
Transverse	Residual	$(a + b + c) - (a' + b' + c')$
	Balanced	$(a - a')\angle 0° + (b - b')\angle 120° + (c - c')\angle 240°$

Note.—a and a', b and b', c and c' represent the lengths of each side respectively of a telephone circuit when subjected to exposure from, and A, B and C phase wires.

An actual example is given below. After the insertion of phantom transpositions in two 200C. lines between two centres approximately 90 miles apart, it was found that the phantom circuit could not be brought into commercial operation owing to heavy induction. The trouble was localised to a particular 7-mile section where the lines were parallelled by a 22 K.V. three-phase balanced power system at widely varying separations due to deviation of routes and curving roads. For the purpose of calculating the effective induction, sections having a greater separation than 11 yards were reduced to their equivalent length at this separation by formula $E = H^{-2.6}$.

The calculations in the table below of equivalent unbalanced exposure indicated that the power transpositions were not suitably located to balance the longitudinal induction, and the telephone (phantom) transpositions were not suitably located with reference to power transpositions to provide balance against transverse induction.

An alteration calculated to reduce the longitudinal equivalent unbalanced exposure from 582 yards at half a chain separation, to the equivalent of 194 yards, by the interchanging of the B and C wires at Hydro poles Nos. 173 and 175 where wires were already terminated, was suggested to the Hydro-Electric Commission, but owing to some difficulty the alteration was performed at Pole 153 in lieu of 173. Calculations with the altered arrangement indicated that the unbalanced longitudinal induction was now the equivalent of 234 yards at 11 yards separation, approximately 40 per cent. of previous unbalance, and this compared closely with the observed reduction of noise, and this study made possible the handing over of the phantom circuit for telephone traffic.

Whereas the previous example was a case of induction primarily from the balanced components of a symmetrical three-phase system, the following case is of disturbance from a power system by no means so well balanced.

For some time past the Hobart-Granton portion of the main Trunk and Telegraph route has been periodically subjected to severe inductive disturbance, when, for pole renewals or other work, the Hydro-Electric Commission fed the parallelling 11 K.V. three-phase route south from the Bridgewater Sub-station instead of north from the Risdon Sub-station as normally operated.

An investigation into the cause of the trouble was recently undertaken and along sections parallelled by the Bridgewater system, where a

22 K.V. Three-phase Parallel.

Section	Actual Length and Horizontal Separation	Computed equivalent lengths at ½ chain separation: a	a'	b	b'	c	c'
H.T. Poles:							
222 to 207	3,484 yds. at ½-chain separation	—	—	340	660	—	—
207 to 190		696	388	—	—	—	—
190 to 173		—	—	—	—	800	600
173 to 153	1,800 yds. at 2 chains 8 yds. separation	—	—	—	—	19	12
152 to 134	1,420 yds. at 1 chain 15 yds. separation	37	24	—	—	—	—
134 to 126	Not considered. 1,300 yds. at ¼ mile separation	0	0	—	—	—	—
125 to 120	400 yds. at 14½ yds. separation	—	—	—	—	195	—
120 to 107	Not considered. 1 mile at ¼ mile separation	—	—	—	0	0	—
106 to 90	1,400 yds. at 2 chains separation	15	23	—	—	—	—
87 to 76	1,200 yds. at 2 chains 15 yds. separation	—	—	—	—	9	9
		748	**435**	**340**	**660**	**1023**	**621**

Longitudinal (Balanced components): $1183 \angle 0°$; $1000 \angle 120°$; $1644 \angle 240°$.

Equivalent unbalanced exposure (Longitudinal) = 582 yds. @ (½ chain).

reasonable degree of co-ordination of the three-phase power and telephone transpositions existed, tests of the induced noise and voltage to ground on well-balanced telephone lines were made.

The fairly high induced longitudinal voltages to ground observed on telephone circuits indicated that the magnitude of the residual voltage component of the power system was high, and the residual effect of the predominant unbalanced harmonic, the 5th, of the voltage wave form was up to 3 per cent. of the fundamental. See Figure 2. A check-up of all power transpositions, connections of single-phase taps, lengths of cables and aerial wires was made over the whole extent of the high voltage system.

This 11 K.V. system furnishes light and power to an area of 1,000 square miles of country and consists of 65 route miles of three-phase and 80 route miles of single-phase branches. A special feature is that at the end of one 15-mile section of single-phase aerial wire extension, 800 yards of three-core, sector-shaped conductor, paper-insulated, oil-impregnated, lead-covered and armoured cable is laid to an Aerodrome, two cores only being used.

The effective capacitance of each core to sheath of the cable above-mentioned is given by the formula:—

$$C = \left(1.2 \frac{0.144}{\log_{10} \frac{d_2}{2r}}\right) 10^{-6} \text{ farads per mile}$$

where r = conductor radius.
d_2 = 2r + Insulation thickness between conductors + Insulation thickness between conductor and sheath.

The effective capacitance of one mile of an aerial wire forming one of a system of similar conductors is given by:

$$C = \left(0.03883 \frac{1}{\log_{10} \frac{2h}{r}}\right) 10^{-6} \text{ farads per mile.}$$

where h = height above ground.
r = radius of wire in similar units.

By calculation, the capacity of the High Voltage cable is 27 times that of an equal length of the aerial wire to which it is connected.

A copy of the computations and a suggested re-arrangement of the connection of certain single-phase taps in order to reduce the residual voltage was supplied to the Hydro-Electric Commission and with the co-operation of the Controlling Power Engineers the suggested re-arrangement was made.

The effect of the action was then specially tested under the conditions of feeding the Hobart-Granton parallel from the Bridgewater Sub-station and the results obtained were good, the total noise units being of the order of one-third of previous readings under similar conditions and little different from those recorded under normal conditions.

The following example shows the high permanent potential which can be induced on telephone lines parallelled by a single-phase extension of an 11 K.V. three-phase system.

From the underground cable terminal pole located 447 yards from an Exchange, an aerial wire subscribers' route is parallelled by a single-phase extension for a distance of 3.5 miles at an average lateral separation of 20 feet. The average height of the telephone wires is 16 feet and the power wires 28 feet.

The current to earth measured on three subscribers' lines traversing the full distance gave values of 3.2, 2.75 and 2.6 milliamps respectively using an Elliott Milliammeter (Dynamometer principle range 0-15) of 1460 ohms resistance. A 1000 ohms magneto bell when connected between one leg of a subscriber's line and earth was caused to ring continuously by the induced current at fundamental frequency (50 cycles). The measured voltage induced between the lines and earth varied with the impedances of the instruments—one of 11,500 ohms resistance indicating 30 volts and another of higher resistance 75 volts. A diagrammatic representation of this test is shown in Figure 7.

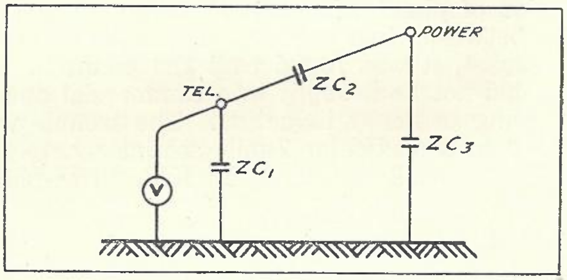


FIG 7

From the average dimensions of the parallel the earth and mutual capacitances and current flowing between power and telephone wires and earth were calculated and the induced voltage for the aerial wire portion disconnected from cable was computed to be 330 volts, and when connected to the Exchange via the cable 200 volts, also the current flowing from the telephone wires to earth was calculated to be 3.9 m.a's. The residual voltage of the single-phase 11 K.V. power line = 6350 volts and the calculations are accurate to within 10 per cent.

The electrostatically induced voltage is independent of the length of parallel and depends on the ratio of the impedances ZC_1 and XC_2, the connection of the comparatively low impedance voltmeter shunting ZC_1 immediately reduces the ratio and accordingly the voltage observed. The effect of an increase of parallellism, however, increases the mutual capacitance and accordingly the value of the current flowing between the two systems and with sufficient length of exposure to such unbalanced power lines, severe damage to apparatus, or possible danger to personnel from electric shock, may occur.

To eliminate these effects at their source, it is necessary to secure the co-operation of the Electric Authority to erect the third wire or insert an isolating transformer between the single-phase tap and the three-phase system. Failing the above remedies, the induced voltage can be:

(a) Drained by connecting the primary of transformer with centre point earthed, across the subscriber's line, the secondary coil being left unconnected.

(b) Neutralised by connecting a neutralising transformer with associated auxiliary wire at the mid-point of the exposure.

Noise Measurements. In Tasmania, for the determination of noise levels on the various circuits and to observe the relative disturbing effects before and after the completion of re-arrangements in power or telephone systems, a shunted receiver testing set is used. This set includes a resistance of 400 ohms in series with a variable resistance (ranging from 0.1 ohms to 111 ohms) which shunts a Bell receiver of 200 ohms impedance. The terminals of the set are connected to the noisy line and the variable resistance is decreased until noise in the receiver is just inaudible and the value of shunt noted. The shunt values are calibrated in Noise Units from 3,600 noise units corresponding to shunt of 1.0 ohms, to 50 units corresponding to 50 ohms.

As the values obtained are dependent on the sensitivity of the observer's hearing, differing results being obtained by different observers, it is necessary to have the observations taken with the same observer for a true comparative value to be obtained.

Also the values obtained are affected by any extraneous noises in the vicinity when tests are being made. Moreover, no allowance is made in the noise shunt of the relative interfering effects of the various frequency components of induced noise.

Experiments have shown that the relative interfering effects of the same power at differing frequencies is not the same, the interference being approximately proportional to the cube of the frequency up to 800 cycles per second, then rises slowly to a maximum at 1050 cycles.

Any noise measuring apparatus should, therefore, include some means of "weighting" the different frequency components so that the resultant measurement will be an indication of the detrimental effects of the noise on the intelligibility of speech over the circuit. This can be done by including a weighting network with an attenuation characteristic that is complementary to the relative interfering effects of the frequencies of the harmonics present.

Abnormal Conditions. The effect of a ground occurring on one-phase wire of an isolated neutral power system is illustrated in Figure 8.

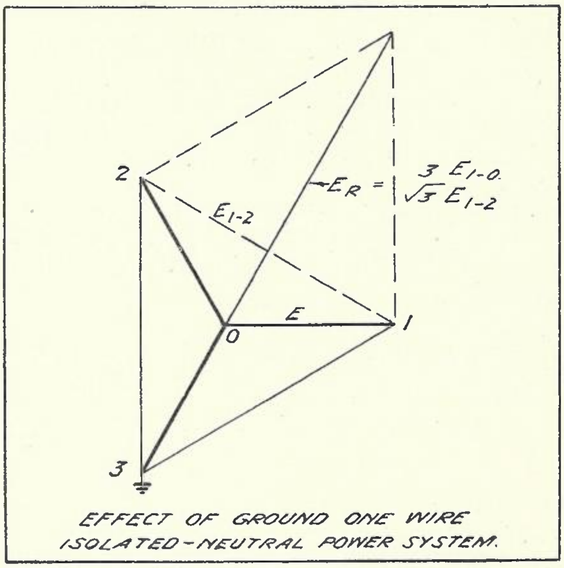


FIG. 8.

The residual voltage E_R which prior to the faulty condition may have been nil rises suddenly to three times the normal phase voltage to ground, and equals 1.732 times the phase to phase voltage, and this abnormally high residual voltage extends throughout the power system.

During switching operations, large residual voltages and currents may exist momentarily due to the several conductors not being energised or de-energised at the same instant. Also open circuits caused by a broken wire or short-circuits will give rise to heavy surges.

Accompanying the above abnormal conditions, severe acoustic shock may be experienced by telephone users or operating staff, and any such cases of shock must be closely followed up to ascertain possible causes and promote remedial measures. One measure at present under test is the use of neon gas-filled arresters, which have a low striking voltage, associated with a step-up transformer. The Hydro-Electric Commission co-operates to the extent of advising this Department, as far as possible, when switching operations are contemplated so that shocks from this cause can be reduced to a minimum.

The severity of such residual effects are minimised by the adoption of the grounded neutral star-connected system, which provides special measures to eliminate the effect of the third harmonic, and this method of high voltage power distribution is now generally favoured.

Conclusion. The value of co-operation is obvious and in Tasmania a Joint Committee of Engineers representing the Hydro-Electric Commission and the Postmaster-General's Department meets monthly to consider improvements to existing layouts and new construction proposals.

MORSE CONCENTRATION FACILITIES

ADELAIDE CHIEF TELEGRAPH OFFICE

H. Hawke

The question of concentrating morse-operated simplex telegraph circuits, such as are used in the smaller country districts of Australia, is an important one with many features and difficulties peculiar to the requirements of such a system.

Factors governing the provision of concentration as applied to telegraph traffic and its circuits may be summarised under the following headings:—

1. Traffic load per circuit.
2. Staffing to meet varying load conditions.
3. Operating table space, which includes provision for filing outgoing traffic and station distribution details.
4. Types of circuits in use in the areas served.
5. Equipment and its space requirements.

For the purpose of a detailed investigation, the above-mentioned headings are subdivided into a number of factors which govern each.

1. **Traffic load per circuit.**
   - 1.1 Circuits serving suburban areas both residential and industrial.
   - 1.2 Lightly loaded circuits serving country towns, which by reason of their geographical position cannot be extended economically to acquire full load.
   - 1.3 Lightly loaded circuits with terminal stations in more remote districts.
   - 1.4 Circuits carrying traffic in excess of simplex load, but insufficient to warrant conversion to duplex.

2. **Staffing to meet varying load conditions.**
   - 2.1 Load conditions with ordinary routine peaks between 9 a.m. and 6 p.m.
   - 2.2 Seasonal loads in specific areas.
   - 2.3 Extraordinary loads on special circuits, such as shipping at out-ports, tourist, special press, sporting, etc.
   - 2.4 Extraordinary loads on a group of circuits serving certain districts, viz., variations in wool and wheat quotations.

3. **Operating Table Space.**
   - 3.1 Space required for a typewriter, and timing off "sent" traffic.
   - 3.2 Accessibility of the key, line relay, and sounder.

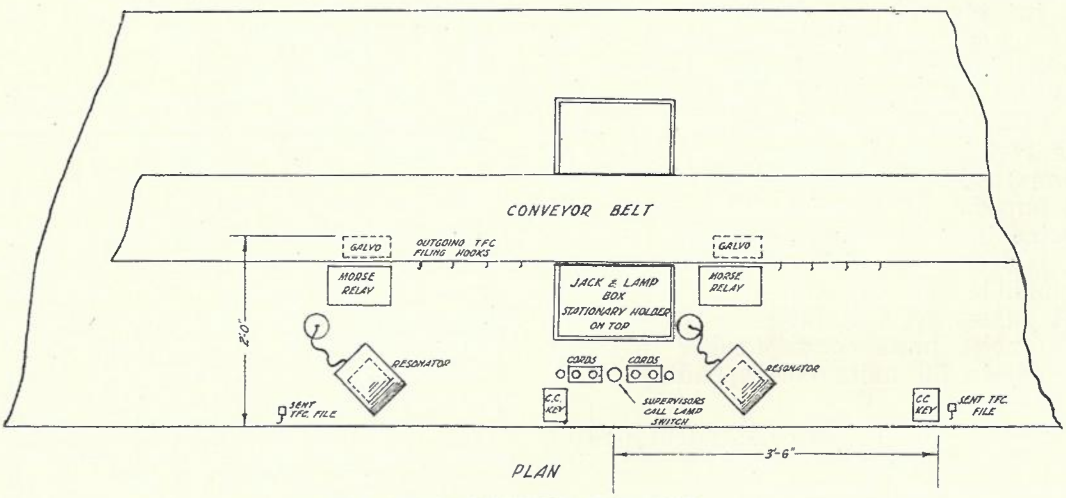


FIG. 1. MORSE CONCENTRATOR TABLE LAYOUT
SHOWING TWO OPERATORS POSITIONS ONLY

   - 3.3 Accessibility of various types of stationery used.
   - 3.4 Easy and quick means of obtaining sub-distribution information on individual circuits.
   - 3.5 Accessibility of disposal of incoming traffic into conveyor belt, and of obtaining traffic for despatch.
   - 3.6 Space for filing waiting outgoing traffic and easy accessibility thereto.

4. **Types of Circuits.**
   - 4.1 Single wire lines.
   - 4.2 Lines derived by cailhos on telephone circuits.
   - 4.3 Lines derived from composited telephone circuits.
   - 4.4 Combinations of lines of 4.1, 4.2, and 4.3.

5. **Equipment and Space.**
   - 5.1 Line equipment, e.g., calling and busy relays, battery feeds, etc.
   - 5.2 Table equipment for access to circuits, e.g., calling and busy lamps, line jacks, plugs, etc.

5.3 Table equipment for operator's set, e.g., key relay, sounder, resonator, etc.

In order to obtain a concentrator system which would be efficient from all aspects, the whole of the foregoing details were investigated thoroughly in South Australia with a view to concentrating the maximum number of circuits possible. The result is that all the suburban circuits and about 70 per cent. of those serving rural areas have been incorporated in the scheme.

In the first instance a traffic survey was made, taking into consideration the requirements as set out in 2.1 to 2.4, and as a result the number of morse stations in the State was reduced to a minimum. This reduction was brought about by the introduction of a regional scheme whereby villages and small country towns disposed of their business by telephone to a major centre.

The major centres were then provided with closed circuit morse facilities connected to omnibus circuits all radiating from Adelaide, and so arranged that each circuit carried the maximum number of stations possible with the available lines in the respective districts.

In dealing with suburban lines the problem was somewhat simplified, as all stations were available to the underground telephone cable network via suburban exchanges. The network radiates from the Central Telephone Exchange (adjacent to the C.T.O.). Offices in these areas were arranged in series groups by suitable jumpering at the Central Exchange. Fully loaded circuits were obtained in each instance.

In the country, groups of offices on short circuits where extension was impracticable presented the most uneconomical arrangement, but wherever possible stations were looped in to provide a fully loaded line. Other country circuits were easier to deal with, as the requisite load was obtained more or less by the addition of stations. In these cases, however, due regard had to be paid to the main weakness of any common battery communication system utilising open wire lines, i.e., line leakage. In the country many of the circuits were derived by a cailho on telephone trunks, and this, together with suitable dividing points in cases of line failure or heavy seasonal and special traffic, was a limiting factor on the longer country circuits.

The staffing and number of working positions to be installed was based on the traffic figures as a whole, due regard being given to the peak and extraordinary loads to be handled. Arrangements were made to meet extraordinary loads by the provision of a number of morse sets installed on an adjacent table so that office distribution and supervision could be effected without interference, and circuits transferred to and from the concentrator positions as required.

Loading and staffing features having been decided upon, it was found that with 12 suburban, 18 country lines, and 10 miscellaneous lines (e.g., sports grounds, racecourses, etc.), a maximum of 12 operating positions would be required, together with six spare morse positions. The table space available consisted of a standard table 4 ft. 6 ins. wide and 25 ft. long, with a conveyor belt 1 ft. wide mounted along its centre. In order to accommodate 12 operators this table was equipped with six operating positions on each side arranged so that two adjacent positions had access to the same lamp and jack field.

Space requirements presented one of the most difficult problems, and owing to the limited table space individual operating positions were reduced to a minimum. Each operator has an area of 3 ft. 6 ins. by 2 ft. deep which contains his line relay, galvanometer, and sounder in an adjustable resonator on his left, whilst on his right hand is the morse key with sufficient space for a pendograph. In his immediate front, space is available for a typewriter, whilst the side of the conveyor belt facing him is fitted with a slide containing distribution information and office hours, etc., of all lines and stations whose traffic is routed via the system. A number of hooks are mounted along the bottom edge of this slide to accommodate traffic awaiting despatch. Stationery baskets are fitted on top of each lamp and jack box, and the cords for connecting the operator's set to the concentrator line are on the right and left of alternate operators, being immediately in front of the jack field. Two cords, one a spare, and a changeover press button switch are provided to prevent interruption in case of cord failure. Filing hooks for traffic despatched and signed off are suitably located, as shown in Figure 1.

The lines comprising the circuits in use are of many types, the simplest being single wire lines through telephone cables to suburban offices. These are the ideal circuits where currents can be fixed, and as leakage is not encountered, the channel's electrical and, therefore, operating characteristics remain constant. Country channels are a mixture of many kinds, including lengths of underground cable, single aerial line, cailho circuit superimposed on both telephone physical, and phantom lines, also several derived by means of composited circuits. The leakage problem on these lines is a very definite factor, and places severe limitations on concentrator working. The use of cailho circuits is being discarded wherever practicable.

The concentrator circuit and equipment is a common battery signalling system with ancillaried line lamp and jack positions multiplied to six points. The equipment consists of a primary line or calling relay, a secondary line relay, and a sleeve or busy relay, ancillaried line and busy lamps, multiplied jack fields, and a number of closed circuit morse sets. The lines terminating on the concentrator are single wire closed circuit systems which, as will be seen from Figure 2, derive line battery via the primary line relay and contacts of the sleeve relay to earth or battery at the distant station. Normally the line is in a closed condition energising the primary line relay, but should any distant station open his key the primary line relay releases, closing the energising circuit of the secondary relay which locks over its own contact and the released contact of the sleeve relay. The other contacts of the secondary relay operate the line calling lamps and pilot lamp relay.

The operator's morse set which is terminated on the tip and ring of a cord and plug also has an earthed sleeve connection, which, when plugged into the jack associated with a calling lamp, completes the sleeve relay circuit.

The sleeve relay carries a changeover contact which releases the locking circuit on the secondary line relay to extinguish the line lamps, and operates a number of ancillaried busy lamps which in each case, like the line jacks, are mounted in strips associated with the line lamps. The other function of the sleeve relay is in opening of the line relay winding, enabling current to flow directly through the operator's morse set via the tip and ring of the jack. On completion of traffic, the line circuit is closed, and on withdrawal of the plug the primary line relay energises, thus restoring normal conditions. On release it is important that contact on the sleeve relay controlling the primary line relay closes before the contact associated with the secondary relay's locking circuit. Failure in this regard will not permit the line relay to operate quickly enough and the secondary relay will be allowed to energise improperly.

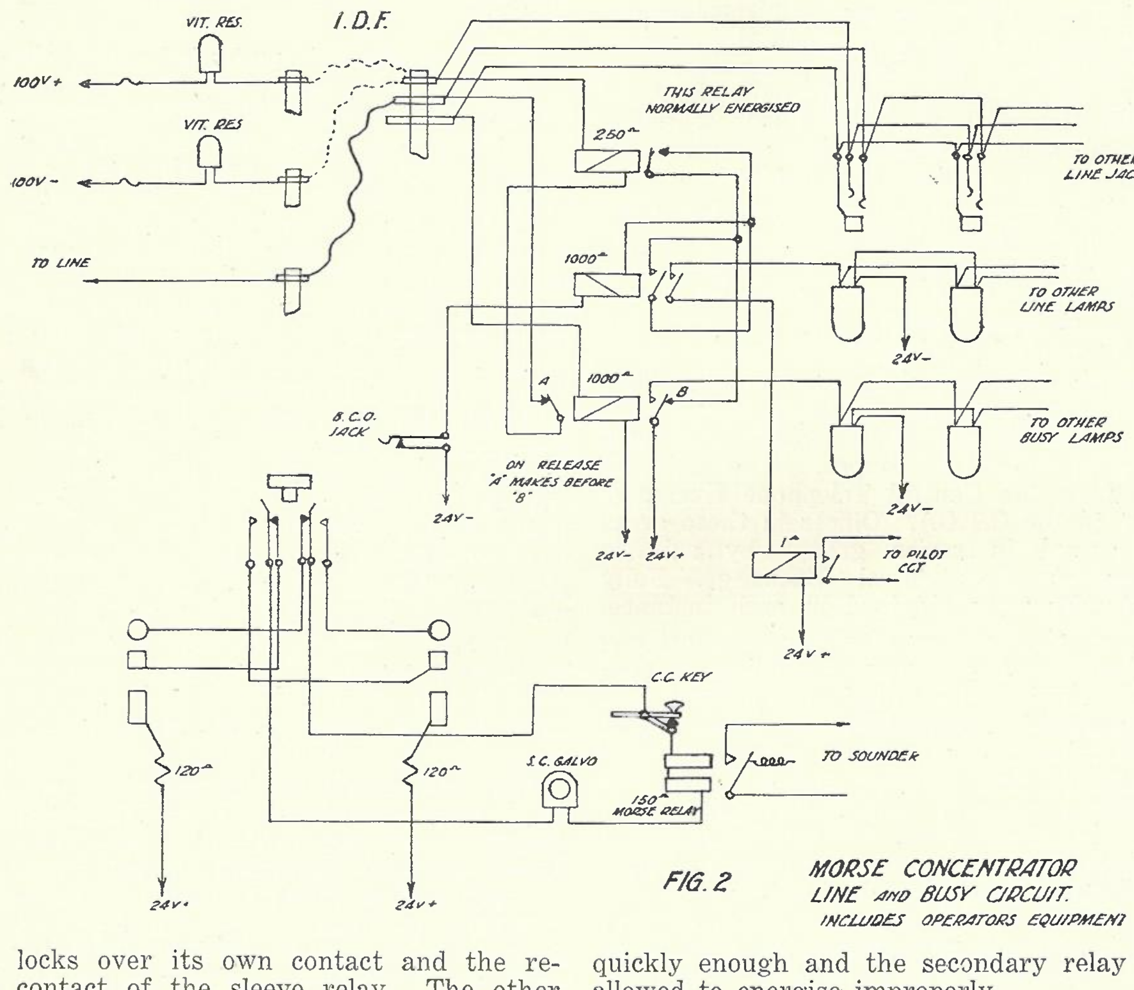


FIG. 2 MORSE CONCENTRATOR LINE AND BUSY CIRCUIT. INCLUDES OPERATORS EQUIPMENT

Coming now to the type of relays employed, it will be seen from Figure 2 that the secondary line relay and sleeve relay are similar to those used in any common battery telephone installation, their functions being in every respect similar to those in telephone switchboard, etc. Unfortunately, the same cannot be claimed for the primary line relay, which is the fundamental piece of apparatus in the whole system, and the one point on which the success of operation of the concentrator depends. This relay is subject to the varying line conditions and must be capable of reliable operation either from the distant end of a circuit, an intermediate station, or perhaps at a point relatively close to the C.T.O. A standard bipolar morse relay embodying the usual adjustment of armature tension, contact travel and pole gap is suitable to a degree, but its physical size renders its use impracticable. The relay required must, therefore, embody all of the foregoing features, together with a low figure of merit, ease of permanent adjustment, and finally must be small in physical size.

A concentrator installation used for suburban lines only, where each circuit is wholly in cable, is ideal as the adjustment given to the line relay can be set and will remain constant. The addition of open wire lines into country districts is the one weakness which limits the scope and usefulness of such a system.

Our thanks are due to the Central Administration for the adaption of a re-designed telephone type of relay that has proved successful under the most exacting of conditions.

The relay is shown in Figure 3. It is a side armature type used in automatic exchange equipment which has been fitted with all the adjustments available on its standard morse counterpart. Tests on this relay, both on the bench and in actual service under varying conditions, have

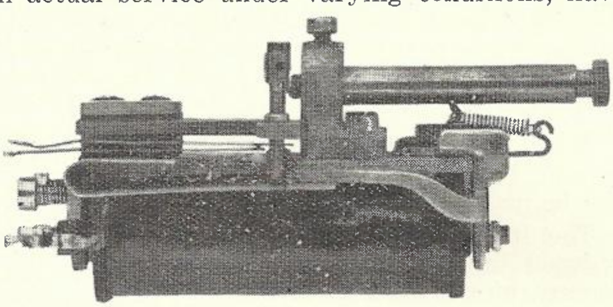


Fig. 3.—Primary Line Relay.

proved that an adjustment can be maintained on a difference of 4 to 6 milliamps over a working range of 10 to 40 milliamps. Analysing these figures, we find it possible under service conditions for a line carrying 30 milliamps to de-energise the relay, not only on open circuit when line leakage is nil, but also on the opening of the distant line keys when leakage conditions set up a loss to the extent of 25 milliamps. Similar adjustments can be obtained for circuits worked on 20 or 40 milliamps normal line current.

Sufficient space for the mounting of the relays presented some difficulty, as although they could be accommodated in almost any vacant space available, due regard to the length of cabling between them and the jack and lamp fields was necessary. In Adelaide the main conveyor belt troughing feeding several tables passes along one end, thus preventing a passage-way through this end, but fortunately the space between adjacent tables and underneath this troughing, which measures 2 ft. 6 ins. x 5 ft. 6 ins. wide, provided an excellent location for a relay cabinet, reducing the cabling to a minimum.

The relays are mounted in sets of three, and with sufficient space to permit adjustments on the line relay. No difficulty was experienced in accommodating in the cabinet, which is fitted with dust-proof sliding-door panels, relay equipment for 50 lines, together with cable terminal strips and jumpering space.

The cable terminal strips include line cable from the main switchboard, the 3-wire jack cable from the table, the line lamp cable, and the busy lamp cable, together with the positive and negative battery feeders which come from a fuse and resistance panel mounted alongside the relay cabinet and underneath the end of the table itself.

By means of jumpering between these strips, which might be termed an I.D.F., it is possible to place any line on to any lamp and jack position, whilst positive or negative battery can also be provided as desired.

In designing the lamp and jack fields mounted on the table, space was again a limiting factor, as not only had the field to be kept small in height and width, but its depth was a most important point, as the operator's cords (working and spare with switch for same) had to be accommodated at a reasonable distance in front of the jack field, whilst due regard had to be given to the cord weights beneath the table. Further, the box containing the lamp and jack strips had to be deep enough to house the main cable form, and the branching forms with sufficient room for access. Figure 1 shows the layout of the table and the space occupied by the lamp and jack boxes.

Although these boxes are multipled, it was impossible to multiple inside the boxes. Each box was cabled to a set of strips mounted vertically on a suitably covered mounting panel erected underneath and across the centre of the table.

As there are six boxes, three each side of the table, these strips were arranged so that each set of three boxes was cabled to individual strips, and a connecting cable was run between the strips, thus allowing one-half of the table to be isolated in case of a multiple fault.

The lamps used are standard 24 volt (line white, busy red), fitted in trunk switchboard 10 unit strips with similar C.B. No. 9 jack strips and designation holders. The lamp and jack strips are screwed to iron multiple standards with butterfly nuts, whilst the whole front is hinged at the bottom. A further means of easy access is furnished by allowing the top of the box to be removed. The cable form is sufficiently long to allow the front to open through

90 degrees, giving full access to all lugs in the multiple fields.

At the main conveyor end of the table a set of battery cut-off jacks has been mounted underneath the table conveyor, and whenever a line is removed from the concentrator at the main switching board, a dummy plug inserted in the battery cut-off jack prevents the line lamp from glowing.

The operator's cord is mounted immediately in front of the multiple field. It is a short cord with single pulley weight directly beneath the table, the weight being protected by a light iron framework to prevent fouling by the operator's body.

A kickback carrier terminal is erected at the end of the table and a number of wire mesh pigeon holes suitably designated are mounted over the conveyor belt and adjacent to the carrier terminal. These pigeon holes are available from each side of the table, and traffic delivered by the kickback is sorted into these receptacles, and then re-distributed along both sides of the table by messengers who place the traffic on the appropriate hooks mounted, as mentioned earlier, at the bottom edge of the belt troughing. The messengers distribute the traffic so that each operator carries approximately the same outgoing load, and whenever possible operators working a line are kept supplied with additional outgoing business as it arrives in the kickback terminal.

Several of the less important duplex circuits serve the outback wheat-growing areas and are extended beyond their duplex terminal to simplex stations by means of duplex-simplex repeaters. The traffic handled on these channels is of a seasonal nature which reduces at times to an ordinary simplex line load. Trials have been made by transferring these circuits on to the concentrator utilising line circuits normally wired for racecourses, etc.

Fortunately, the intermediate station to station traffic on the omnibus lines is small, but when necessary it renders one operator on the concentrator ineffective as he keeps the particular line plugged with his set to prevent the line lamp operating and other operators interrupting the intermediate station business. This method is practically equivalent to intermediate stations handling the whole of their traffic through the concentrator.

In general very little maintenance is necessary, with the exception of alteration to primary line relay adjustments on long country lines during periods of changing weather conditions. These are effected quickly and easily by the mechanical staff on receipt of advice from the traffic supervisor. Routine maintenance tests of table equipment, i.e., cords, relays, keys, etc., are made weekly in addition to a general daily inspection.

Recent figures disclose that the system is capable of handling approximately 19,440 M.U. between the hours of 9 a.m. and 6 p.m. During this period an average of 18 men are employed, each for six hours, so that each operator would handle in these circumstances 1,080 M.U. per shift. This load is increased on peak occasions, but by transferring lines to individual morse sets on the adjacent table, the concentrator load can be maintained at a fairly even figure.

The introduction of the system outlined has reduced lag between any two stations on the concentrator by 60 per cent., and in addition a saving of 12 operators, or 40 per cent. staff reduction has been effected.

ANSWERS TO EXAMINATION PAPERS

The answers to examination papers are not claimed to be thoroughly exhaustive and complete. They are, however, accurate so far as they go and as such might be given within the time allowed by any student capable of securing high marks.

EXAMINATION No. 2024.—FOR PROMOTION AS SENIOR MECHANIC, TELEPHONE INTALLATION AND MAINTENANCE SECTION.

C. R. COOK, A.M.I.E.Aust.

QUESTION:

1. (a) Define:—(i) Impedance; (ii) Dielectric; (iii) Farad.

(b) Explain the following terms and give an example of the application of each:—(i) Electro-polarised relay; (ii) Eddy Currents; (iii) Mutual Induction.

ANSWER:

(a)—

(i) **Impedance** is the effective resistance offered to the passage of an alternating current. It is dependent upon frequency, inductance, capacitance and resistance. It is measured in ohms and its value "Z," for a circuit of "R" ohms resistance, "L" henries inductance, and "C" farads capacitance at a frequency of "f" cycles per second is:—

$$Z = \sqrt{R^2 + \left(2 \pi f L - \frac{1}{2 \pi f C}\right)^2}$$

(ii) A **Dielectric** is a substance which offers a high resistance to the passage of an electric current and which can withstand the application of considerable potential difference without breaking down and allowing a discharge to take place through it.

(iii) A **Farad** is the Practical Electro-Magnetic Unit of capacity; a conductor has a capacity of 1 farad if a charge of 1 coulomb raises its potential by 1 volt.

(b)—

(i) An **Electric-polarised Relay** is one which is polarised by an electric current of fixed direction flowing through one of its windings while the current in a second winding may flow in either direction to oppose or assist the magnetic effect of that flowing in the first, resulting in a normal or operated condition of the relay depending on the direction of the current in the second winding.

Such a relay is used as the F relay in an Auto-Auto Repeater.

(ii) **Eddy Currents** are induced currents in a mass of metal under the influence of a varying magnetic field.

The release of the B relay in a final selector is governed by the effect of eddy currents in the copper slug of the relay.

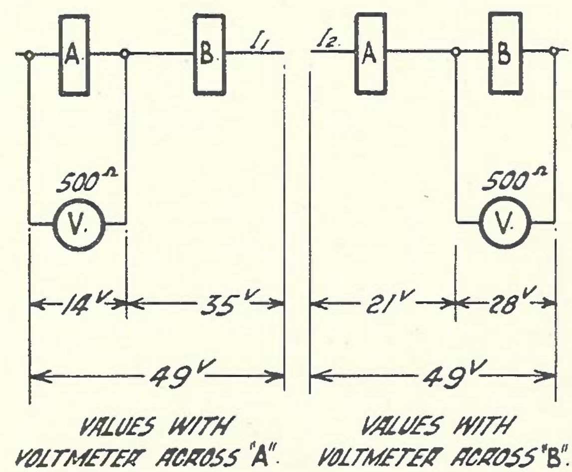
(iii) **Mutual Induction** is the electro-magnetic effect whereby a change of current strength in a circuit will produce another current in an adjacent but insulated circuit. The induced current always opposes the current which produces it.

The induction coil in a subscriber's telephone is an application of this principle.

QUESTION:

2. Two relays A and B are connected in series with each other between battery terminals giving a constant potential difference of 49 volts. When a voltmeter of 500 ohms resistance is connected across A and B in turn, the readings are 14 and 28 volts respectively. Calculate the individual resistances of A and B.

ANSWER:



Voltmeter across "A."

The current flowing when the voltmeter is connected across A is:—

$I_A = (14/A + 14/500) = 35/B$-by ohms law.

Taking a common denominator for the LH side of the equation—

(7000 + 14A)/500A = 35/B.

Divide both sides of the equation by 7, thus giving—

(1000 + 2A)/500A = 5/B or

(500 + A)/250A = 5/B.

Now multiply the equation by 250 AB and obtain—

500B + AB = 1250A, from which

AB = 1250A — 500B . . . . . . (1).

Voltmeter across "B."

The current flowing when the voltmeter is connected across B is—

$I_B = (28/8 + 28/500) = 21/A$,

from which as in the foregoing AB = 375B — 500A.

Equate both values of AB

375B — 500A = 1250A — 500B,

from which B = 2A.

Substitute 2A for B in equation 1.

$2A^2 = 1250A - 1000A$, from which

A = **125 ohms,**

and as B = 2A, therefore

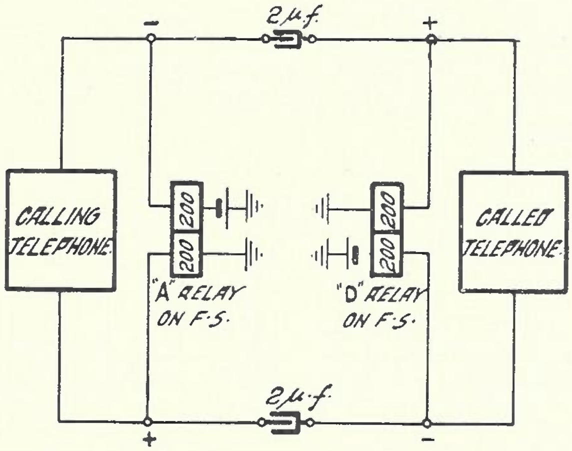
B = **250 ohms.**

QUESTION:

3. (a) Show by means of a schematic diagram the manner in which speaking battery is supplied to two subscribers connected to the same automatic exchange when they are conversing with each other.

(b) In the power supply system of an exchange, what methods and precautions are adopted to prevent: —(i) Crosstalk; (ii) Ringing induction; (iii) generator noise?

ANSWER:



(b) Crosstalk is prevented by—

(i) Employing a secondary battery of negligible internal resistance, and utilising busbars, cables, switches and protective equipment so designed that there will be a drop of not more than 1 volt between the battery terminals and the subsidiary distribution points in the exchange.

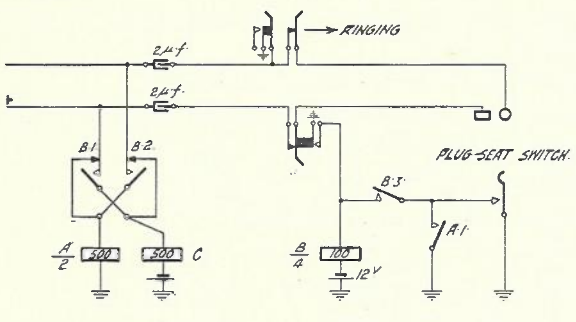
(ii) Ringing leads consist of twisted pairs which are isolated from power leads and conductors carrying speech currents.

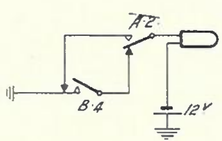
(iii) If the batteries are floated, a special telephone type generator is used and if necessary a choke coil or electrolytic condensers are connected in the output circuit of the machine. Both the charge and discharge leads for each battery are run as far apart as practicable. The positive and negative discharge cables from each battery should be of equal length and bonded together.

QUESTION:

4. Draw a schematic circuit of the manual end of any automatic to manual junction arrangement with which you are familiar. Explain its operation.

ANSWER:





When the loop is placed on the line at the repeater in the automatic exchange, battery from retard coil C flows around this loop to operate relay A. The calling lamp circuit is completed via B4 and A2. The telephonist operates the speaking key, ascertains the number required, inserts the plug in the jack and rings. The extra contacts on the ringing key complete the circuit of relay B. B4 opens the calling lamp circuit; B1 and B2 reverse the battery over the junction and cause registration of the call against the calling subscriber, whilst B3 provides a holding circuit for B via A1 and the plug seat switch in parallel. When the calling subscriber clears, relay A releases and the calling lamp glows, the circuit being via A2, B4 operated, and ground. Relay B holds so long as the plug seat switch is operated and also holds the repeater in the automatic exchange. When the plug is replaced, relay B releases, the calling lamp circuit is opened and the removal of battery from the positive side of the junction clears the repeater in the automatic exchange.

QUESTION:

5. List the functions of each relay on a straight line final selector with which you are familiar.

ANSWER:

The designations and functions of the relays on a final selector are:—

A. Impulsing Relay feeds battery to the calling subscriber and closes the circuit of "B" relay. Responds to impulses from the subscriber's dial and causes the vertical and rotary magnets to operate. When released it prepares the circuit for the release magnet.

B. Guard and Release Control Relay connects ground to release trunk to hold switches in previous ranks and to guard the call against intrusion. Its release closes the release magnet circuit.

C. Impulse Steering Relay operates during the vertical train of impulses and releases at the end thereof, preparing the circuit for the operation of the rotary magnet.

D. Supervisory and Battery Feed Relay feeds speaking battery to the called subscriber and reverses battery from relay A back to previous switches in the connection to provide for supervision.

E. Rotary Control Relay releases at the end of the rotary impulses and prepares the circuit for the testing of the condition of the called subscriber's lines.

F. Ring Trip Relay operates when direct current flows through the called subscriber's loop and cuts off the ringing current and allows the operation of the D relay.

G. Busy Control Relay tests the called party's line for an engaged condition and if such exists informs the calling subscriber by transmitting the busy tone.

H. Wiper Cut-in Relay operates when the subscriber's line is disengaged and connects the wipers to the speaking and ringing circuit after the K (cut-off) relay of the subscriber's line switch has operated.

J. Meter Control Relay controls the period for which the booster battery pulse is applied to the private wire to operate the subscriber's meter.

QUESTION:

6. A subscriber has an exclusive magneto service. Describe the necessary arrangements at his premises before and after the conversion to automatic working of the exchange from which his service is provided.

ANSWER:

Before the cut-over of the automatic exchange, the insulation resistance of the subscriber's wiring should be tested to ascertain that it will withstand a constant pressure of 50 volts and the high peak voltages caused by the operation of the dial. If necessary, the wiring should be replaced. An automatic telephone should be installed in a permanent location and the magneto telephone temporarily installed in a convenient position. The automatic telephone should be connected, and temporary wiring run to the magneto telephone so that both telephones are connected in parallel. The bells of the magneto telephone must be disconnected to prevent a permanent loop when the automatic exchange is cut-over. The automatic telephone should be tested with the test desk and the subscriber instructed as to its operation.

After the cut-over, the magneto telephone and associated wiring should be dismantled, any temporary connections made permanent, the service again tested and the subscriber's operation of the telephone checked.

QUESTION:

7. Describe the construction and operation of a lead acid secondary cell. What tests should be conducted on an exchange battery before it is placed into service?

ANSWER:

A cell consists of a number of positive and negative plates burnt to lead busbars and supported on glass slabs in a wood, lead-lined box. For cells up to 450 Ah capacity glass boxes are used, whilst for portable cells rubber composition boxes are employed. The positive plates are of the Plante type, whilst the negative plates are of the box type. Adjacent plates are of opposite polarity and are spaced evenly by the use of glass tube or woodboard separators. To provide for even working of the end positive plates there is one additional plate in the negative group. The plates are immersed in the electrolyte, which is composed of sulphuric acid and distilled water, specific gravity 1.200. Glass spray plates are placed on the tops of cells to prevent the entry of dust and to arrest the loss of acid through spraying while the cell is on charge. The boxes are supported by glass or porcelain insulators.

When a cell is charged the active material of the positive plates is PbO_2 and that of the negatives is spongy lead in a metallic state. When the cell discharges the sulphuric acid, H_2SO_4 is split into H and SO_4 ions. The H ions move through the electrolyte to the positive plate and reduce the peroxide to monoxide PbO, which combines with the acid to form lead sulphate thus—

$$PbO_2 + 2H + H_2SO_4 \longrightarrow PbSO_4 + 2H_2O$$

At the negative plate the SO_4 ions combine with the lead to form lead sulphate, thus—

$$Pb + SO_4 \longrightarrow PbSO_4$$

When a cell is being recharged the H ions move to the negative plate, and the SO_4 ions to the positive plate.

The chemical reactions are the reverse of the above, and are: $PbSO_4 + 2H \longrightarrow Pb + H_2SO_4$ at the negative plate, and $PbSO_4 + SO_4 + 2H_2O \longrightarrow PbO_2 + 2H_2SO_4$ at the positive plate. As the cell approaches full charge the amount of lead sulphate on the plates is insufficient to combine with all the ions reaching the plates. Hydrogen gas is given off at the positive plate and oxygen gas is given off at the negative plate from the combination of SO_4 ions, with the water H_2O to give O_2 and H_2SO_4. This is termed gassing, and indicates that the cell is fully charged.

The following tests should be conducted:—

(i) A test for ampere hour capacity to ensure that the battery will give its rated output when discharged at the 10-hour rate from a fully charged condition down to 1.85 volts per cell.

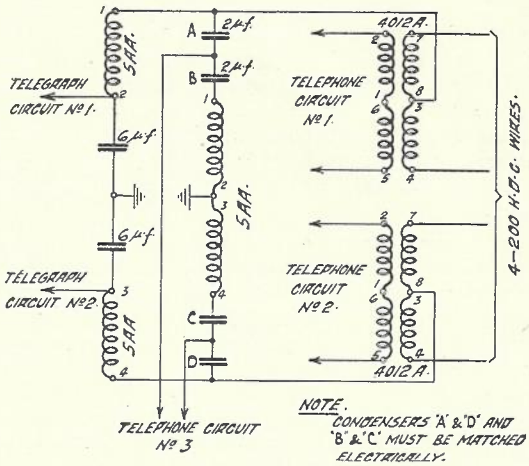
(ii) A test for ampere-hour efficiency, which is the ratio of the current in amperes multiplied by the time in hours for charge and discharge, the discharge being subject to the conditions specified above.

(iii) A test for watt-hour efficiency, which is the ratio of the ampere hours multiplied by the average voltage for charge and discharge under the conditions specified above.

QUESTION:

8. Two pairs of 200-lb. hard-drawn copper wire connect a country exchange to the main trunk exchange. Describe with the aid of diagrams how you would provide three speaking channels and two morse circuits over the two pairs of wire. How would you provide for signalling over the three speech channels?

ANSWER:



The diagram shows schematically the electrical connections at one end of the line which would provide for the required facilities. The method consists of superimposing a telephone phantom circuit on two pairs of trunk wires and connecting the composite circuit equipment to this phantom. This consists of two 4012A transformers, 2-5 A.A. retards and six condensers which are connected as shown. To avoid interference with the telegraph circuits signalling current of at least 135 cycle frequency is used over the phantom circuit. Ordinary 16 cycle signalling can be employed on the side lines.

The required facilities could also be given by connecting composite equipment in each of the side lines instead of on the phantom circuit. This, however, would not be as economical as the method given.

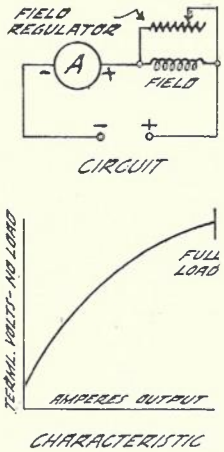
QUESTION:

9. (a) Explain the essential differences between a series wound generator and a shunt wound generator.

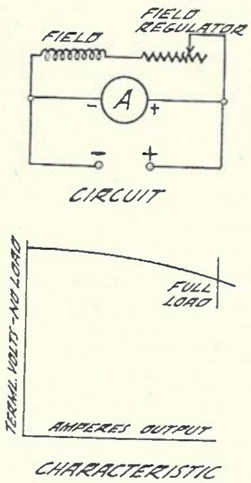
(b) In what regard does a special telephone type generator differ from one manufactured for commercial purposes?

(c) What additional equipment must be used if a commercial type generator is used for floating the batteries in a telephone exchange, and why?

ANSWER:



SERIES GENERATOR



SHUNT GENERATOR

(a) In a series wound generator, the current which flows through the armature also flows through the field windings. Thus as the current increases, the terminal E.M.F. also increases according to an approximately linear law. With a further increase in current the terminal E.M.F. reaches a maximum value when the field becomes saturated. (See curve.) An increase in current beyond this point causes the terminal E.M.F. to drop.

In a shunt wound generator (see sketch), the field is in parallel with the armature winding. With this generator on open circuit the field can be considered as in series with the armature and the generator will build up its own field and give full voltage on no load. An increase in current causes only a slight reduction in the terminal E.M.F.

(b) A special telephone generator is constructed so that the output is as free as possible from electrical pulsations. This is effected by—

(i) An increase of about 50 per cent. in the number of armature coils and slots;

(ii) A corresponding increase in the number of commutator bars;

(iii) Cutting the slots in the armature at an angle to the axis of the shaft; and

(iv) Extending the pole pieces so that they encase a greater section of the armature.

(i) and (ii) raise the frequency and reduce the amplitude of the generator pulsations and (iii) and (iv) cause a further reduction in amplitude.

(c) A choke coil must be connected between the battery and the generator so that the electrical pulsations will be smoothed out and so eliminate noise on speech circuits. The inductance of the choke should be sufficient to eliminate this noise, but its ohmic resistance should be sufficiently low to cause a negligible drop of potential in the circuit.

QUESTION:

10. Why is one terminal of the battery in an automatic exchange connected to earth? Which terminal is so connected and why is that particular one chosen?

ANSWER:

One terminal of a telephone exchange battery is earthed for the following reasons:—

(a) To provide a return circuit for signalling currents on junction line circuits.

(b) To reduce the number of fuses required in the power supply system and to avoid the necessity of insulating some of the return conductors.

(c) To prevent crosstalk and other disturbances due to leakage and capacity effects between the circuits connected to the battery.

(d) To ensure prompt indication of earth faults and assist in their location.

(e) To assist in identifying wires in external plant.

The positive terminal of the battery is earthed—

(a) To prevent electrolytic erosion caused by leakage currents.

(b) To ensure a more reliable indication of partial earth faults by preventing the formation of an insulating oxide coat on the fault conductor.

(c) To reduce the causes of fuse operation.

EXAMINATION No. 2026.—FOR PROMOTION AS SENIOR MECHANIC, TELEGRAPH MAINTENANCE.

S. WEBSTER

QUESTION:

1. (a) What is meant by double current working?

(b) What are the advantages of double current working?

ANSWER:

(a) Double current working is so called because in this system an E.M.F. of negative potential is applied at the sending end to transmit a marking signal, and a positive E.M.F. of equal value is applied to send a spacing signal.

At the receiving end, in order to receive double current signals, it is necessary to provide an instrument, the operation of which is dependent upon the direction of the current passing through its windings (e.g., polarised relay).

(b) The advantages are greater speed of working due to (i), (ii) and (iii) and more stable working due to (iv) because double current working

(i) hastens the discharge of the line;

(ii) enables the relay to be worked in the most sensitive condition, i.e., a neutral setting;

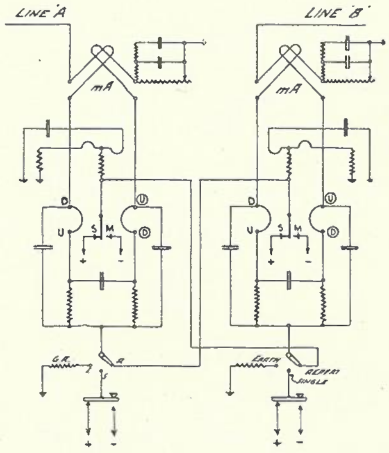
(iii) reduces the effects of the residual magnetism of the cores of the relay;

(iv) reduces the effects of any variation in the value of the received current, due to leakages, etc., since both marking and spacing currents are equally affected.

QUESTION:

2. Why are repeaters on long telegraph lines? Give a sketch showing the schematic circuit of a fast speed differential duplex repeater.

ANSWER:



Quest. 2.—Fig. 1.

Notes:

(1) Equal batteries usually connected to same source through common battery resistances.

(2) A Polarized Sounder and a Wheatstone Receiver governing a Sounder are generally provided for monitoring and observation purposes. They are connected through leak resistances to the tongues of the relays, one to each relay.

Repeaters are used on long telegraph lines in order that a greater speed of working may be attained.

The speed of working of a circuit is inversely proportional to the square of the length of the line thus:

$$\text{Speed of working} = \frac{K}{L^2CR.} \quad \text{where } K = \text{a constant}$$

L = length of line (miles)

C = capacity per mile

R = resistance per mile.

If the line be divided into two circuits of equal length, the speed of working of either section would be:

$$\frac{K}{(\frac{1}{2}L)^2\ C.R.} = \frac{K}{\frac{1}{4}L^2\ C.R.} \text{ or } \frac{4K}{L^2\ C.R.}$$

Hence, the inclusion of a repeater at the electrical centre of a line would increase the speed of working of the total circuit to four times the original speed.

QUESTION:

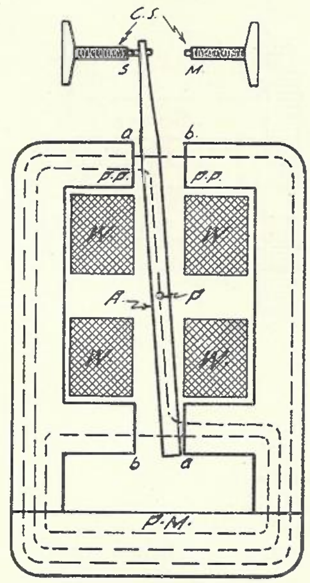
3. Show by means of a sketch the magnetic circuit of a Creed 27 V polarised rēlay. Explain the movement and action of the armature.

ANSWER:

(a) When no current is passing through the windings and the armature is resting on one contact S, the main magnetic circuits are across the pole gaps as shown. A small portion of the magnetic flux induced by the permanent magnet passes through the armature, as shown, holding it firmly on the contact S.

(b) When a current passes through the windings in such a direction that it reverses the polarity of the armature, the armature is repelled at points a and attracted at points b. This causes the armature tongue to move rapidly to the other contact M and here, if no current is flowing, a retaining flux passes through the armature in a direction opposite to that passing under condition (a).

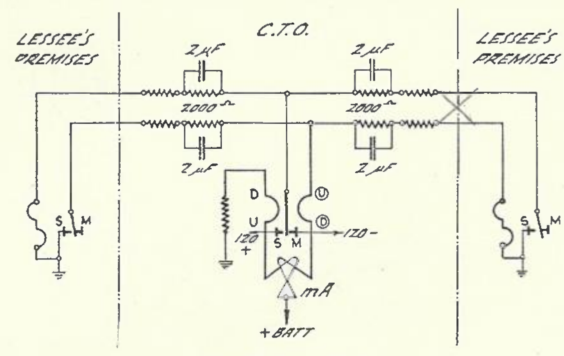
(c) Similarly when the flow of current is reversed, the armature tongue is moved from contact M to S.



(d) The movement of the armature connects the tongue and its associated terminal to either the S or M contact, according to the direction of the current through the winding.

QUESTION:

4. Draw a schematic circuit showing the connections necessary for a Teleprinter point to point local service.



Quest. 4—Fig. 1.

Note.—At the C.T.O. a monitoring and observation teleprinter is provided. By means of suitable switching facilities this teleprinter may be used to test, with either lessee or to monitor on through traffic.

QUESTION:

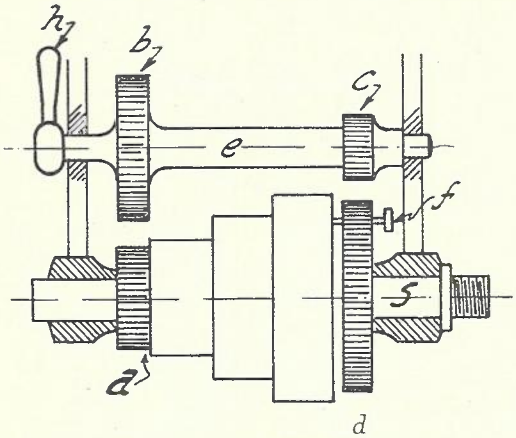
5. Show by means of sketches the construction of the head stock of a back geared lathe, and explain the operation.

ANSWER:

The gear d is keyed to the spindle S. The cone is fixed to gear a and is free to revolve on the spindle S. The back gears b and c are fixed to the ends of a hollow shaft e which is supported on an eccentric shaft on brackets at the rear of the headstock.

When the gears b and c are not in mesh with gears a and d, the cone may be fixed to the gear d by means of the pin f. When thus connected, the cone and spindle revolve together.

When the back gears are to be used, this pin is disengaged and this frees the cone from the gear d.



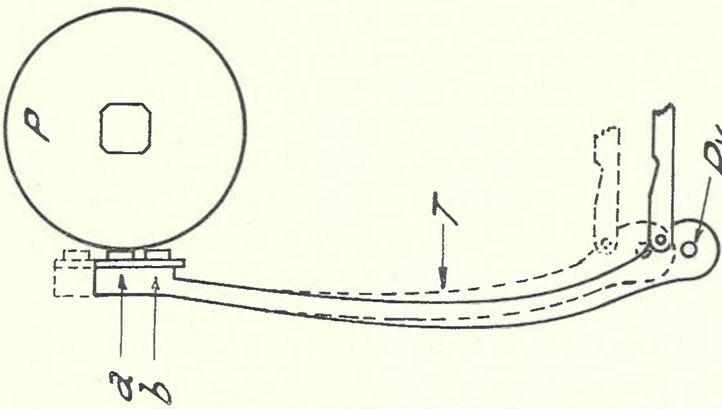
The back gears are then brought forward by partly rotating the handle h to engage with gears a and d. The drive is then from cone gear a to b and c, and from c to gear d and spindle.

When the back gears are in use, the turning speed is greatly reduced, and it is then possible to take much deeper cuts.

QUESTION:

6. Compare the methods employed in the Morkrum printer and the Creed teleprinter 7C in the selection of upper- and lower-case characters. Sketches should be used.

ANSWER:



Quest. 6—Fig. 1.
P—Platen
T—Type Bar.
Pv—Pivot
a—Letter Type
b—Figure Type.

In both Morkrum Printer and Creed Teleprinter 7C any particular code combination is common to an upper- and lower-case character, e.g., Letter Q—Figure 1.

When a combination is received, the case of the printed character is determined by the position of some mechanical part of the machine. The position of this part has been predetermined by the sending of a figure or letter case shift signal.

In the Morkrum Printer, the position of the type basket is the deciding factor.

This basket, in which the type bars are mounted, can be locked in either one of two positions (upper or lower).

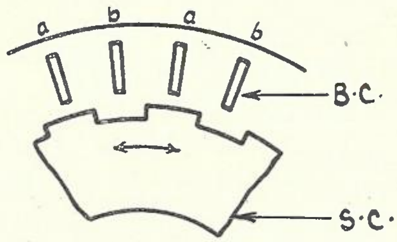
As shown in Figure 1, each typebar carries two characters, a and b, one above the other.

When the type basket is in the lower position, the upper type (a) strikes the platen and is printed, whilst the lower type (b) clears the paper.

When the type basket is in the upper position, the lower type (b) strikes the platen and is printed. The position of the typebar when the type basket is in the second position is shown dotted in Figure 1.

In the Teleprinter, figures or letters are printed according to the position of the shift comb S.C. in Figure 2.

When the receiving combs are set up in accordance with the received signal, a space is provided beneath two adjacent bell cranks. One of this pair (a) corresponds to a figure character and the other (b) to a letter. The shift comb is free to turn through a small angle on the central bearing and according to its position one only of this adjacent pair of bell cranks can be drawn inward.



Quest. 6—Fig. 2.
SC—Shift Comb.
BC—Bell Crank.

The radial movement of the bell crank stops the rotating type head so that the letter corresponding to bell crank b, or the figure corresponding to bell crank a, is in between the type hammer and the platen and is printed.

QUESTION:

7. Explain with the aid of sketches how a double Murray multiplex system divides the use of the channel between the two sending operators and two receiving operators at each end of the channel.

ANSWER:

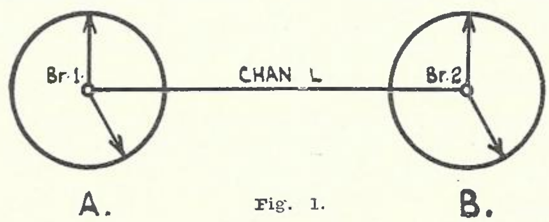


Fig. 1.

The Murray multiplex system divides the channel time between operators, by the use of rotating brush distributors.

In Figure 1, A and B are two Murray terminal stations joined by the two-way channel L. Br. 1 and Br. 2 are the sets of rotating brushes of mux. distributors making contact with the segments of their respective plateaux.

The brushes rotate in synchronism and maintain the same phase relationship indefinitely.

For the purpose of simplicity, the send and receive rings at Station A have been developed in Figure 2.

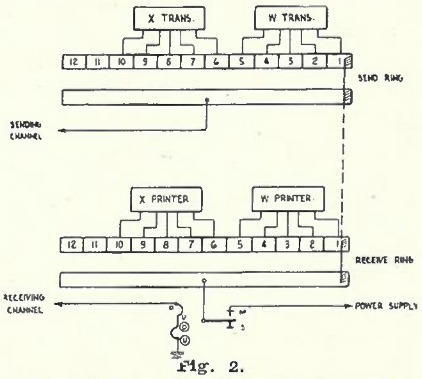


Fig. 2.

The figure indicates the W and X transmitter and printer connections at Station A. The arrangements at Station B are exactly similar. By the action of the transmitter on W arm, Marking or Spacing potentials are applied to the send segments in accordance with the code; and as the send brush passes over these segments the potential on each is applied to the line and operates the polarised relay at Station B.

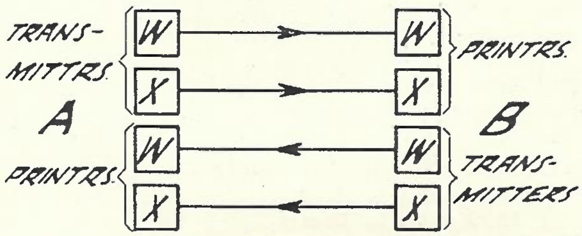


Fig. 3.

Simultaneously with the operation of the relay by the potential applied from segment 1 at Station A, the receiving brush at B is passing over segment 1 of the receiving ring. The first impulse magnet is, therefore, operated or unoperated according to whether the relay tongue is on M or S contact.

Because the brushes are in synchronism, the succeeding printer magnets are similarly controlled. The segments 1-5 are associated with the W arm and segments 6-10 with the X arm.

Since at each station a send and receive brush are rigidly fixed and rotate together, the receiving brush at A must be in synchronism with the send brush at B.

Transmission may, therefore, take place from B to A simultaneously with transmission from A to B.

The system as described, therefore, divides the use of the channel in each direction between the two arms as indicated in Figure 3.

QUESTION:

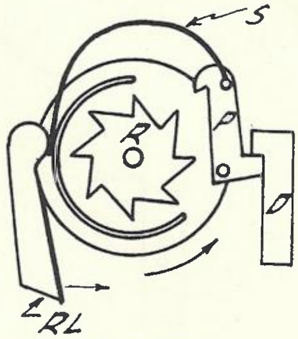
8. Compare the clutches employed on the receiving cam drums of the Creed Teleprinter 7C and Morkrum Teletype receiving unit. Sketches should be used freely.

ANSWER:

The essential difference between the clutches employed in the Teleprinter 7C and the Morkrum Teletype receiving unit is that the former consists of a ratchet and pawl whilst the latter is of a friction type.

Figure 1 shows the main parts of the Teleprinter receiving cam clutch. When the cam or drum is revolving the pawl P is forced into engagement with the ratchet R under the action of the spring S.

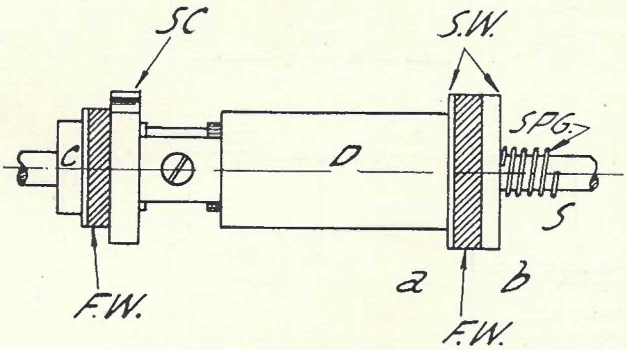
When the drum completes one revolution, the detent D, being in the path of the pawl, forces it to disengage from the ratchet. The end of the retention lever R.L. rests in a hollow in the drum and holds the drum in a fixed position.



Quest. 8. —Fig. 1.
D—Detent
P—Pawl
S—Spring
R—Ratchet
RL—Retention Lever.

Note.—Two pawls and two ratchet wheels are mounted side by side. The ratchet wheels are so disposed that the teeth on one appear half-way between those on the other. The arrangement is equitable.

When a start of spacing signal is received, the detent is drawn out of the path of the pawl, the pawl engages with the ratchet, and, as before explained, remains engaged until the drum has completed one revolution.



Quest 8.—Fig. 2.
FW—Felt Washers
SW—Steel Washers
D—Drum
S—Spindle
SC—Stop Cam
SPG—Spring
C—Collar.

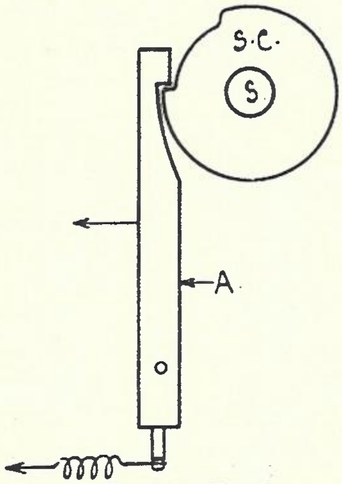
The Morkrum Teletype receiving drum and clutch are shown in Figure 2. The drum, to which the stop cam S.C. and steel washer S.W. (a) are fixed is free to revolve on the spindle S. The steel washer S.W. (b) is keyed to the spindle, but is free to move along it. The collar C is fixed to the spindle.

Oil-impregnated felt washers F.W. are placed between the ends of the drum assembly and the internal surfaces of the collar and steel washer S.W. (b).

The spring S PG applies a force in the direction shown, thus keeping the felt washers under pressure.

The spindle is revolving continuously, and, due to the friction between the surfaces of the felt and steel washers, the drum tends to revolve with it.

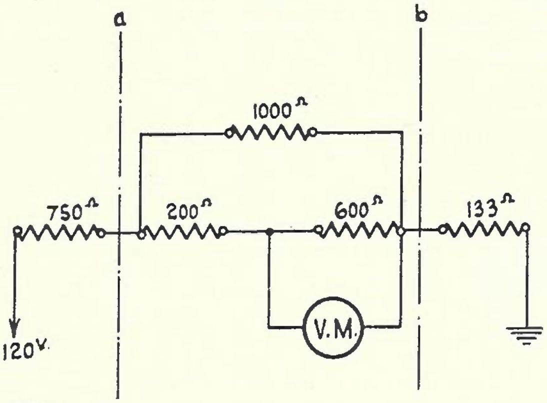
When the start signal is received, the armature A releases the stop cam as shown in Figure 3. The drum makes one complete revolution at the end of which the detent on the armature is again in the path of the notch in the stop cam and brings the drum to rest.



Quest. 8—Fig. 3.
A—Armature
SC—Stop Cam
S—Spindle.

QUESTION:

9. Assuming a voltmeter of infinite resistance, what voltage would be indicated by VM in the circuit below:



ANSWER:

To find joint resistance of 1000 ohms and 800 ohms in parallel.

$$\text{Joint conductance} = \frac{1}{1000} + \frac{1}{800} \text{ ohms}$$

$$= \frac{4 + 5}{4000} = \frac{9}{4000} \text{ ohms}$$

$$\text{Joint resistance} = \frac{4000}{9} \text{ ohms.}$$

$$\text{The total resistance of circuit} = 750 + \frac{4000}{9} + 133 \text{ ohms}$$

$$= \frac{6750 + 4000 + 1197}{9} \text{ ohms.}$$

$$\text{Voltage drop across a b} = \frac{4000}{11947} \text{ of } \frac{120}{1} \text{ volts.}$$

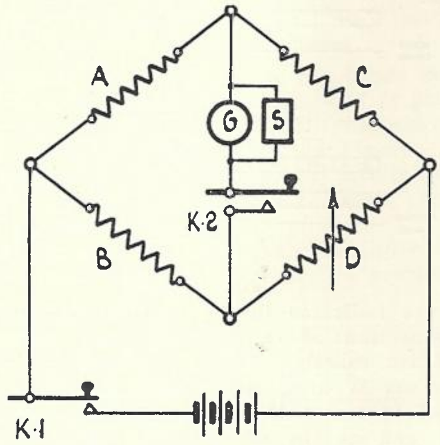
$$= 40.2 \text{ volts approximately}$$

$$\text{and voltage drop across 600 ohms} = \frac{600}{800} \text{ of } \frac{40.2}{1}$$

$$= 30.2 \text{ volts approximately.}$$

QUESTION:

10. Draw a schematic diagram of a Wheatstone bridge and explain how you would measure a resistance of 2 ohms using the bridge.



Quest. 10—Fig. 1.
A & B—Ratio Arms
C—Unknown Resistance
D—Variable Resistance
G—Galvonometer
S—Shunt
K1 & K2—Keys.

ANSWER:

Assuming that is known that the resistance value to be measured is low, the ratio arms are set at some convenient ratio, say, 100 to 1.

10 ohms in A arm.
1000 ohms in B arm.

To take readings generally, K1 is first closed, then after a short interval K2 is closed and reading taken.

With the galvanometer shunted with a low resistance shunt, apply potential and adjust variable resistance until the galvanometer shows no deflection.

Then increasing the value of the shunt and adjusting the variable resistance D, refine the balance until the galvanometer with unity shunt, shows no deflection.

Then resistance of $C = \frac{D}{100}$, i.e., if variable resistance is 200 ohms, the resistance of the coil measured is 2.00 ohms.

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