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OCTOBER, 1947

CONTENTS

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The Telecommunication Journal of Australia

Vol. 6, No. 5 *October, 1947*

MR. S. H. WITT, A.M.I.E.E. (LONDON), M.I.E. (AUST.), F.I.R.E. (AUST.).

Mr. Witt, Supervising Engineer, Research, is proceeding to Geneva to take up a five-year appointment as a member of the International Frequency Registration Board on the nomination of the Australian Government. Australia is one of the 11 countries selected by the International Telecommunications Conference at Atlantic City to nominate a member of this Board, which will deal with all questions of radio-frequency assignments. The members thereof will not act as national representatives but as an independent panel of impartial experts.

The Postal Electrical Society wishes him success in his new sphere and takes this opportunity of expressing its gratitude to him for the continuous and very effective support he has given so readily to the Society. After its reconstruction in 1932 he was twice elected President of the Society—in 1933 and in 1942. He is well known to our members for his lectures and to our readers by the many papers he has contributed to the Journal.

Mr. Witt began his engineering career in the Postmaster-General's Department as a Junior Instrument Fitter in 1909 and was appointed as an Engineer in 1913. In 1921-1922 he visited America, England and Europe to study the latest methods in telephone, telegraph and radio communication and, as a result of this visit, he planned the trunk line network of the Commonwealth. In addition, he was responsible for the introduction of carrier systems into Australia. In 1923 he undertook the task of establishing the Research Laboratories and in 1924 was promoted to the position of Supervising Engineer in charge of Research, which today numbers more than 140 officers on its staff.

His was the responsibility for planning and, at least in the initial stages, for the construction of the National Broadcasting System in Australia. Later, he directed the design and construction of "Radio Australia," the World Broadcasting Station at Shepparton, Victoria. During the war years he was associated with many Boards and Committees dealing with the application of Radar and Radio Communication for war purposes and supervised this Department's contribution to the Radar programme.

In 1945-46 he visited England as an Australian representative at the Commonwealth Communications Council and was a member of the Commonwealth and Empire Conference on Radio for Civil Aviation. He also visited America and attended the Telecommunications Conference at Bermuda on behalf of Australia. During March, 1947, Mr. Witt again represented Australia at the meeting of the Commonwealth Communications Council in London. He was a member of the Australian Delegations to the Universal Postal Congress held at Paris in May, 1947, and to the International Telecommunications Conference in Atlantic City, U.S.A., in July, 1947.

Mr. Witt is an active member of The Institution of Engineers, Aust., of which he is a Councillor, and in 1945-46 was Chairman of the Melbourne Division. He is a Councillor of the Institution of Radio Engineers (Aust.) and has been a Vice-Chairman of that Institution.

At a recent meeting of the Society the opportunity was taken to express to Mr. Witt the thanks of members for his invaluable assistance and friendship over the years and to tender him the best wishes of the Society in his new and onerous position. The occasion was marked by the presentation of a memento and the announcement of his election to Life Membership by a unanimous vote of the Committee.

AUTOMATIC TELEPHONE DIALS

J. H. T. Fisher, B.E., A.M.I.E, (Aust.)

GENERAL INFORMATION ON SIX PARTICULAR MAKES

Introduction: It is proposed to compare the general features of dials available from overseas. In particular, this article describes the various methods of giving the "inter-digital pause" or minimum time interval between successive trains of dialled impulses, and discusses the relative merit of introducing this pause at the beginning or at the end of each train, having regard to the various types of automatic switchgear with which the dial might be required to operate in Australia.

The dials included in this discussion are listed in Table I, and a general summary of the comparisons is given in Table II.

In all dials considered, the rate of impulsing is nominally 10 impulses per second.

Reliability of Electrical Contact: Experience indicates that the use of double contacts and the presence of a slight rubbing action when the contacts close, materially assist in ensuring reliability of contact.

The rubbing action exists in the Siemens No. 10 dial and, to a lesser extent, in the W.E. 5E dial, the impulse contacts having a slight "follow" after making. There is no rubbing action in the A.T.M. 24C and A.E.C. 24 dials except when the impulse contacts are lifted clear of the impulse cam at the end of each train. No rubbing action is provided in the S. & H. 180a and Ericsson S2836 dials. Of the dials examined, only the W.E. type has double point impulse contacts.

TABLE I.

Illustration	Type	Manufacturer	Country of Manufacture
Fig. 1	No. 10	Siemens Brothers & Co. Ltd.	Great Britain
Fig. 2	24C	Automatic Telephone & Electric Co. Ltd. (A.T.M.)	Great Britain
Fig. 3	24	Automatic Electric Co.	U.S.A.
Fig. 4	5E	Western Electric	U.S.A.
Fig. 5	Fg. Sch. 180a	Siemens and Halske	Germany
Fig. 6	S2836	Telefon AB. L. M. Ericsson	Sweden

The specimens compared are the latest types available in each case, but do not necessarily represent current practice of the manufacturers concerned. The 24C and 24 types are almost identical, differing only in the finger plate, ratchet wheel, and other respects indicated in Table II.

Impulse Contacts

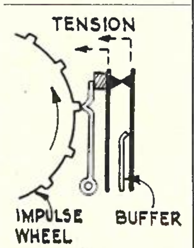
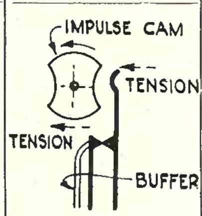
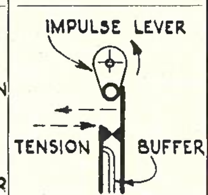
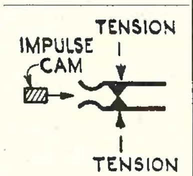
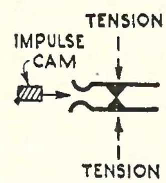
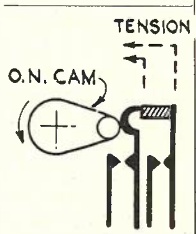
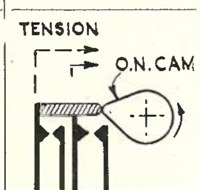
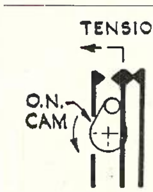
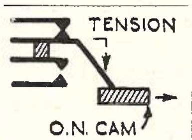
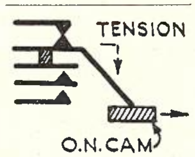
The make to break impulse ratio and the rate of impulsing are inherently bound up in the physical dimensions and adjustment of the dial parts and in the governor adjustment respectively, and are not considered here. Desirable features of these contacts, however, are:—

(a) reliability of electrical contact,
(b) uniformity of impulse ratio,
(c) freedom from contact "bounce"; and
(d) efficient suppression of impulses during forward motion of dial.

Uniformity of Impulse Ratio: The maximum of impulse ratio uniformity would be obtained if each impulse were formed by the same cam surface operating on the same impulse springs. This is not the case in any of the dials examined but, in the A.T.M. 24C and A.E.C. 24 dials, a rotating double cam is used, so that only two cam surfaces are involved and each surface produces every alternate impulse (Figs. 2 and 3).

In the S. & H. 180a and Ericsson S2836 dials, rotating triple cams are used, so that three cam surfaces are involved and each surface produces every third impulse (Figs. 5 and 6). In these two dials the impulse springs are separated by the cam teeth entering between them. This calls for the impulse springs to be symmetrically disposed with respect to the cam teeth before separation, which necessitates equal tension on each spring. As impulse-ratio is normally adjusted by means of impulse spring tension, this means that impulse-ratio adjustment would be more complicated in the S. & H. and Ericsson dials than in the other dials examined. In the case of the S. & H. dial, a detent spring (Fig. 5), operated by a cam on the main shaft, engages a notch in any one of the impulse-cam teeth at the end of the return motion of the finger plate; this locks the cam at the correct orientation for commencement of the next

TABLE II.
Summary of Comparisons of Six Makes of Automatic Telephone Dials

TYPE OF DIAL.	Siemens No. 10.	A.T.M. Type 24C. A.E.C. Type 24.	W.E. Type 5E.	Siemens and Halske Fg. sch. 180a.	Ericsson (Sweden) Type S2836
Impulse Contacts					
Break length per cent.	66.6 (63 to 70).	A.T.M. 66.6 (63 to 70). A.E.C. 61.5.			
Mode of operation.	Toothed impulse wheel on main shaft.	Double cam on governor worm-gear shaft.	Toothed impulse wheel on main shaft, operating impulse lever.	Triple cam on governor worm-gear.	Triple cam on governor worm-gear shaft, driven by ratchet wheel secured to shaft.
Spring Assembly.					
Type of contacts.	Single point.	Single point.	Double point.	Single point.	Single point.
Method of suppressing impulses in forward direction.	Slipping - cam masks impulse wheel teeth.	Pawl on main shaft trails and does not transmit drive to double cam and worm-gear shaft.	Impulse lever trails over impulse teeth in a position clear of impulse springs.	Pawl on pinion trails and does not transmit drive to triple cam and worm gear.	Pawls on either side of triple cam. One pawl engages ratchet slots in frame - locking cam. Other pawl trails over ratchet secured to worm-gear shaft.
Off-Normal Contacts					
Mode of operation.	Cam on main shaft.	Cam on main shaft.	Cam on main shaft.	Cam on main shaft.	Cam on main shaft.
Spring Assembly (Dial normal).					
Type of contacts.	Single point.	Single point.	Double point.	Double point.	Single point.
Inter-Digital Pause					
Duration (pulse periods, approx.).	2¼.	A.T.M. 2¼. A.E.C. 1½.	1.	2.	1½.
Position with respect to impulses.	Before.	After.	Before.	After.	After.
Method of production.	Slipping-cam on impulse wheel, masking impulse teeth.	Cam on main shaft, lift-in impulse springs clear of impulse cam.	Reversal of trailing direction of impulse lever against impulse wheel.	Short circuiting of impulse contacts by cam operated off-normal contacts.	Short circuiting of impulse contacts by cam operated off-normal contacts.
Remarks.	Depends on friction between cam and disc on main shaft.	Positive operation by cam.	Positive operation by impulse wheel and lever.	Depends on off-normal contacts.	Depends on off-normal contacts.

Governor

Speed ratio to main shaft.	90:1.	A.T.M. 126:1. A.E.C. 117:1.	19.4:1.	112:1.	91:1.
Rotation.	Forward (with slight slipping) and return.	Return only.	Forward and return.	Return only.	Forward slightly (slipping and return).
Bearing thrust.	Both ways.	One way.	Nil.	One way.	Mostly one way.
Drive.	Spur gears and worm.	Spur gears and worm.	Spur gears only.	Spur gears and worm.	Spur gears and worm.
Remarks.	Spring clutch on worm-gear shaft permits some slipping in drive on forward rotation and allows governor to over-shoot after dial returns to normal position.	Ratchet wheel on spur gear, and pawl on main shaft, transmit only return drive to governor. Self-lubricating worm gear.		Ratchet wheel on worm gear and pawl on pinion transmit only return drive to governor. Self-lubricating worm gear.	Spring clutch on worm-gear shaft transmits only return drive positively to governor and allows governor to overshoot after dial returns to normal position.

General

Fitting and overall diameter.	3 point standard 3⅜″.	A.T.M. 3 point standard 3⅜″. A.E.C. Non-standard 3″.	Non-standard 3″.	Non - standard 3-7/32″.	3 point standard (adapter casing) 3″.
Type of terminals.	Screws.	Screws.	Screws.	Solder lugs.	Solder lugs.
Type of main spring.	Spiral.	Helical.	Helical.	Spiral.	Helical.
Remarks.	Moderately noisy in operation.	A.T.M. Noisy in operation. A.E.C. Quiet in operation.	Complex construction. Moderately quiet in operation.	Extreme simplicity of construction and mechanism. Quiet operation.	Quiet in operation.

forward rotation. A similar function is performed by the stepped spring-pawls on the impulse-cam of the Ericsson dial (Fig. 6), which fall into ratchet slots in the dial frame and retard the cam at the correct orientation.

In the Siemens No. 10 (Fig. 1) and W.E. 5E dials, each impulse is produced by a separate tooth on the impulse wheel, so that up to ten cam surfaces are involved. As the full number of teeth is employed only when "0" is dialled, wear will not be uniform on all teeth, and hence impulse ratio may not remain uniform. The toothed impulse wheel in the W.E. 5E dial is concealed within the body of the dial in Fig. 4.

Freedom from Contact "Bounce": The impulse contact springs, which must operate at the rate of 10 impulses per second, "remake" at a high speed after separation, and, being made of elastic material, tend to rebound on impact, or "bounce." When "bounce" actually occurs, it results, of course, in distorted signals.

In order to eliminate "bounce," it is necessary to arrange for the kinetic energy of the moving parts on impact to be absorbed. This may be effected by

(a) an elastic damping system,
(b) friction damping, or
(c) some combination of (a) and (b).

The fundamental principles of these methods are illustrated diagrammatically in Fig. 7.

In Fig. 7 (a) a spring, which is pre-loaded with the contacts unoperated, holds the stationary contact against a stop. When the contacts close, with proper design the energy of the moving contact is absorbed in extending the spring and in overcoming the inertia of the stationary contact, which is deflected away from the stop (References 4 and 5).

In Fig. 7 (b) a flexible buffer behind the stationary contact is deflected on impact of the moving contact, and the rubbing friction between the stationary contact and buffer absorbs some of the kinetic energy.

In Fig. 7 (c) the same device is used in the stationary contact, and, in addition, the moving contact is pre-loaded, i.e., the moving contact is borne on a leaf spring which is tensioned against the stationary contact when in the static "made" position. When the contacts close, the energy of the moving contact is absorbed in flexure of the leaf spring and in friction between the stationary contact and its buffer.

The impulse contact arrangements in the dials examined are shown diagrammatically in Table II, the contacts being shown in the closed position as when the dial is normal.

(i) In the Siemens No. 10 dial, when the impulse contacts are open, the stationary contact spring is pre-loaded by tension against a buffer (compare Fig. 7 (a)).

(ii) In the A.T.M. 24C and A.E.C. 24 dials, when the impulse contacts are closed, the moving contact spring is pre-loaded by tension against the stationary contact, which has a buffer behind it (compare Fig. 7 (c)).

(iii) In the W.E. 5E dial, when the impulse contacts are closed, the moving contact spring is pre-loaded by tension against the stationary contact which is pre-loaded by greater tension against a buffer.

(iv) In the S. & H. 180a and Ericsson S2836 dials, when the two moving impulse contact springs are closed, they are both pre-loaded by mutual tension.

In all these cases, conditions of "bounce" are governed by such factors as degree of contact spring pre-loading, impact force on closure, and the inertia, deflection characteristics and natural period of vibration of the contact springs and buffers, and it is obvious that the effect of such factors cannot be estimated from a visual examination.

Oscillograph measurements are often used to detect contact bounce, but no check was made of the adjustment of the contact springs of the sample dials under discussion, and, consequently, no cathode ray oscillograph measurements were made of these dials.

Suppression of Impulses during Forward Motion of Dial: As will be seen from Table II, each of the dials examined uses a different means to achieve this (except the A.T.M. 24C and A.E.C. 24 dials, which are equivalent in this respect), although the S. & H. 180a and Ericsson S2836 dials use somewhat similar means. In the Siemens No. 10 Dial (Fig. 1), maintenance of the correct frictional adjustment would be most necessary, as, if the slipping cam were badly worn or out of adjustment, it would be possible for this cam to slip too much. In such cases, the inertia of the slipping cam resisting the frictional pull during forward motion might result in failure of the cam to mask all teeth of the impulse wheel during

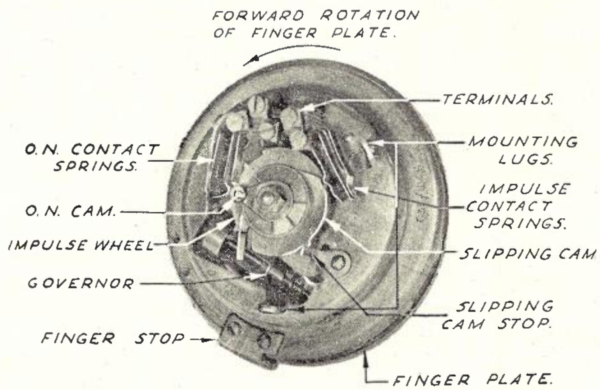


Fig. 1.—Siemens No. 10 Dial—rear view. (Normal position.)

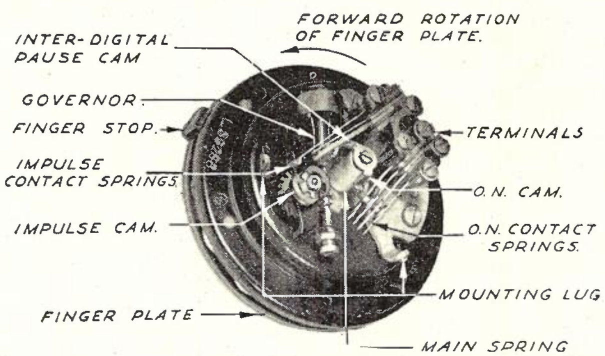


Fig. 2.—A.T.M. Type 24C Dial—rear view. (Normal position.)

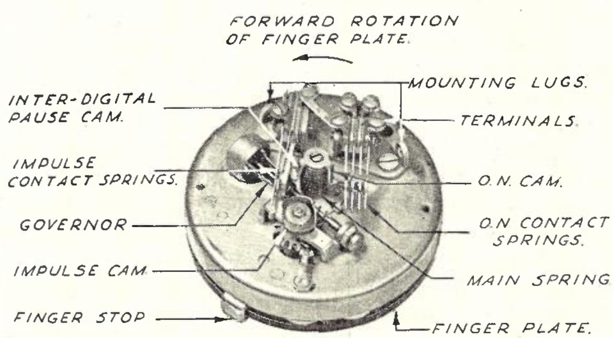


Fig. 3.—A.E.C. Type 24 Dial—rear view. (Normal position.)

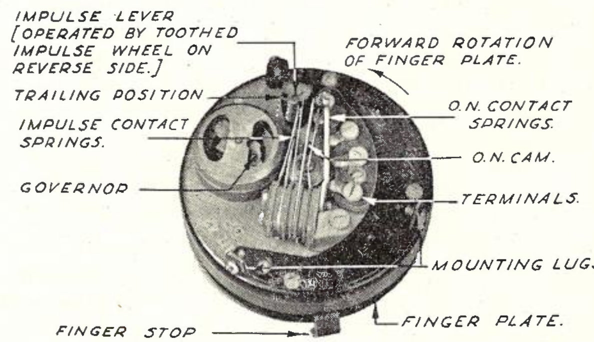


Fig. 4.—W.E. Type 5E Dial—rear view. (Normal position.)

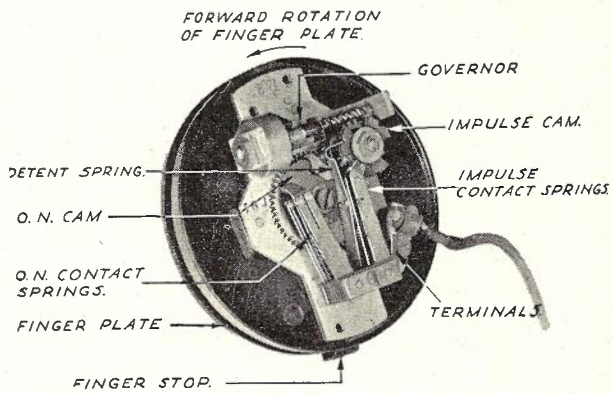


Fig. 5.—Siemens & Halske 180a Dial—rear view. (Normal position.)

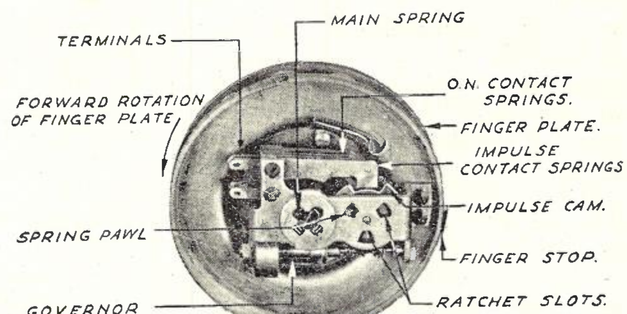


Fig. 6.—L.M. Ericsson Type S2836 Dial—rear view. (Three-point mounting adapter cap removed—normal position.)

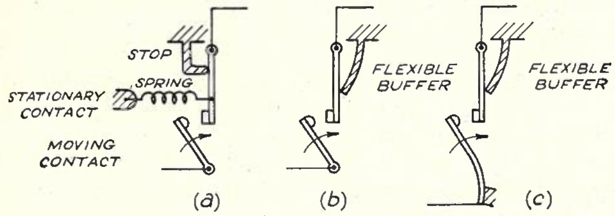


Fig. 7.—Methods of eliminating contact bounce.

this period, which would produce false impulse during the forward rotation.

Off-Normal Contacts

In all dials examined, the off-normal contact springs are operated by some form of cam attached to the main shaft, and there is appreciable "follow" in the pair of springs which "make" when the finger plate is rotated forward from its normal position. In the W.E. 5E and S. & H. 180a dials, contact of the off-normal springs is further improved by the use of double point contacts.

Inter-Digital Pause

The purpose of the inter-digital pause is to introduce sufficient delay between successive trains of impulses to permit exchange switchgear to operate and extend the calling subscriber's connection through to the circuit which is to receive the next train of impulses.

Duration of Pause: From Table II it will be seen that the W.E. 5E dial has the shortest pause, equivalent to approximately one dialling impulse only, while the Siemens No. 10 and A.T.M. 24C dials have the longest, equivalent to approximately $2\frac{1}{4}$ impulses (the length of impulses in all dials being approximately the same). To this pause is added the time taken to pull the finger-plate round to the stop and let go, but this obviously depends on the digit dialled and on the finger speed of the person operating the dial.

Position with respect to Impulses: The inter-digital pause may be introduced **before** or **after** each individual train of impulses. It is obvious, however, that this affects the first train of impulses only, as there will be such a pause between successive trains of impulses in either case, and a pause after the final train serves no useful purpose.

Normally, there will be a delay between the lifting of the telephone receiver and the commencement of the first train of impulses, due to the time which the operator or subscriber takes to lift the receiver, pull the dial round to stop, and let go. This, however, depends on the speed of the individual, and may be reduced to a very low duration if the receiver has previously been removed from the switch-hook and a call is initiated by releasing the switch-hook with one hand and commencing to dial immediately with the other.

In such a case, the pause between initiation of the call and commencement of the first impulse train will be negligible unless the inter-digital pause is located **before** the impulse train, as in the Siemens No. 10 and W.E. 5E dials. At Footscray Exchange, Melbourne, in which the subscriber is initially connected to a Discriminating Selector Repeater via a 2000 type Bi-motional Finder, the time from the lifting of the receiver to the connection to the first impulse accepting switch is appreciably longer than any pause practicable in any rotary type of dial design.

To meet such cases "dial-tone" is introduced in an automatic telephone system. Dial-tone is fed back to the calling subscriber only when the switching connection to the circuit which is to receive the first impulse train has been completed in the exchange, and it thus provides a signal which indicates that dialling may safely be commenced. Instructions provided for subscribers read, "Always listen before attempting to dial." This instruction is necessary even with dials having a pause as long as has Siemens No. 10, and, if the instruction is followed, the positioning of inter-digital pause **before** impulse-trains becomes unnecessary.

The positioning of the inter-digital pause **before** impulse trains may, to some extent, reduce the probability of false connections due to lost impulses in cases where subscribers do not listen for dial tone, but it will by no means eliminate all such false connections, and, in the case of some exchange equipment, it may eliminate very few. Dial-tone is therefore an essential requirement, and if this signal is used by subscribers, in accordance with instructions, a dial having an inter-digital pause **after** impulse trains is quite satisfactory.

Method of Production of Pause: In the Siemens No. 10 dial (Fig. 1) the inter-digital pause is produced by the slipping cam, which prevents operation of the impulse contacts until the finger plate, on its return rotation, has moved through an angle equivalent to approximately $2\frac{1}{4}$ impulses.

In the A.T.M. 24C and A.E.C. 24 dials the inter-digital pause is produced by a cam on the main shaft (Figs 2 and 3), which lifts the impulse contacts clear of the double impulse-cam at the end of the return rotation of the finger plate, for a period equivalent to approximately $2\frac{1}{4}$ impulses in the case of the A.T.M. dial and $1\frac{1}{2}$ impulses in the case of the A.E.C. dial. This method is quite positive.

In the W.E. 5E dial (Fig. 4) the inter-digital pause is created during the movement of the impulse lever from the trailing position (which it occupies during forward rotation of the finger plate) to the impulsing position, at the commencement of return rotation, and is equivalent in length to approximately one impulse. This method is quite positive.

In the S. & H. 180a and Ericsson S2836 dials, the inter-digital pause is produced by the off-normal cam (Figs. 5 and 6) on the main shaft, which operates a pair of "make" contacts forming part of the off-normal contact spring assembly.

These contacts short-circuit the impulse contacts at the end of the return rotation of the finger plate, for a period equivalent to approximately 2 impulses in the case of the S. & H. dial and 1½ impulses in the case of the Ericsson dial.

Governor

Each of the dials is provided with a centrifugal governor of the spring controlled friction type, to regulate the return speed of finger-plate rotation.

Governor Speed: The governor speed of the W.E. 5E Dial is approximately 19.4 times the mainshaft speed. As centrifugal force is proportional to the mass of the rotating weights, to their radius about the governor centre, and to the square of the speed of angular rotation, this means that in order to obtain a similar speed control, this governor is necessarily larger in diameter and has heavier weights than the governors in the other dials examined, which are all driven at considerably higher speeds (i.e., from 90 to 126 times the mainshaft speed—see Table II).

The normal method of speed adjustment is by altering the set or tension of the governor springs. In the Siemens No. 10 and W.E. 5E dials, the springs are not particularly accessible, but in the other dials the springs are more exposed, and they may be more susceptible to accidental damage when the dial is removed from the telephone.

Direction of Rotation: In the A.T.M. 24C, A.E.C. 24 and S. & H. 180a dials, due to the use of a ratchet, the governor rotates during the return motion of the finger plate only. This reduces wear on the worm gearing teeth, the governor bearings and the friction surfaces, and also means that the axial thrust on the governor shaft, due to the worm gear drive employed, is in one direction only, so that only one bearing has to withstand thrust.

In the Siemens No. 10 and Ericsson S2836 dials, the drive is transmitted to the governor through a spring clutch on the shaft of the worm gear. During forward motion of the finger plate this clutch slips, so that the governor is driven positively only during the return motion, but the clutch also permits the governor to overshoot when the finger plate returns to its stop, so that the governor is not stopped too abruptly. In the Ericsson dial the slip of the clutch is almost 100% during forward motion, so that the governor has the same advantage as regards wear and thrust as the A.T.M. 24C, A.E.C. 24 and S. & H. 180a dials. In the Siemens No. 10 dial, however, the slip during forward motion is very slight and the governor rotates almost the same amount in both directions.

In the W.E. 5E dial the governor is driven during both forward and return motions. However, as the governor speed is relatively low and spur gearing only is employed, the wear would be correspondingly slight, and there is no axial thrust on the bearings.

Governor Drive: In the W.E. 5E dial the governor is driven from the main shaft through a train of two pairs of spur gears and pinions. In the other five dials examined the drive is through one spur gear and pinion pair, and a worm gear and worm. Of these dials, the A.T.M. 24C, A.E.C. 24 and S. & H. 180a dials employ a worm gear of laminated construction, having a layer of oil impregnated fibre between two outer layers of metal. This makes the worm gear self lubricating.

General Details

Fitting and Overall Diameter: The Siemens No. 10, A.T.M. 24C and Ericsson S2836 dials examined would fit the standard 3 point mounting provided on telephones of the P.M.G. Department in Australia. The three point fitting of the Ericsson dial, however, is provided by means of a rear adapter cap, having a hole for wiring leads; this adapter causes the dial, when mounted, to project approximately 7/16″ further from its mounting than the Siemens No. 10 or A.T.M. 24C dials, but it would serve to protect the dial mechanism from dust and possible damage when removed from the telephone, the latter two dials having no such protective rear cap.

The A.E.C. 24, W.E. 5E and S. & H. 180a dials examined had no provision for standard 3 point mounting. However, the A.E.C. dial could be provided with a body having a 3 point fitting similar to that of the A.T.M. 24C dial, and, by means of rear adapter caps similar to that fitted to the Ericsson S2836 dial, the W.E. and S. & H. dials also could be made to fit standard 3 point mountings. Adapter caps large enough to contain the mechanisms of these dials would cause the W.E. 5E dial to project about 13/16″, and the S. & H. 180a dial about 11/16″ further from the mounting than the Siemens No. 10 and A.T.M. 24C dials.

The overall diameter of a dial is of importance when it is required to mount flush in a telephone, e.g., in wall type Public Telephones used in Australia. The overall body diameter of the Siemens No. 10 and A.T.M. 24C dials is standard in this respect, i.e., 3½″. The A.E.C. 24, W.E. 5E and Ericsson S2836 dials, however, have an overall body diameter of 3″, and in the S. & H. 180a this dimension is 3-7/32″.

Terminals: The Siemens No. 10, A.T.M. 24C, A.E.C. 24 and W.E. 5E dials examined are provided with screw terminals. In the Siemens dial the terminals are close together. In the A.T.M., A.E.C. and W.E. dials the terminals are spaced further apart and are not likely to cause trouble.

The S. & H. 180a and Ericsson S2836 dials are fitted with solder lug terminals and, in order to avoid a soldering operation when replacing dials, it would generally be necessary to provide the dial with a short flexible five-conductor cord having spade lug terminations at the free end for connection to terminal screws in the telephone instrument. The S. & H. dial examined had such a cord connected and anchored to it, and the

Ericsson dial was provided with an anchor clip for a similar cord. Such a method of connection, however, would be inconvenient compared with the method of connecting leads already in the telephone to screw terminals on the dial.

Main Spring: The Siemens No. 10 and S. & H. 180a dials were fitted with flat clock type spiral springs. These are housed in cylindrical casings which serve also to retain lubricant. The A.T.M. 24C, A.E.C. 24, W.E. 5E and Ericsson S2836 dials, on the other hand, were fitted with wire type springs wound in a helix, and without lubricant.

Number Plate and External Finish: In all dials the number plates are of metal and detachable, obviously with the intention of providing numerals with or without letters or symbols to suit the telephone administration concerned. In all but the Ericsson S2836 dial, these plates are in the form of a flat ring secured by some form of clip to the body of the dial behind the finger plate. In the Ericsson S2836 dial the number plate is in the form of a disc secured at the centre of the finger plate, with numbers at its periphery, there being no provision for mounting a plate similar to those in the other dials. All number plates are of enamel or similar hard finish, the Siemens No. 10, A.T.M. 24C, A.E.C. 24 and W.E. 5E dials having black letters on a white background, while the S. & H. 180a and Ericsson S2836 dials have white letters on a black background. The Siemens, A.T.M., A.E.C. and W.E. dials only are provided with a clipped holder for a disc instruction card at the centre of the finger plate. The external finish of dials could obviously be varied to suit the telephone administration concerned. It is interesting to note that the Siemens and Halske dial has a moulded plastic body and finger plate.

General Construction and Operation: From the subscriber's point of view, it is desirable for a dial to be quiet in operation. In the A.E.C. 24 dial, noise is largely eliminated by the use of a rubber mask adjacent to the brass ratchet wheel. This mask has teeth which project beyond the teeth of the brass ratchet, and cushion the blows of the pawl during forward rotation. The rubber is possibly a synthetic material to obviate the deterioration produced by oil in natural rubber.

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5. "The Vibration of Electric Contacts," M. N. Russell and S. Kleilien, Electrical Engineering, Transactions, April, 1944.

MR. A. R. GOURLEY

With deep regret we record the death of Mr. A. R. Gourley, who took suddenly ill after returning home from the office on Friday, 21st November, and passed away on the following Tuesday, 25th November, 1947. The news came as a great shock to his many friends throughout the Service, and his loss has caused much concern amongst those who were closely associated with him.

This Society owes much of its progress to Mr. Gourley. From 1932 to 1942 he was Secretary and from 1935 to 1944 one of the Board of Editors of the Journal. A tribute was paid to him in our issue of February, 1943, when recording his election as a Life Member of the Society, a distinction conferred on him in recognition of his outstanding service. The success of this Journal is largely due to the enthusiasm, energy and leadership which he displayed as a foundation member of the Board of Editors.

He has given splendid service to the Department, mainly in the Telephone Equipment Section, Central Office, where he held the position of Assistant Supervising Engineer, Service. He will be long remembered for his cheerful manner and ready laughter, in addition to his outstanding ability and wise counsel to all those who sought his advice.

All those who knew him will earnestly regret the loss of a valued officer, and will mourn the absence of a good friend. We extend to Mrs. Gourley and her family our deep sympathy in their bereavement, and wish to express the high esteem in which her husband was held by all members of this Society.

PORTABLE TRAFFIC RECORDER (RESISTOR TYPE) FOR USE IN AUTOMATIC EXCHANGES AND P.A.B.X'S

W. M. D. Squair

Introduction: The need for a method of recording traffic flow in automatic exchanges not equipped with B.P.O. type traffic recorders, other than by tedious visual observation of switch groups, has led to the development and use of a simple portable recorder on which the actual number of simultaneous connections in each switch group under observation, may be read directly from an ammeter in terms of direct current values. As is well known, traffic flow is measured in "traffic units" (T.U.) and the traffic flow through a switch group at a particular instant in T.U. is equivalent to the number of simultaneous connections in that group. Accordingly, the Portable Traffic Recorder has been designed to enable instantaneous counts of simultaneous connections to be made at regular short intervals (say three-minute intervals) throughout a given period (usually the "Busy Hour") and the average traffic flow in T.U. is then obtained by averaging these readings.

General Description: The Recorder consists of a control unit with which may be associated up to 48 portable resistor units. The control unit is housed in a cabinet which may be placed on an associated stand (Fig. 1) and comprises essentially a uniselector, ammeter, 50 volt dry cell battery, keys, relays and lamps (Fig. 2). A suitable ammeter is a 10 inch "Elliot" with a 1-75 scale. The uniselector is a three level 50 point switch and is controlled by a non-locking key. On the first level of the switch, two bank contacts are used for testing purposes and the remaining 48 contacts are wired to spring type terminals mounted on the back of the control cabinet. These terminals are connected to the private wires of the group of switches under test through resistances which are mounted in portable units. When installed, jumper wires are run from the terminals on the control unit to the resistor units. The uniselector is stepped to associate the ammeter circuit with each test wire in turn.

Fig. 1.—Traffic Recorder Control Unit.

The portable resistor unit (Fig. 3) is of pothead type construction and consists of 52 1W 0.5 MΩ (1 per cent. accuracy) vitreous resistors in 4 groups of 13. One side of each group of 13 is commoned and brought out to a spring type terminal (which is jumpered to the control unit) and the other side of each resistor is connected to one wire in a 52 wire flexible cable about seven yards in length.When in use the resistor unit is usually hung from an exchange cable runway in a convenient position as close as possible to the terminal points of the switch group under observation (Fig. 4) and the free ends of the flexible cable are terminated with non-soldered wrapped connections on the private wire terminal of each switch in the group concerned.

As the private wire of an engaged switch is earthed, there will be a current flow of 0.1 m.a. (50 volts through 500,000 ohms) for each engaged switch when the ammeter circuit is momentarily connected to a particular resistor unit. The ammeter on the control unit which has a moving coil system of approximately 600 ohms resistance, is suitably shunted and calibrated to give a full scale deflection of 75 points with a current flow of 7.5 m.a.; so that each point represents one circuit connected to earth and the number of switches in use at the moment of test may be read directly by the number of points deflection on the ammeter.

Four groups of not more than 13 switches each can be connected through the one resistor unit provided all the private terminals concerned are close enough to be reached by the free ends of the flexible cable. When there are more than 13 switches in a group, the sets of 13 resistors may be placed in parallel up to a maximum of 75 resistors (limit of ammeter range). This involves the use of a second resistor unit when the switches

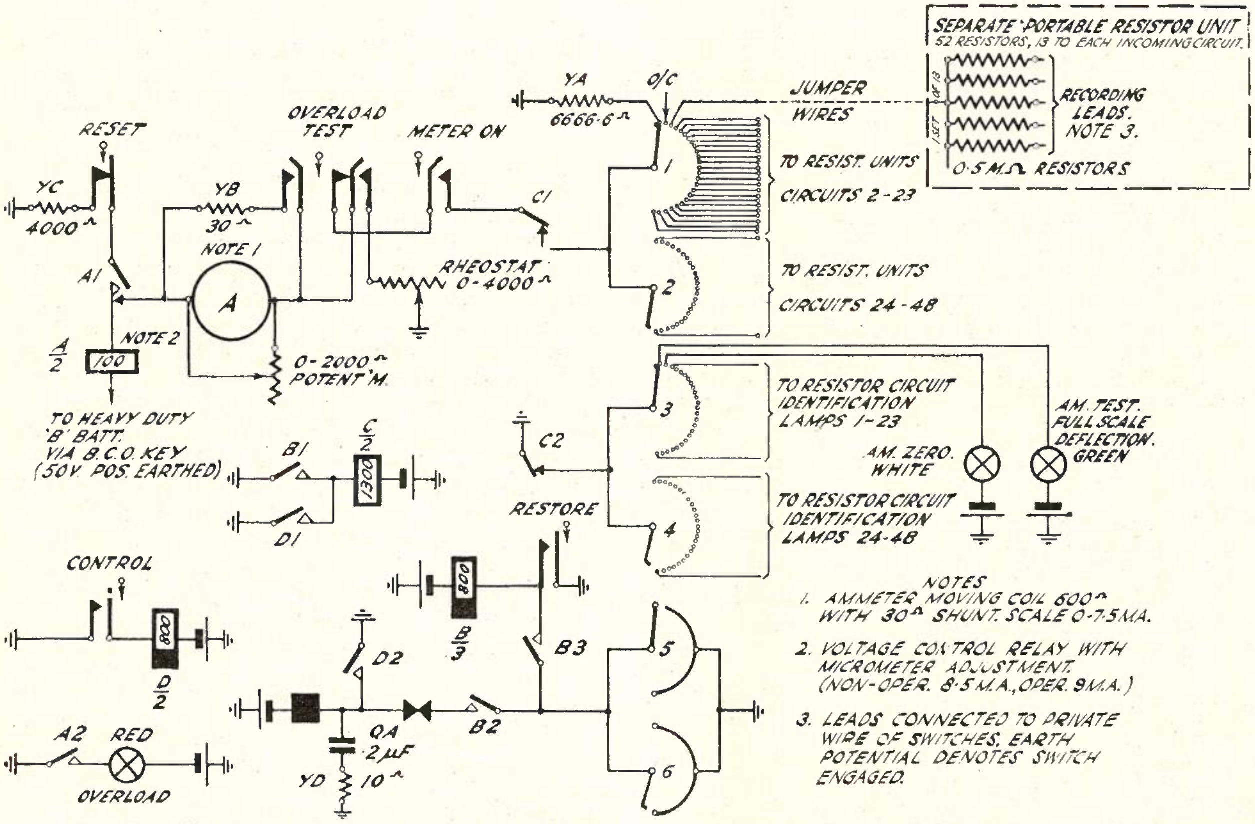


Fig. 2.—Circuit Elements.

exceed 52. When the number of switches in any one group exceeds 75, it is necessary to read the simultaneous connections in more than one reading, afterwards adding the results to obtain the total for the group. Up to 48 groups of switches may be connected to each control unit.

Typical examples of the staff and recorder equipment needed to read an exchange are as follow. In each case the work was completed in two weeks.

1. At Chatswood Main Exchange (7,100 subscribers—pre-2000 type equipment) the traffic was read on all switch groups with the exception of the junction groups incoming from other exchanges (which were read at the originating exchanges), by four readers each operating a control cabinet.
2. At Petersham Branch Exchange (4,100 subscribers—pre-2000 type equipment) the traffic was read on all switch groups including incoming junction groups by two readers each operating a control cabinet.
3. At Maroubra Branch Exchange (2,400 subscribers—pre-2000 type equipment) the traffic was read on all switch groups by one reader using one control cabinet.

It has been found that with small groups such as final selector groups on 100 number line units, one reader can read four times as many groups in the same time as with the old visual count method and that on larger groups he can read from six to twelve times as many groups. In addition, the results obtained are more accurate as the reading of busy switches in a group is instantaneous. The parts needed for the Recorder are easily obtainable; it can be built at low cost and maintenance charges are negligible.

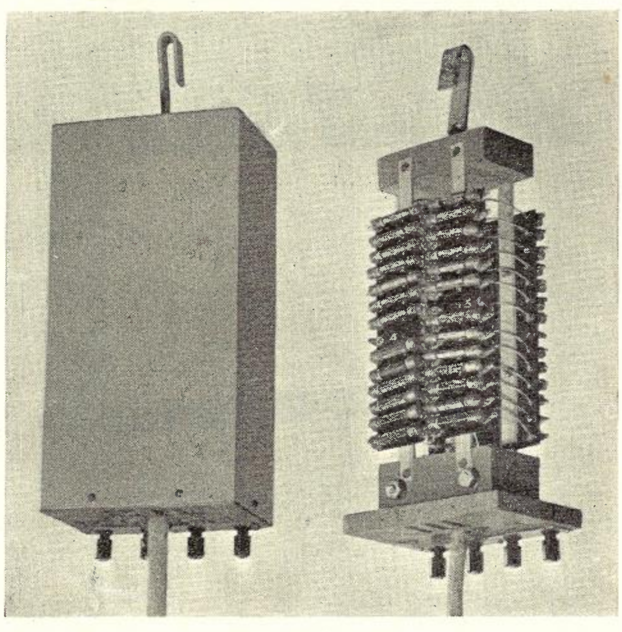


Fig. 3.—Resistor Unit.

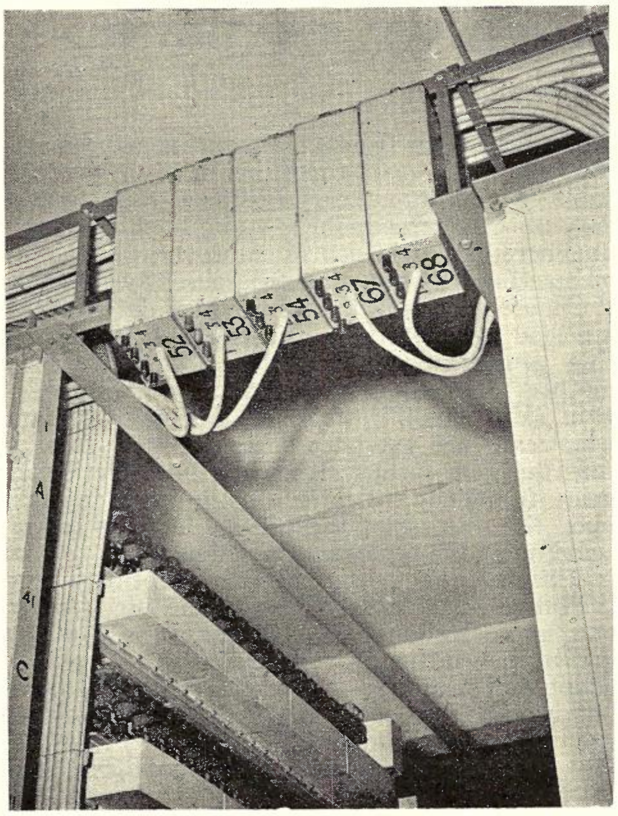


Fig. 4.—View of Resistor Units in position ready for jumpering to Control Unit.

Brief Circuit Description (Fig. 2): With the "Battery" Key and "Meter On" Key operated and the uniselector wipers in the normal position, i.e., wipers on No. 1 contact, a full scale deflection of 7.5 m.a. (75 points) should be obtained on the ammeter through the 6,666.6Ω test resistance (the equivalent of 75 resistors 0.5MΩ in parallel). This deflection may be adjusted by means of the 0-2000Ω variable shunt resistance which, together with a fixed shunt, is connected across the ammeter.

When the "Control" Key is operated, relay D (slow release) operates and D2 contacts complete the motor magnet circuit and D1 operates relay C. When the Control key is restored and D releases, the uniselector steps to the second contact. The second contact position serves as a test position because as this contact is open circuit no deflection of the ammeter should occur and the zero adjustment of the ammeter may be checked and adjusted as necessary. The Control key is operated and released to effect the stepping of the uniselector and each time relay C releases its contacts complete the ammeter and identification lamp circuits.

A designated Identification Lamp shows the operator which recording circuit he is observing and a deflection is obtained on the ammeter equivalent to the number of switches engaged in the group under observation.

The access uniselector may be restored to normal from any position on the bank by operating the "Restore" Key, which closes the circuit of relay B (slow release).

A fast operating relay (A) is connected in series with the ammeter to protect it from excessive current. This relay is fitted with micrometer adjustment and is adjusted to operate with 9 m.a. When operated the relay opens the ammeter circuit, locks up through resistance Y.C., and lights a red "overload" lamp. A Reset Key restores conditions to normal when desired. The ammeter guard feature may be tested by operating the Overload Test Key, which places an additional 30 ohm shunt across the ammeter, so increasing its range from 7.5 m.a. to 15 m.a. The current may then be increased to the 9 m.a. value by operation of the special 0-4000 ohm rheostat provided for this purpose.

EXPANSION OF LONG-DISTANCE V.F. DIALLING IN AUSTRALIA—PART II.

F. P. O'Grady

In the previous issue of the Journal the general discussion on the requirements of long distance dialling led to the conclusion that a thorough investigation is warranted into the merits of a completely automatic trunk line network, and the following further observations will be directed to that aspect. Incorrect figure references were made on page 204, the final page of Part I. In line 18, Fig. 18 should read Fig. 12, and in line 32, Fig. 19 should read Fig. 18. Fig. 19 is repeated here as reference to it is made in this Part.

The Effect of V. F. Dialling on Transmission Planning: It is clear that if automatic zone centres are established and the system is converted from a Mesh to a Star type, then it will be necessary to face up to the practical problem of cutting up the long distance circuits which at present pass direct from the capital city through the proposed zone centre. The additional expense in providing extra carrier terminals for this purpose has been mentioned previously and the economics of this problem can be investigated on the lines suggested. There are other aspects, however. At present the carrier systems are lined up to give satisfactory transmission equivalents from end to end. If the carrier systems are cut into two systems at the point "B" mentioned earlier (Figs. 15 and 16), then it is clear that the point "C" will no longer necessarily be switched to point "A" over the carrier system. Generally speaking, the existing facilities from point "A" to "B" will consist of physical circuits in most cases and the majority of these will be two wire V.F. circuits. These circuits have been provided in the main, as mentioned earlier, by cutting back the original long distance physical circuits from "A" to "C." The comparatively short distance physical circuits from "A" to "B" provide satisfactory transmission for the traffic between those points. When all the circuits passing from "A" to "B" are placed in one group with automatic switching at "B," it is clear that any one of the circuits can be picked up and used to form part of a through circuit from "A" to "C." A physical circuit from "A" to "B" in many cases would be unsatisfactory to form part of a circuit from "A" to "C." Obviously, if they were capable of providing the desired net loss from "A" to "C," they would be unnecessarily good for service from "A" to "B." In actual practice, most of them would be just good enough for service from "A" to "B" and quite unsuitable for extension beyond.

Similar problems exist in a capital city network where the line plant must provide sufficiently good transmission equivalents from a main exchange to another, so that even when a call is switched through to the most distant branch exchange, the overall net loss is satisfactory. In practice, the transmission loss from a main exchange to another is really better than it need be. In other words, the cable conductors are larger than is strictly necessary for calls from main to main. In short distance underground cable routes, however, this method of meeting requirements is apparently considered the most economical. The practice dates back to a period long before alternative means of meeting this problem were available. One alternative method, of course, would be the use of inserted gain (V.F. amplification) at the main exchange, when calls are extended to the branch exchange. Inserted gain means either the introduction of a voice frequency repeater as required, depending upon the routing of the call or, in some cases, it could mean the removal of a pad which is normally in circuit on a voice frequency repeater, where the latter forms a fixed part of the junction from one main exchange to another. So far as is known, the latter arrangement has not yet been adopted in local networks in any part of the world, but it is understood that in Germany, extensive use was being made of V.F. repeaters switched into circuit as required at the main exchanges.

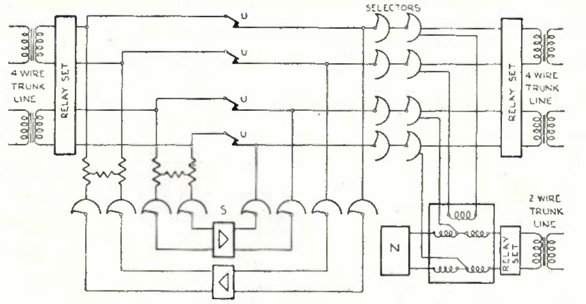


Fig. 19.—Insertion of automatic repeaters.

See Fig. 19 (repeated from Part I). With the trunk line network, however, the physical lines from "A" to "B" are usually already provided and, in most cases, it would be very expensive to change the line conductors to a heavier gauge.

The remaining means of meeting the problem, therefore, is the use of inserted gain at the automatic zone centre. This inserted gain (or subtracted loss) will be such that when the circuit is switched from "A" to "B" through to "C," the overall loss from "A" to "C" will be satisfactory. It is at this point that formidable problems are encountered. As most of the existing plant from "A" to "B" is on a two wire physical basis, it is necessary to use two wire V.F. Repeaters at "B." While reasonably satisfactory balance networks can be provided at "B" and thus a reasonable amount of gain realised from the V.F. Repeaters, very serious practical difficulties arise when the trunk network is viewed as a whole. This is illustrated in Fig. 20. It will be clear that, in many cases, when the automatic network is fully developed, there will be calls established from an R.A.X., through a parent exchange, through a group centre, through a zone centre, through a regional centre and then back through a zone centre, a group centre and a parent exchange to any R.A.X. (taking one of many possible combi-

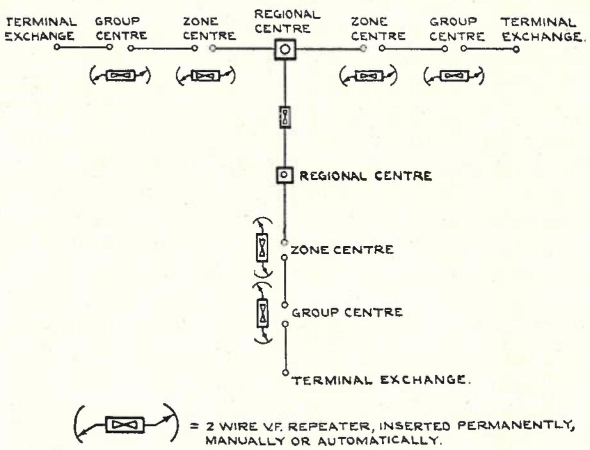


Fig. 20.—Typical combinations involving several V.F. repeaters in tandem.

nations). There may be, under these circumstances, several sections of physical lines in tandem with quite a number of V.F. repeaters in series. Experience has shown that the operation of several V.F. repeaters in tandem on open wire physical lines is usually far from satisfactory, if reasonably low loss circuits are to be established over-all. The use of a V.F. repeater in the form of a cord circuit repeater, at manual tandem points, has long since proved to be impracticable. Any automatic switching method used to give the equivalent of cord circuit repeater performance would at least have to be based on the use of sufficient wipers and bank contacts to enable a precision network to be picked up for the particular trunk line being switched through. The so-called compromise networks are very unsatisfactory with V.F. repeaters where there is a chance of several repeaters being involved in tandem in the one connection. With manual switchboards, the restriction of the cord circuit to a two or possibly three conductor arrangement makes the use of precision networks practically impossible. The use of separate network plugs and jacks is a cumbersome expedient. Experience has shown that operators cannot be relied upon to use such special methods as selecting network cords for only a small percentage of the total traffic being handled.

Fortunately, automatic switching devices are not limited to two or three conductors. If purely automatic through working is used in future therefore, arrangements can be made for V.F. repeaters to form part of the connecting circuits and to be provided with precision networks. Fig. 21 refers. A difficulty, however, is that there will be a long interim period, in which some of the zone centres will not only have automatic "through" trunk switching equipment, but will also have a manual switchboard. The operator there will have to have access to the same trunk circuits as the automatic equipment. In fact, arrangements would no doubt be necessary, as mentioned earlier, for automatic trunk calls from, say, Station "A" at "B" to be automatically routed to the manual board if group congestion occurs on the route from "B" to "C." It will then be necessary for the manual operator to establish the through call when a circuit finally becomes available. To retain the feature of a V.F. Repeater with precision networks, still using the conventional switchboard circuits, presents quite a difficult problem to a circuit designer. The use of separate network cords, as indicated and shown

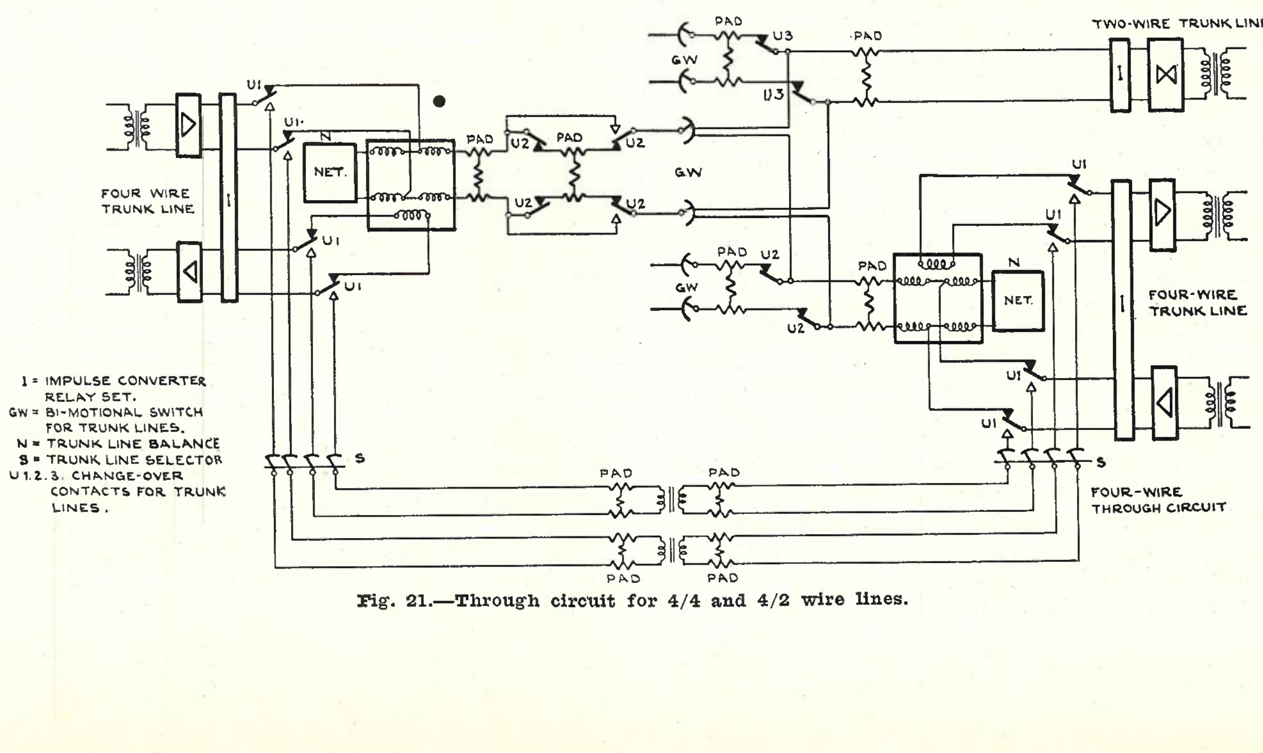


Fig. 21.—Through circuit for 4/4 and 4/2 wire lines.

in Fig. 22, has been tried to a limited extent, but is thought to be a rather unsatisfactory solution.

Need for 4 Wire Working Throughout the Trunk Network: The use of V.F. repeaters at zone centres, even with precision networks, is not likely to be a completely satisfactory solution. The remaining alternative appears to be in the use of four wire circuits from regional to zone centres. With four wire circuits, satisfactory stability and transmission equivalents can be maintained without difficulty. Carrier circuits are

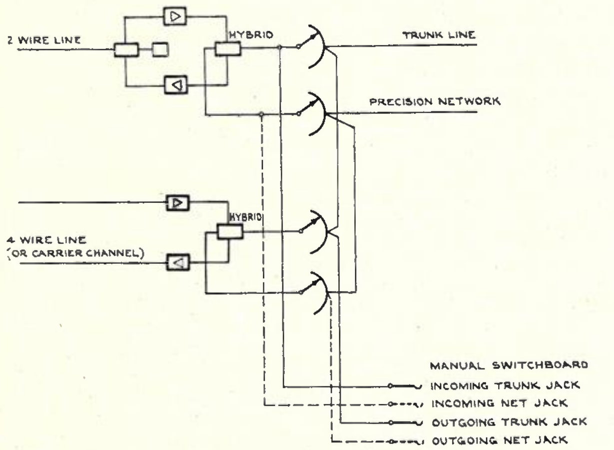


Fig. 22.—Showing difficulties of 4-wire switching on mixed auto. and manual basis.

equivalent to four wire circuits and therefore where these form part of the group from "A" to "B," no difficulty would be met in providing low loss circuits from "A" to "B" on these particular channels. With the physical lines, however, it would be difficult in many cases to set aside two pairs for each trunk channel (to work as a four wire circuit). In some cases, trunk cables would exist from "A" to "B" and there would be sufficient pairs to utilise all circuits on a four wire basis. The utilisation of two pairs per circuit would, of course, hasten the time when the trunk cable would need replacement or relief. Fortunately, in many cases, the improved efficiency to be expected from merging a number of small groups into one large group of circuits from "A" to "B" would be sufficiently great to enable two pairs in the cable to be set aside, to work each circuit on a four wire basis, without appreciably increasing the total number of cable pairs in use. Whether this statement will be true in every case, will depend upon the exact details of the present arrangement of groups of circuits passing through the cable, but it does appear that this general conclusion can be relied upon where trunk cables exist at present. With open wire physical lines, however, it is not the practice to have spare pairs ahead of requirements, consequently the above method of meeting the needs is not available.

Zwei Band (2 band) System Possibilities: Another possible means of making the physical circuits suitable for use between "A" and "B" as links in built-up connections can be provided by the Zwei Band system or some modification of it. This is shown in Fig. 23. This system was developed in Germany several years ago, to enable existing two wire trunk cables to be converted to four wire operation, without reducing the total number of channels available in the cable, below that represented by the number of pairs. A special carrier system, which amounts in practice to one half of a single channel carrier system is utilised to carry the speech from point "A" to "B" while the physical pair, on which it is superimposed, is utilised to carry the voice from "B" to "A." The circuits are combined in the usual Hybrid Coils at the terminals and the system provides a stable low loss circuit equivalent to a four wire circuit between the two points. Various modifications of the system are in use but all give the same general performance.

While the performance with underground cable circuits is quite satisfactory, there is little available information to indicate what its performance would be like on open wire physical circuits. Fortunately, the Zwei Band frequencies chosen are usually quite low and the effects of varying line attenuations, due to weather changes, are therefore not likely to be serious. The lower side band of 5.4 kc/s is used, for example, in one type of Zwei Band System. In combination with the ordinary voice frequency transmission in the reverse direction, it provides the equivalent of a four wire circuit of satisfactory stability and volume efficiency, but it cannot quite provide the band width which is deemed necessary to meet present-day requirements. If the carrier frequency is chosen much above 5.4 kc/s, it is diffi-

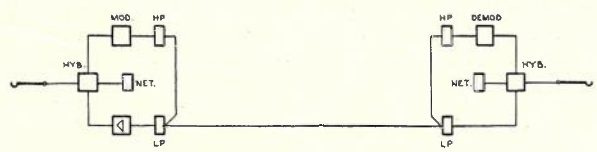


Fig. 23.—Zwei Band (2 band) system simplified schematic.

cult to operate the Zwei Band System underneath existing standard three channel open wire carrier systems. The band width provided by this system is actually quite good and compares more than favourably with much of the existing plant in situ, for example, V.F. Loaded cable pairs in junction and trunk cables. If traffic from "A" to "B" only were to be handled, the band width would be ample, but, as any one of these links may be picked up with automatic working and form part of a long built-up connection between any two points in Australia, the overall quality will not be satisfactory unless the band width of the individual links meets the requirements, for example, of the C.C.I. As the circuits from regional centre to regional centre and from regional centre to zone centre are bound to take part in a greater number of long built-up calls than are circuits at the remote ends of the network, and as it is difficult to discriminate (with automatic working) between one circuit in a group and another, it seems desirable that these circuits from regional centre to zone centre should provide as good a band width as possible. The regional to regional circuits are all provided, or shortly will be provided, by carrier systems exclusively (many of them by the 12 channel carrier system in which the band width is exceptionally good). Unfortunately, the greatest number of physical lines will be encountered between the regional centre and the zone centre.

The use of the Zwei Band System, in spite of its slight narrowing of the band width (see Fig. 24), appears to be the most practical way of making these physical open wire circuits suitable

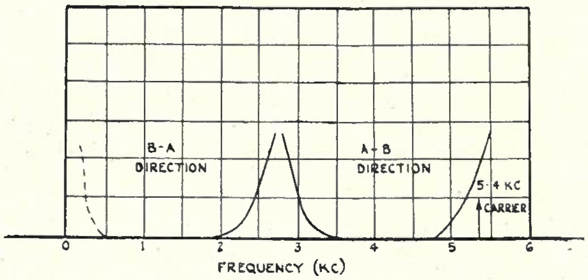


Fig. 24.—Two band frequency chart.

for use in an automatic network. There will be other obvious alternatives in certain cases, for example, by installing additional carrier systems from "A" to "B" it would be possible to release sufficient physical pairs to operate them on a four wire basis, using two pairs for each circuit.

Traffic Calculations on Trunk Networks: In order to determine the best arrangement, it is necessary to investigate the total number of circuits which will be required under the proposed automatic switching scheme between the various points. With the present trunk network, based on a manual system, the traffic data which is available is not quite in the form required by an engineer to determine switching quantities and channel quantities. At present the traffic records are based on the business hours from 9 a.m. to 6 p.m., and the data shows the number of "speech periods" (S.M.) carried on each circuit during those hours. A "speech period" is equal to three minutes and it covers actual talking time only. Traffic figures outside the above hours are disregarded in determining the number of trunk circuits required, since a cheap tariff is in operation in the slack hours and it would obviously not be sound business to provide additional channels merely to meet demands in the cheap tariff hours which did not occur also in the business hours. In other words, if the subscribers desire to obtain the benefits of a cheap tariff they cannot expect quite the same grade of service as given during the full rate tariff hours.

It is considered at present that multiplying the number of "speech periods" by 1.6 will give a fairly reliable indication of the occupied time of the trunk, allowing for the ineffective time involved in setting up the connections, releasing, etc. It is found also that the ratio of total to busy hour reading is about 8 to 1. For the period 9 a.m. to 6 p.m., the number of traffic units is given by the equation

$$\text{T.U.} = \text{S.M.} \times 1.6 \times \tfrac{1}{8} \times {}^{3}/_{60}$$
$$= 0.01 \text{ S.M.}$$

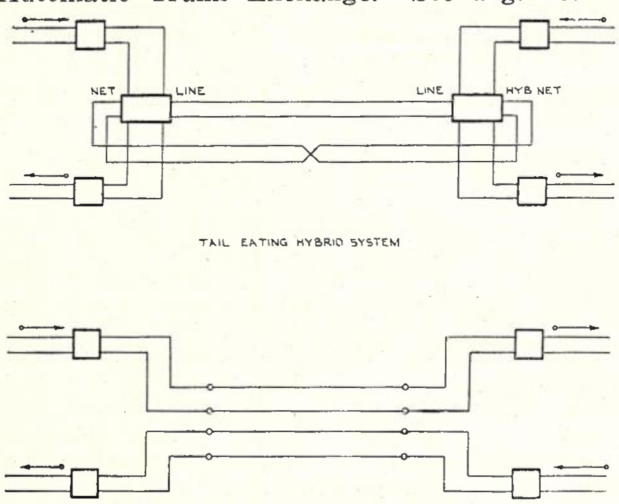
Where T.U. = busy hour traffic units
and S.M. = number of Speech Periods per business day.

It is difficult to lay down what should be regarded as a satisfactory grade of service because of the many factors involved, but tentative calculations are usually made for a grade of service of .005 (5 calls lost per 1,000). From the standard "switch provision curves" used for automatic exchange networks, it is then possible to determine the number of channels required to carry any given quantity of traffic based on the available data. Calculations have to be made for three periods—present, near future and for requirements for a reasonable number of years ahead, and it is then possible to determine the exact economic factors involved in establishing automatic zone centres and re-arranging the existing facilities to fit in with the proposed schemes.

Results of Traffic Studies of Automatic Working: Studies made on the above method show such substantial reductions in the number of trunk circuits required between typical centres, that there is little doubt that automatic trunk switching must be introduced as soon as circumstances permit.

Some Immediate Problems: On the assumption that economic consideration and the better service given to the public will warrant the introduction of automatic trunk systems, it is clear that a number of pressing problems of detailed design must be faced very shortly. As indicated briefly above, there is little doubt that four wire working or its equivalent is essential between the regional centre and the zone centre and between the zone centre and the group centre even if it is not carried still further. In this respect much interest attaches to a published German article which shows the many advantages to be derived from the utilisation of four wire working right into the subscriber's telephone. While this principle might be regarded as rather fantastic, at first, there is little doubt that if the sending and receiving functions of the telephone were dealt with over separate pairs of wires (or equivalent means) and if the four wire system were continued through the entire network, there would be a very substantial improvement in transmission performance and there would, in many cases, be a substantial reduction in line plant charges, since it would enable much smaller conductors to be utilised (where physical lines are required).

On the assumption that such a forward step must necessarily take a long time, however, it seems that Australia must plan initially for four wire working from the regional centres to at least each group centre. This means that all switching equipment at intermediate points between two non-adjacent group centres should be on a four wire basis. This can be achieved by joining two carrier systems together at the switching point on the "Tail-eating" system in which the hybrid coils of the two systems are connected "line to line" and "net to net" (with a reversal between the tip and ring conductors of the network side). This method is used at present in the Melbourne Automatic Trunk Exchange. See Fig. 25. It



Four wire (go and return) system.
Fig. 25.—Four wire switching systems.

meets requirements of transmission stability, etc., very well, but is open to the objection that accidental reversals in jumper wires may cause incorrect phase conditions to exist which may be difficult to detect (except by special maintenance measures). Another method which can be described as a true four wire method is to disconnect the hybrid coil on through connections and join the modulator of one system to the de-modulator of the other, and vice versa. This system provides the best possible measure of stability in the overall connection and is free from difficulties due to accidental jumpering changes which might put reversals in one pair of wires or the other.

At Zone Centres a particular circuit may be joined through to another circuit capable of four wire switching, or it may be joined through to a local subscriber or a short distance physical line capable of working only on a two wire basis. In the Melbourne Automatic Trunk Exchange, the trunk circuit automatically changes its termination from four wire to two wire, depending upon the circuit to which it is connected. This is done with relays which respond to marking conditions established via the automatic switches. See Fig. 26. In other installations abroad all two wire circuits are provided with hybrid coils and thus built out, as it were, to look like four wire

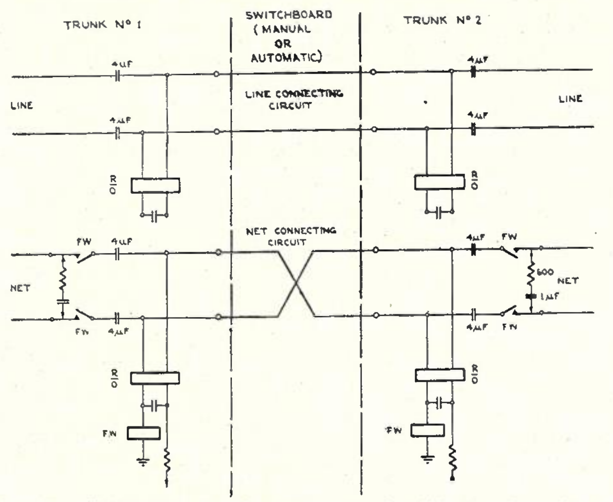


Fig. 26.—Melbourne trunk exchange simplified schematic of 4 wire/2 wire discrimination circuits.

circuits facing the switching equipment. See Fig. 27. An accurate balance network can be provided with this hybrid coil, to match the particular line as closely as possible. In the Melbourne Automatic Trunk Exchange, when circuits are switched two wire only, a compromise network only can be used, since there is no hybrid coil on the two wire circuit. The system which builds out two wire lines to look like four wire circuits

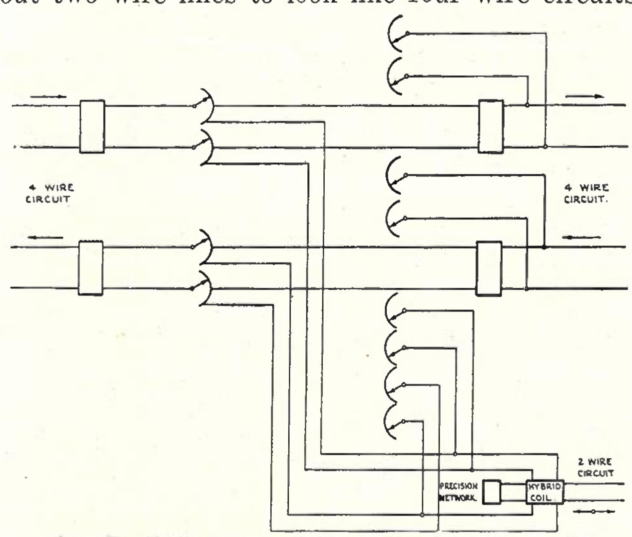


Fig. 27.—Four wire switching, with hybrids on all two wire circuits.

(facing the switching equipment), has the advantage of simplifying the trunk circuits by eliminating the need for relays to discriminate between two wire and four wire conditions. It necessarily reduces the fault liability by reducing the number of contacts in the talking path. On the other hand, it involves the fitting of a hybrid coil or equivalent on every two wire circuit in the Exchange. An incoming trunk circuit may be switched at one moment to a local subscriber's line and the next minute through to a four wire circuit beyond the switching point. Thus it would apparently be necessary, with this system, to have a hybrid coil for each subscriber's line or, at least, for each selector or junction circuit which gives access to the local subscribers' lines. See Fig. 28.

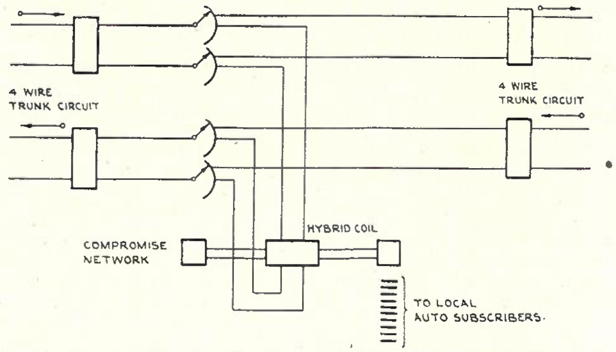


Fig. 28.—Four wire switching of trunk lines, with two wire switching to local subscribers.

While the above problems have been set out in some detail it should be emphasised that it would be wrong to assume that these problems are so serious as to defy solution at present. On the contrary, an astonishing amount of progress has been made in solving the engineering and circuit design problems presented. Many ingenious combinations of signalling and switching equipment are available at present to meet these requirements. The points above are set out with the object of drawing attention to the substantial problems which have arisen in the extension of long distance automatic switching and the solutions which have or are being adopted rather than to allow the impression to be formed that automatic trunk switching may be quite suitable for city areas but unsuitable for long distance trunk traffic.

V.F. Signalling Methods: The next problem of interest in the introduction of automatic trunk switching is that of signalling over the system. This has been referred to in other articles. Various forms of signalling suitable for long distance trunk traffic are available and many of them are in use in varying degrees in different parts of the world. The signals required to direct the switches at the zone and group centres to the desired points may take the form of V.F. signals passing over the actual talking channel or may take the form of signals transmitted by independent means such as the carrier signalling system or the carrier telegraph system referred to elsewhere. Whichever of these or other possible systems are adopted, several interesting problems come up for consideration and one of these is the question whether signals should be permitted to travel right through the system from end to end of a long built-up connection or whether signals should be trapped at the incoming end of each section and signals only retransmitted forward when required. Space does not permit a full discussion of the points at issue here. Some signals need to be transmitted as quickly as possible from end to end of the complete system, while others have to be transmitted with particular care regarding the distortion introduced. Dialling impulses, for example, must be kept within closely defined limits. Other signals can be transmitted with appreciable delays and with quite large amounts of distortion without any effect on the working of the complete system. The Siemens 2 V.F. equipment utilised throughout Victoria and recently extended to the interstate routes between Adelaide and Melbourne, between Melbourne and Sydney and also between Adelaide and Sydney, has been carefully engineered to provide for a very wide variety of possible signalling requirements, and its performance in service has been excellent. It appears to provide for most of the likely contingencies in the development of the automatic trunk network and in association with the motor uni-selector it provides facilities for four wire switching to be effected (using any of the possible methods, such as tail-eating, hybrid coil, etc.).

Numbering Scheme for Trunk Network: Another problem which arises with the automatic trunk network is that of the design of a numbering scheme for a whole State (and perhaps even for the whole of Australia). While complete "subscriber to subscriber" dialling may be a long way off, it is a possibility which must be kept in mind, since it will almost certainly be introduced in the first place on a small scale as part of a State network. While it may be possible to utilise certain systems of numbering with skilled operators using them, it may not be possible to use these systems if subscribers are ever allowed to dial their own trunk calls over an appreciable distance. The various numbering systems which can be used are divided broadly into two types, one known as the "closed numbering" system and the other the "open numbering" system. The closed numbering system is one normally employed in capital city networks. In this case a study is made of the existing layout of the local telephone network and a decision is made to establish exchanges to serve certain portions of the area. Decisions are made as to which will be main exchanges and which will be branch exchanges served from these main exchanges. Blocks of numbers are allotted to each main exchange and to each branch exchange, and subscribers are connected up in accordance with these blocks of numbers. See Fig. 29. The theory is that, apart from unforeseen requirements, a particular subscriber is allotted an individual number and this number is not changed in the future. Any other subscriber, no matter where he is situated in the local network, can reach the subscriber mentioned, by dialling the appropriate digits. In other words, this particular combination of digits is used only for one subscriber and it is not necessary for the user of the telephone to have any idea where the subscriber is located in relation to the telephone network. All he has to do is to look at the Telephone Directory and dial the digits shown. (In practice, unforeseen requirements mean that sub-

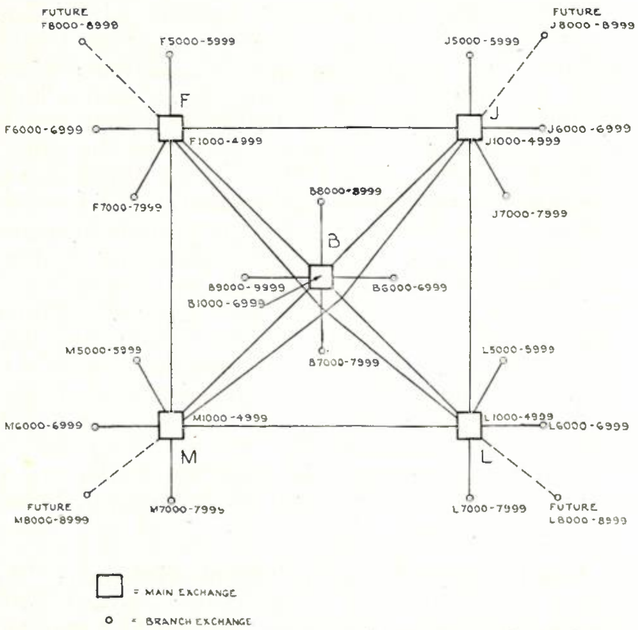
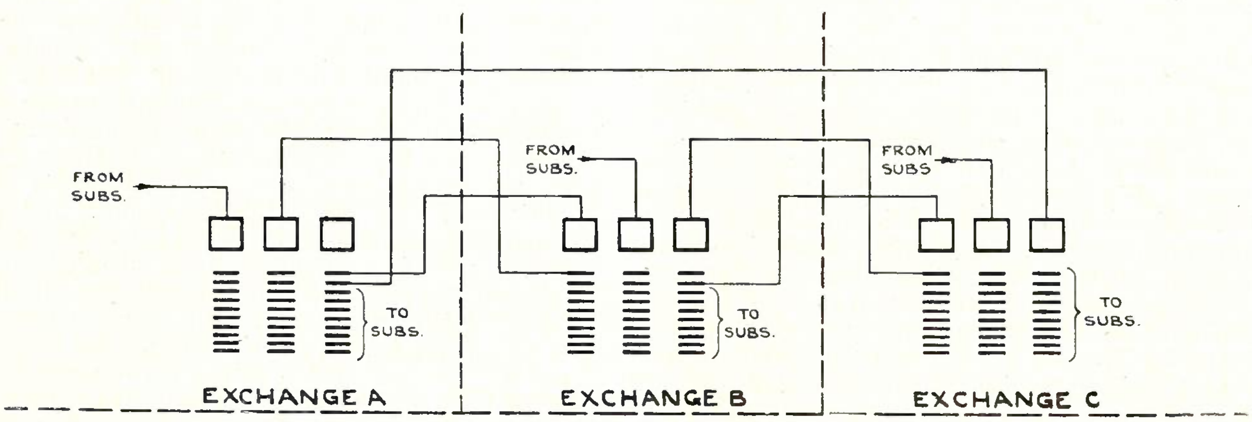


Fig. 29.—Simple numbering scheme, capital city network, closed system.

scribers' numbers are changed occasionally, but the essential principle is retained that a subscriber is reached by dialling the same digits no matter which other subscriber is calling him.) The closed numbering scheme pre-supposes that accurate information is available regarding the growth of the network and exchanges are planned and blocks of numbers are set aside to meet the growth in any suburb.

With an open numbering scheme, conditions are quite different. Subscribers connected to a particular exchange have numbers allotted to them in the conventional way and, so far as interconnection between one subscriber and another on the same exchange is concerned, subscribers retain the same numbering features as in the closed numbering system. When a subscriber dials beyond his own exchange, however, to reach a subscriber in another exchange, he dials a prefix which selects a junction to the other exchange and he then dials the subscriber's number. Another subscriber dialling in from a third exchange to the second would not necessarily dial the same prefix in order to reach the second exchange, as was used by the first subscriber mentioned. See Fig. 30. In other words, the subscriber making the call with the open numbering system would need to know not only the wanted party's number but would require a knowledge of the exchange network, and would use a prefix which would differ as he originated the call from one exchange or another. The open numbering system has the advantage that unexpected growth in parts of the area can be met simply by opening new exchanges without regard to the existing exchanges, and is thus more flexible in some respects.

Nation-Wide Numbering Schemes: With the closed numbering system applied to a whole country, a subscriber has a number which is used exclusively by him and not by any other subscriber in the country. This number contains sufficient digits to ensure that the subscriber's number will remain unchanged no matter what growth occurs in the various exchange networks throughout the country. From the subscriber's point of view, this is obviously a desirable arrangement. It also has the advantage that the subscriber can print his number on his letterhead stationery paper, and another subscriber in any part of the country need dial simply the digits shown, in order to reach the wanted subscriber. The calling party need not know anything about the make-up of the telephone network of the country. On the other hand, the system has the obvious disadvantage that if reasonable provision is to be made for growth, then a very large number of digits must be allotted for the subscriber as soon as his telephone service is first provided. If much of his traffic is of a local character in and around his own capital city, for example, it is obvious that the early digits in the number will

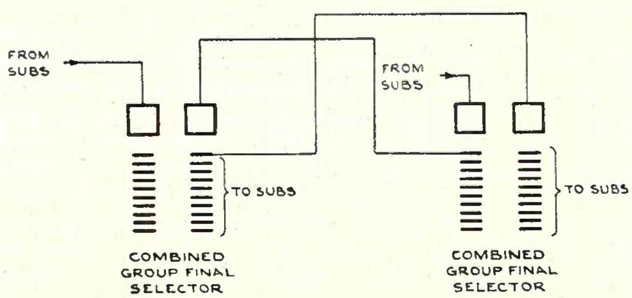


A reaches B by dialling prefix O
B reaches A by dialling prefix O
C reaches A by dialling prefix O

C reaches B by dialling prefix X
A reaches C by dialling prefix X
B reaches C by dialling prefix X

Fig. 30.—Typical open numbering scheme.

often have no function to perform and the digits will have to be absorbed by switching selector repeaters or registers or by some similar arrangement. This means that the subscribers in a particular city are burdened with the necessity for dialling one, two or three early digits in every number which have no real function on local calls. With the "open" numbering system, however, a subscriber has a number made up of the minimum number of digits to suit particular conditions in his own local area. With nation-wide dialling, however, he cannot print this number on his letterhead stationery and expect subscribers in any part of the country to reach him merely by dialling the digits shown. To take a simple case of an isolated R.A.X. of about 100 lines, a particular subscriber's number might be 55 and, so far as other subscribers on that R.A.X. are concerned, they need only dial those two digits to reach him. If, later, the network expands and another R.A.X. is opened in the vicinity and direct automatic working is provided between the two R.A.X's, then it is clear that there are now two subscribers each having the same number 55. A subscriber on the first R.A.X. wishing to dial 55 on his own R.A.X. will lift the receiver and dial 55. This is indicated in Fig. 31. If, however, he needs the subscriber 55 on the other R.A.X., then he must, obviously, dial a preliminary digit, say "0," which will steer the call to the second R.A.X., and he will then dial 55 and reach the wanted subscriber.



Final selector action on all levels but "O," where it functions as group selector.

Fig. 31.—R.A.X. trunking open numbering scheme.

Similarly, when additional R.A.X's are established in the vicinity, it will be necessary for each R.A.X. subscriber to dial a preliminary digit to first of all establish a connection to the required R.A.X. before dialling the subscriber's number. This is the open numbering system, and the duty of familiarising himself with the preliminary digit required to steer the call first of all to the R.A.X. desired is placed on the individual subscriber.

With the closed numbering system, on the other hand, it would be necessary to determine the limits of growth of the entire area to be served by the group of R.A.X's before the first one is established. Suppose it is determined that 10-100 line R.A.X's will cover the growth in the future. Fig. 32 shows the position. A closed numbering system could be evolved by allotting a three digit number to each subscriber and arranging that the first digit is absorbed when the call is for a subscriber on the same R.A.X. The advantage of the closed numbering system in this case is that every subscriber in the 10 R.A.X. exchange area has a distinctive three figure number and a subscriber need not know anything of the composition of the network in order to reach any one of the 1,000 subscribers. On the other hand, it is obvious that if most of the traffic is local within each R.A.X. exchange, this subscriber is merely burdened with the necessity of dialling the preliminary digit which performs no effective function on local calls. There is also the disadvantage that a first selector stage or some switching selector repeater or similar mechanism is involved in every call, whether local or outside the particular exchange. The capital cost and annual charges thus involved may be quite appreciable. There is also the disadvantage that should unexpected growth occur then it may be difficult to add the eleventh and subsequent R.A.X. to the area while still retaining the closed numbering system. With the open numbering system, the subscriber would dial only two digits for a local call, and there would be the minimum amount of equipment in use on each call. When he desires a call to another exchange he would have to find out from the telephone directory or by some other means what preliminary digit he would need to dial first of all to reach the wanted R.A.X., and he would then dial the subscriber's two digits.

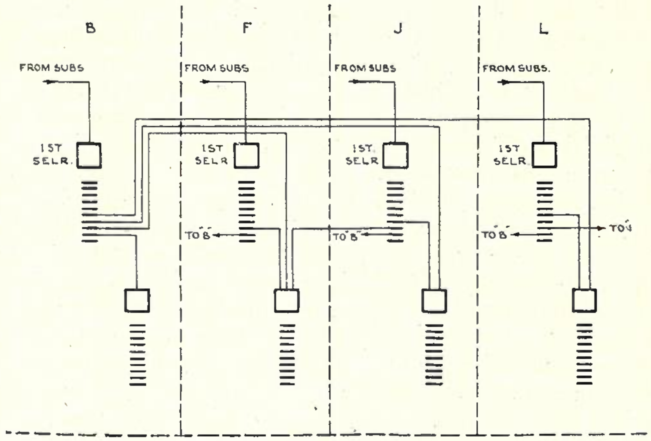


Fig. 32.—R.A.X. closed numbering scheme simplified. (Broad outlines only.)

It seems fairly clear that neither the closed nor the open numbering system is completely satisfactory and, in considering the extension of long distance dialling either on an operator or subscriber basis, over an entire nation, the problems involved in the numbering system become quite difficult. In Germany, where limited amounts of automatic trunk traffic were being handled before the war, the German Post Office had established a series of rural automatic networks with complete inter-communication, using multi-metering systems and allowing the subscribers to dial their own trunk traffic. The first decision of the German administration was that the subscribers would have difficulty in dealing with an open numbering system and they therefore prepared a closed numbering system for each rural network of automatic exchanges. This necessitated the use of switching selector repeaters or similar devices. It meant that as soon as a subscriber lifted the receiver, as well as preparing the switching equipment for the local call, it was necessary for the selector to extend his circuit into the centre of the rural network, as, obviously, it would not be known when he lifted the receiver what number he was about to dial. This meant that a trunk line to the main trunk switching exchange in the centre of the network was taken into use on every call and would be dropped out if he dialled the digits indicating a local call. This "holding time" on the rather expensive trunk circuits to the main exchange was obviously undesirable loading and, where the percentage of local traffic was high, it proved to be highly undesirable in its effects on circuit provision (in the groups of trunk lines to the centre exchange). Where the percentage of traffic to other R.A.X's was high, however, this effect was not so important. The German Post Office later decided that subscribers could readily work with an open numbering system and subsequent installations were designed on this basis.

These exchange networks, however, were far from a nation-wide basis, and more recent investigation in America, where plans are being formulated for operator dialling over the entire nation (to be possibly followed later by subscriber dialling), has shown that a simple open numbering system would be quite impracticable for a nation-wide network. An operator, for example, in New York desiring to reach a subscriber in any other part of the country, would have to spend considerable time in looking up lists of routing instructions, in order to determine what digits to dial to reach the subscriber. In addition, she would have to dial (or key send) a very large number of digits, in many cases. A compromise between the open and closed numbering system is therefore apparently the best practical solution. This is made possible by arranging that one particular digit (or digits) on the dial will be reserved exclusively for automatic trunk service beyond the local city area. If this particular digit is not dialled, then the subscriber dials the other digits (just as he does in any Australian city network) and reaches any subscriber in that area on a closed numbering system. Each city has its own closed numbering system. See Fig. 33.

If the subscriber (or operator) dials the special digit which indicates that a call is being made over the trunk line network, beyond his city limits, he will be connected immediately to some form of register mechanism, which will accept the digits as he dials them and will store the information in some suitable manner (e.g., the director mechanism used in London would be suitable, and there are many other types of register systems in common use, for purposes such as this). Having stored the necessary number of digits in the register mechanism, it is now possible to depart considerably from the ordinary step by step method of working, and several valuable improve-

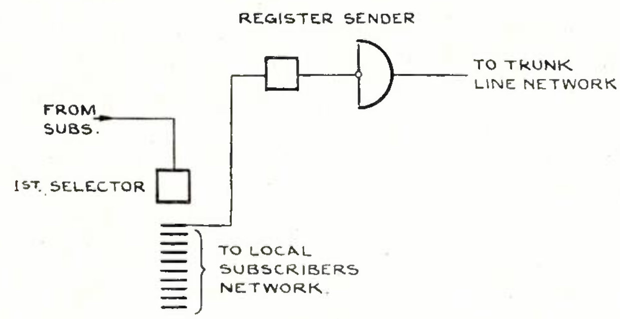


Fig. 33.—Possible use of register-sender for trunk dialling network.

ments can be effected in steering a call to the desired subscriber. The plans under current discussion in America are based on retaining the closed numbering system for subscribers in a given local area, who will continue to dial the ordinary 5, 6 or 7 digits which they are accustomed to use to reach another subscriber in the same area, If, however, they dial the particular digits (in the first and second places) this will indicate to the switching equipment that a trunk call beyond the local area is being made. A common control register mechanism will then come into operation and will store the total number of digits dialled by the subscriber (or operator, for the first few years). The choice of the special digits, which indicate a trunk call, is made possible by the fact that, with the present numbering system in each American local area, certain digits, e.g., 0 and 1, never appear in the first two spaces of a local automatic numbering system. The plans under discussion in America envisage a condition in which the digits used by the operator to reach a particular subscriber in any part of the United States or Canada will be different from those required to reach any other subscriber in these areas. In other words, the subscribers, looked at from a trunk line network point of view, are on a closed numbering system, but, on the other hand, the difficulties which would arise in the application of a normal closed numbering system (which places the entire country on a single local area basis), are avoided in the proposed plans to use register devices. These plans will retain the advantages of a simple numbering system for all calls within a local area, but at the same time it will not be necessary for telephonists or subscribers to know the composition of the network in order to determine what digits to dial in order to reach a subscriber in any part of the country.

The American plans are based on the use of the Bell System standard type dial which has several letters, as well as figures, in each of the spaces of the dial. The letters are different from those used in Australia and are arranged as shown in Fig. 34, as follows:—

Digit	1	No letters
„	2	ABC
„	3	DEF
„	4	GHI
„	5	JKL
„	6	MNO
„	7	PRS
„	8	TUV
„	9	WXY
„	0	Z

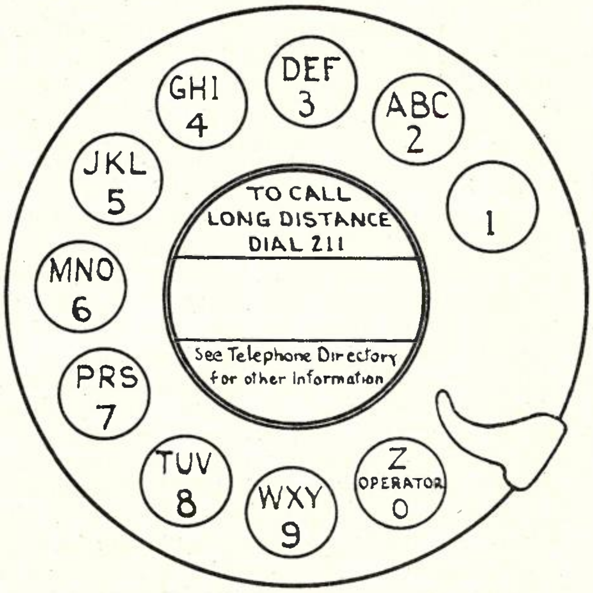


Fig. 34.—Bell telephone system dial.

The common arrangement in use in most large cities is to spell out the first two letters forming the name of the exchange by selecting the letters from the dial and then dialling the number digits required. Electrically, of course, the effect is exactly the same as if a simple series of number digits were dialled, but instead of a 7 figure number appearing as 2316100, e.g., the number is shown in the telephone book as CEntral 16100. The subscriber dials the first two letters of the exchange name, followed by the 5 numerical digits required. (A somewhat similar system is in use in London director area but the arrangement of letters and numbers on the dial is different from the American.) It will be noticed that there are no letters in the first space on the American dial. The last space on the dial (0 and Z) is never used in the first or second place of a telephone exchange name. The 0 is usually reserved so that by dialling this single digit the assistance of a manual operator can be obtained for any purpose required. This means that each dial has really only 8 spaces which are available, as far as letters are concerned, in building up a numbering scheme for a nation-wide basis. The theoretical number of separate exchanges which could be reached in a local area using the American system would be $8 \times 8 \times 10 = 640$. If the capacity of every telephone exchange were 10,000 lines the theoretical capacity of a local numbering area would be 6,400,000 subscribers. In practice, such a large number of subscribers cannot be fitted in. For example, very few exchanges are completely filled to 10,000 lines and many of them are in small places which have only a few hundred lines but which, nevertheless, have to be allotted a group of numbers just as they would have if they were large initially. In using the principle of dialling the first two letters of the exchange name it will be noticed that certain combinations are unusable since, although they would have separate letters in the first two places of the name they would really represent the same electrical impulsing arrangements since the same actual number digits would be dialled in each case. For example, one exchange cannot be called ADams and another office called BEacon, since a glance at the dial will show that the first two digits would be identical and, naturally, the switching equipment could not discriminate between the two exchanges.

Numbering Scheme for America: American investigators have estimated that between 50 and 75 separate numbering areas should suffice for the United States and Canada, even when the total number of telephones reaches a figure many times greater than the 26,000,000 telephones in use today. If there are less than 100 numbering areas to be accommodated and if each local area can be served with a 7 digit basis (two letters and 5 figures), it seems that by setting aside a separate two-digit prefix code for reaching each numbering area over trunk lines, that nine digits are sufficient to give every subscriber in the country a number for trunk purposes which is quite separate from that of any other subscriber. In addition to the nine digits it is necessary, however, to add a further special digit to facilitate the working of the machine switching equipment in the originating exchange in determining the route to be followed by each trunk call. In America, where neither 1 nor 0 is used in the first two places of a local numbering scheme it is practicable to arrange that should either of these figures appear in the second place it will serve to distinguish the call as a trunk call to go beyond the local numbering area.

This scheme requires the dialling of a total of 10 digits as a maximum, in order to reach any subscriber in the United States or Canada from any one point. On this basis, therefore, the entire country may be regarded as on a closed numbering basis. On the other hand, if the subscriber in a particular city requires another in the same city he need not dial the 10 digits but is required only to dial the ordinary 7 digits as a maximum, as he does at present (in the smaller cities, of course, he will dial only 3, 4, 5 or 6 digits, depending on the size of the local numbering area concerned). If he dials 10 digits, however, which contain either the figure 1 or 0 in the second place, then the switching equipment will note that the call is to be routed to a distant numbering area, and it will carry out the necessary switching required. The first 3 digits of the 10 digit number will really form the distinguishing code to pick out one particular distant city area from another. Where operator dialling is involved (as it will be in the initial stages), the operator who is handling the originating call will need to dial only the normal number of digits if the call is to a party in the same numbering area. If she has means to enable her to plug in to a trunk line going direct to a particular distant numbering area required, then again she need only dial the normal number of digits required to select the particular subscriber in that distant numbering area. If, however, she has a call to a distant numbering area to which she has no direct trunk circuits, then it is clearly necessary to provide special equipment to enable her to reach the distant party without danger of confusion and without spending a good deal of time in looking up routing instructions. It is at this point in the problem that the particular types of switching equipment require detailed consideration. If the entire nation were on a step by step equipment basis, without registers or directors of any kind, it becomes apparent that the task of laying out a numbering scheme for the whole country which will be practicable from an operator dialling point of view becomes quite formidable. Conclusions reached, at this present stage of investigations in America, are that some form of register and common control equipment is essential to provide a reasonably satisfactory solution to the engineering problems involved.

In America, at present, the very large cities are provided with register systems for local calls either in the form of panel switching systems or cross bar switching systems. These devices lend themselves to the introduction of some of the desirable features of a nation-wide operator and subscriber dialling system. Where registers are provided, the subscriber (or operator) dials the digits specified into a register in which the information is stored electrically until the subscriber or operator has finished dialling. From the information contained in the storing mechanism the register is able to determine what steps are next necessary in order to effect connection to the distant subscriber. The number of digits which are transmitted from the register need be of no relation to the digits sent in from the subscriber. The register can itself determine the most suitable route to follow to reach the distant subscriber, and it can automatically provide for the use of an alternative emergency route, should the normal trunk circuits be unavailable for any reason.

Step by Step Numbering Problems in Australia: Where step by step equipment is in use, the common arrangement is to allot the level 0 from the first selector to establish a call beyond the local numbering area where a trunk line must be taken into use. For example, most R.A.X. subscribers in Australia dial 0 to reach the parent exchange over trunk lines. If the parent exchange is assumed to be automatic and there are more than ten R.A.X's trunking into it, then, generally speaking, the first thing is for an R.A.X. subscriber to dial 0 to select a trunk to the parent exchange where the call will come up on a second selector. He will then dial a two-digit code to select one particular R.A.X. or another. He will thus pass through the second and third selectors in the parent exchange and will seize a trunk to the particular R.A.X. required. He will then dial the subscriber's digits, which may involve 2, 3 or 4 digits, depending on the size and numbering arrangement in that R.A.X. If the parent exchange serving a group of R.A.X's is, in turn, connected to a group centre which is also automatic and if this, in turn, is connected to its zone centre (also automatic) and then through to the capital city, it is quite likely an originating subscriber of an R.A.X. will proceed as follows. He first will dial 0 to reach his own parent exchange. He will then dial two digits to select a trunk to the group centre, a further two digits to select a trunk to the zone centre, and then one or possibly two digits, to select a trunk to the capital city. He will then dial digits to pass through the capital city to select a trunk to a zone centre on the other side of the city, and will repeat about the same number of digits again to steer the call finally to the R.A.X. desired. He will then finally dial the subscriber's digits. Whether he dials one, two or three digits to pass through a switching centre, a group centre or a zone centre will depend naturally on the number of exchanges in the area served by each of these centres. In densely populated parts of the country there would be sufficient exchanges to require the use of 3 digits to steer the call through a zone centre, for example. The subscriber originating the call would need to know the exact combinations of digits required to steer the call out of each switching centre passed through en route with this scheme. It would be impossible to avoid conditions arising where 15 to 20 digits would need to be dialled by one particular subscriber to reach another. While this large number of digits is obviously undesirable, the principal difficulty is that the particular combination of digits would be different, depending entirely on where the calling subscriber was located in relation to the called subscriber. Space does not permit a detailed analysis, but a simple illustration will suffice. The R.A.X. subscriber, for example, would dial 0 to reach the parent exchange and then, say, two digits to select a trunk to the group centre. At this point he would dial 1 or possibly 2 digits to reach the zone centre. A subscriber living in the group centre, however, would obviously not have to dial the early digits since he has already reached some distance along the way. Thus the called party's number would be different, as it appeared to a calling party from the distant R.A.X., on the one hand, or to a calling party on the group centre exchange, on the other. With step by step methods, therefore, it appears, on available evidence, that an open numbering system is practically unavoidable. The conditions mentioned earlier apply with increasing force as the complete network in the country is converted to automatic working. There seems little doubt that some equipment over and above the standard step by step equipment is necessary in order to enable operators and subscribers to avoid the need for looking up complicated routing instructions and dialling an unwieldy number of digits.

Problems Facing Australia: In considering the application of operator dialling (in the first instance) over the whole of Australia, there are certain clearly defined principles which help to define the problem. At present, each of the six States has its own main trunk exchange located in the capital city. The telephone development in each city is such that six digit local numbering systems are likely to suffice for many years, and certainly a 7 digit numbering system would be adequate for the future. Telephone development outside the capital cities is naturally small, since it follows the general trend of population density and, at present, most of the population is concentrated in the capital cities. The amount of automatic telephone equipment in the country towns is, therefore, only quite small at present, but intensive development may be anticipated in that group of exchanges suitable in size for R.A.X. methods of operation. As mentioned earlier in this article, however, it should be kept in mind that even where manual subscriber services continue for many years in some country areas, there is no reason why automatic trunk switching cannot be put into use with benefit to the telephone service. Automatic trunk switching will enable the originating operator to reach the distant automatic subscriber quickly and reliably, or will enable her to reach the manual operator controlling the distant manual subscriber (where the subscriber still has a manual service). The principal features of automatic trunk switching have been mentioned earlier and, in order to introduce this on a logical basis, without constant changes, it is obviously desirable to have a planned numbering scheme adopted even though it is anticipated that many of the individual exchanges will remain manual for many years to come.

Before such a numbering scheme for each State or for the whole of Australia can be prepared, it will obviously be necessary to decide whether simple step-by-step equipment is to be retained throughout Australia, or whether a departure from existing practice is to be made and some form of register equipment is to be incorporated into the telephone system. A discussion of this further phase of the matter must be left for a future article.

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SOUND RECORDING AND REPRODUCING — PART 1

F. O. Viol

DISC RECORDING

During the last few years the technique of sound recording has developed rapidly, due chiefly to the use of a direct playback method of disc recording which has found its greatest use in broadcasting. It may be said that the requirement of broadcast authorities for improved performance and the research of sound recording engineers have been responsible for the advances so far achieved. Even so, it must be admitted that, at present, the systems in use are not ideal, and even disc recording has basic weaknesses which cannot be readily overcome. In the following discussion, disc recording as used for broadcasting will be explained, together with its limitations. In addition, other systems in use will be dealt with also, so that the merits of each can be judged.

New methods of sound recording, including magnetic tape, magnetic wire and Philips-Miller (cut film), have been developed during the last few years, and each has a place in broadcasting; however, the laterally recorded disc is still the favoured method of sound recording, for three important reasons. Firstly, the sound is spread out on a flat disc so that all parts are available simultaneously and any part can be selected instantly. Thus a series of extracts can be played in any order, in quick succession, while the unwanted parts are omitted. This rapid editing is not possible with wire or tape wound on spools. Secondly, gramophone machines are required for the playing of commercial discs, and it is possible, at a small cost, to make them suitable for the replay of the direct playback type. Thus, there is available throughout the broadcast system replay equipment in quantity for both types of discs. Thirdly, by the same process as is used to press domestic discs, copies can be obtained in quantity relatively cheaply and having the same life. In addition, the metal matrices which are made during the process are the most permanent form of sound recording yet developed, and are of value for records which are of national interest and which are kept for historic reasons.

Disc recording requires the engraving on the flat surface of a disc, generally an aluminium base coated with cellulose nitrate, of a groove of spiral form. The cutting head to which the signal is applied controls the cutting stylus which responds to the sound waves, and moves at right angles to the motion of the disc. Hence the stylus can move up and down to produce a vertical ("hill and dale") recording (Fig. 1A), or sideways to produce a lateral recording. In the latter case, the stylus moves in the same plane as the disc such that the depth of cut is constant (Fig. 1B). As the vertical recording requires special reproducing equipment and there is not the cancellation of the even harmonics of tracing distortion (1), this method is not used in Australia.

When a sine wave voltage of varying frequency and constant voltage is applied to an ideal cutting head of the moving iron type, and the resulting grooves replayed with an ideal reproducer of the

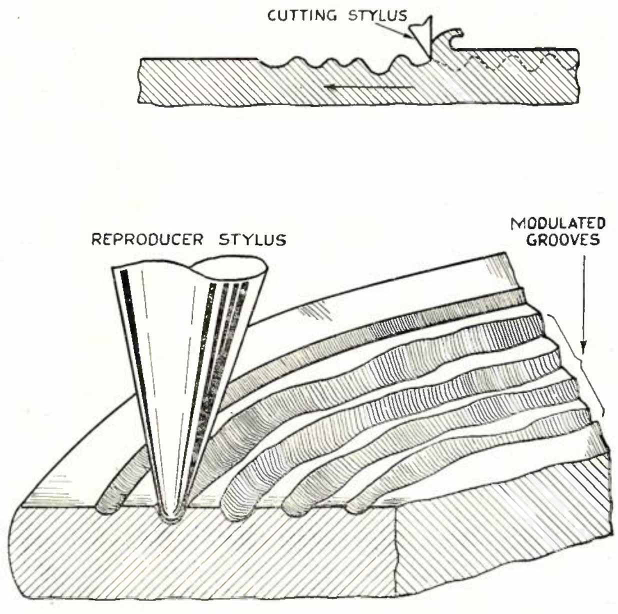

Fig. 1a.—Vertical Type Record Groove.

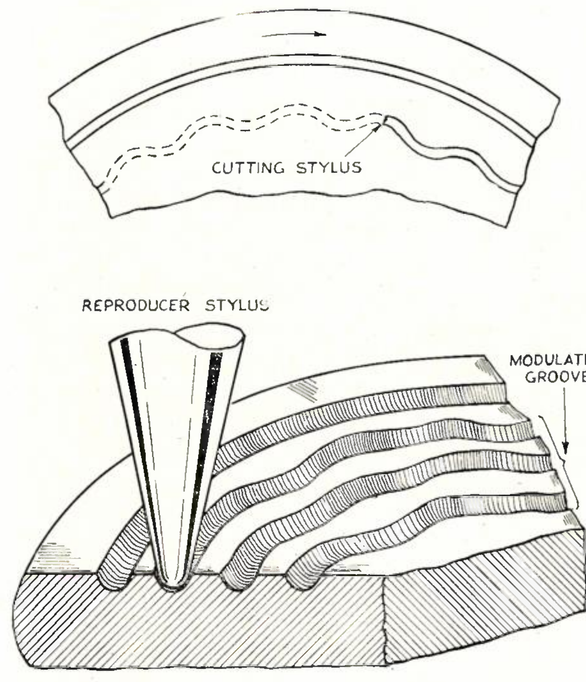

Fig. 1b.—Lateral Type Record Groove.

same type, the output voltage obtained will be constant. If the modulated grooves are now examined it will be found that the amplitude of the sine waves is not constant, for, with a cutting head of this type supplied with a constant voltage, the amplitude is inversely proportional to frequency, and the peak velocities attained by the cutting stylus are constant. Should a frequency weighting network be used in the recording amplifier to limit the amplitude of the lower frequencies, and an inverse network be used in the reproducer circuit, a constant voltage will again be obtained. Thus a satisfactory overall frequency response is possible even though the velocity of the cutting stylus is no longer constant. At a given frequency f with an amplitude A, the peak velocity of the cutting stylus is $2\pi f A$ so that the recorded signal level can be stated in terms of frequency and peak velocity, and, when a constant voltage is applied to a system, the relationship between frequency and the velocity recorded is known as the recording characteristic.

RECORDING CHARACTERISTIC

The terms "constant amplitude" and "constant velocity" refer to the recording characteristic, and Fig. 1 shows how these terms have been derived. In Fig. 1c are shown two frequencies of constant amplitude such that they are an octave apart, i.e., one is twice the frequency of the other. It will be seen that the maximum slope is proportional to frequency. Thus the distance d_{2f}, which is proportional to the slope of the higher frequency, is exactly twice the value of d_f, the lower frequency. As the frequency increases, so does the slope, in proportion. But the slope is determined by the lateral velocity of the cutting stylus, and this velocity is at a maximum where it crosses the zero axis of the groove, which is then the point of maximum slope. Thus we have sound waves recorded at a constant amplitude with a varying slope and velocity.

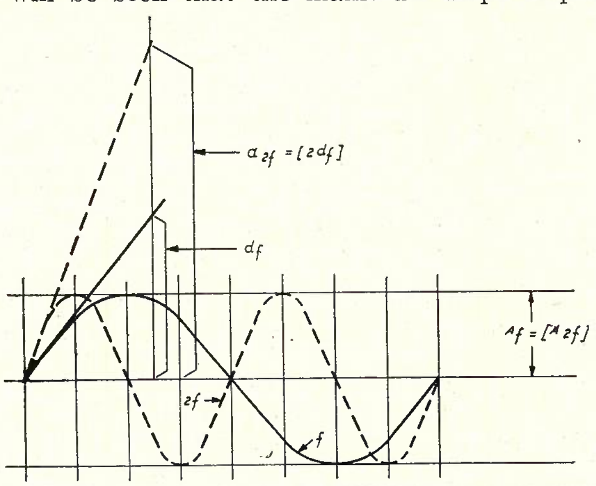

Fig. 1c.—Constant Amplitude (Variable Velocity and Slope).

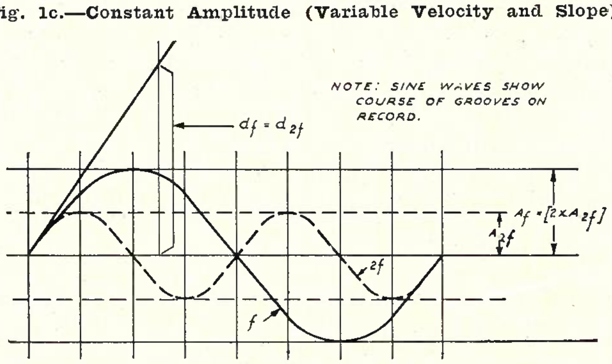

Fig. 1d.—Constant Velocity (Variable Amplitude).

In Fig. 1d, two sine waves, again an octave apart, are shown, but in this case the slope and, therefore, the velocity at zero axis is constant such that d_f is equal to d_{2f}. The variable in this case is the amplitude, and the amplitude of f is exactly twice that of 2f, i.e., the higher the frequency the less the amplitude, but, more important, the lower the frequency the greater the amplitude. Theoretically, this is the characteristic obtained from an electromagnetic cutting head, as the stylus moves with constant r.m.s. velocity, but, in practice, the head may be designed to record at constant amplitude for one part of the frequency range, and constant velocity for the other.

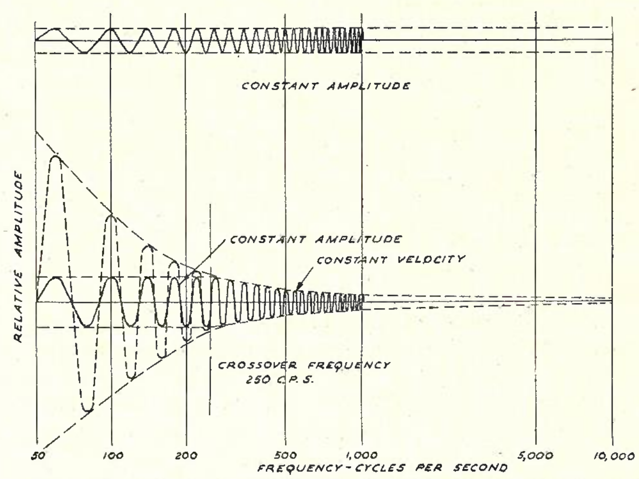

Fig. 2.—Constant Amplitude and Constant Velocity Modulation for Wider Frequency Range.

An examination of Fig. 2 shows that if constant amplitude alone were used, at the higher frequencies the velocity would be high and the slope (wave front) so steep that the cutter would be prevented from performing its legitimate excursions by the walls of the groove contacting the rear of the cutter, and the replay stylus would be unable to follow the grooves. This limitation of the constant amplitude system can best be illustrated by considering Fig. 3, which shows the shape of a square wave signal applied to the input of an ideal recording system, and the groove which the stylus would have to cut under the constant amplitude system. It will be seen that it is not practicable to record or replay such a groove. Under the constant velocity system, the groove, as shown, is a function of stylus velocity and is not beyond the capabilities of the recorder

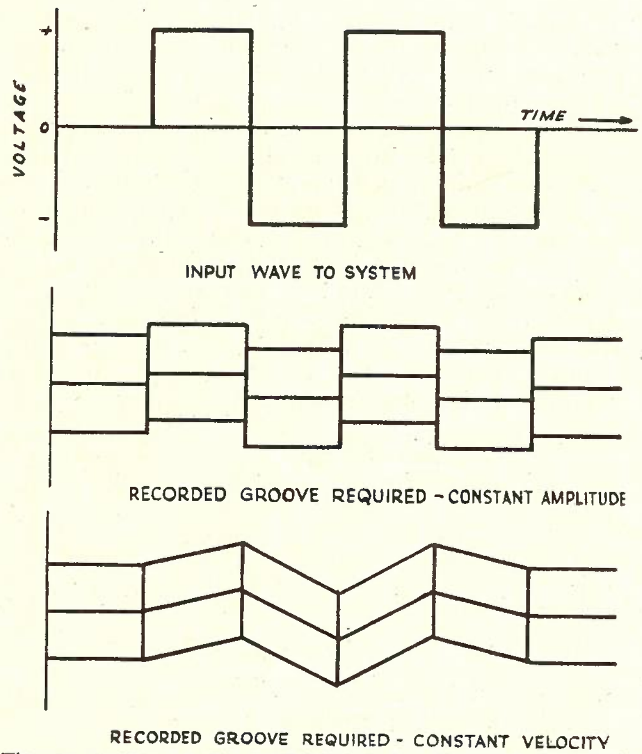

Fig. 3.—Square Wave as Recorded by Constant Amplitude and Constant Velocity System (Ideal Recorder).

or the reproducer. If now constant velocity were used, at the lower frequencies, Fig. 2, the amplitude would be so great that the cutter would cut into adjacent grooves. For this reason, both methods are used in disc recording. By adopting constant amplitude for the lower frequencies, and constant velocity for the higher, a satisfactory recording characteristic is obtained, and, in practice, the changeover occurs at about 250 c/s for commercial or shellac coated disc, while 500 c/s is used for direct playback discs.

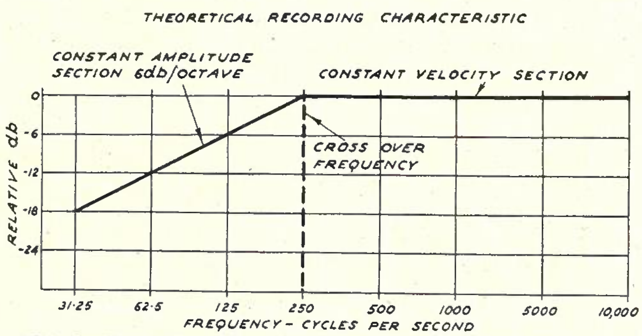

Fig. 4.—Recording Characteristic with 250 c/s Crossover.

So far, the actual frequency response obtained from the characteristics discussed has not been shown. In Fig. 4 the theoretical curve from the use of constant amplitude to 250 c/s and constant velocity above that frequency is shown, and it will be seen that the rate of attenuation of the lower frequencies is 6 db/octave, i.e., although the amplitude of the sine waves is constant, the voltage output at 125 c/s is 6 db lower than at 250 c/s when replayed by a pickup in which the voltage generated is proportional to the velocity of the armature.

Unfortunately, a standard recording characteristic has not been generally adopted, although a standard has been prepared by the National Association of Broadcasters in America. A factor which has an important bearing on this matter is the noise on discs and the tendency to unduly weight the importance of signal to noise ratio.

The record used for direct playback generally consists of a flat aluminium disc coated with a lacquer of cellulose nitrate with plasticizers, including castor oil. Actually, the composition is kept a trade secret by manufacturers. The emulsion has a definite grain size, and the unavoidable presence of minute particles of dust and other foreign matter results in noise when a disc is replayed. As the noise heard during replay is of a high frequency nature, a recording characteristic has been adopted by some authorities which accentuates the higher frequencies during recording, and, on replay, a suitable equaliser is used to restore the frequency response to normal. An improvement of 8 to 12 db is claimed for the recording characteristic shown in Fig. 5. This is the standard proposed by the National Association of Broadcasters of America, and follows closely the "Orthacoustic" characteristic which has been used for some years in that country.

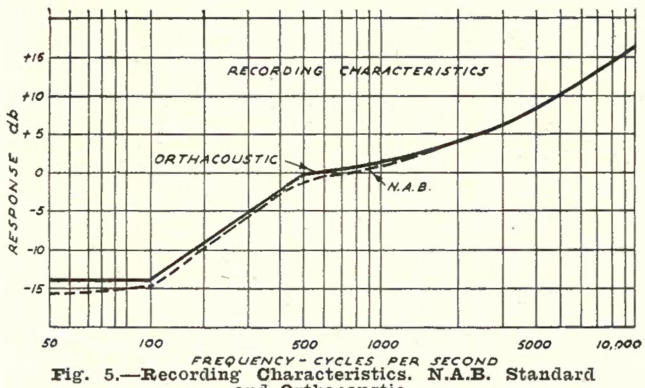

Fig. 5.—Recording Characteristics. N.A.B. Standard and Orthacoustic.

TRACING DISTORTION

Before an examination can be made of the factors that determine the overall quality obtained from a disc recording, it is first necessary to examine the distortion obtained due to the replay stylus tracing the grooves, i.e., "tracing distortion," for it has been shown that under certain conditions the stylus is unable to follow the modulation of the grooves faithfully, hence non-linear distortion must result (1, 3). The third harmonic distortion for constant amplitude and constant velocity is as follows:—

Constant amplitude: $D_3 = 1/16\ (ka \times kr)^2$ .... (1)

Constant velocity: $D_3 = 3/16\ (ka \times kr)^2$ .... (2)

where a = peak amplitude of groove modulation in inches.

r = tip radius of reproducing stylus in inches.

k = $2\pi f/V = f/RN$.

R = radius of the groove in inches.

f = frequency in cycles per second.

N = turntable speed in revolutions per second.

V = record groove velocity under stylus in inches per second.

A comparison of equations (1) and (2) shows that for a given amplitude of groove modulation and the same conditions of modulating frequency, groove speed, and stylus tip radius, the third harmonic distortion is only one-third of the value which would be obtained for constant velocity recording. It is also evident that in constant amplitude recording, for a given groove velocity, k, and hence ka and kr, vary directly as the frequency. Thus, each time the frequency doubles, the distortion increases sixteen-fold, whereas in the constant velocity case each time the frequency doubles the amplitude halves, and hence ka remains constant and the distortion increases as the square of the frequency. As k is small for frequencies below 1000 c/s, it is usual to limit considerations of distortion to frequencies above this figure.

An examination of Fig. 5 shows that the preemphasis of the higher frequencies is at the rate of 4 db/octave, which approaches the 6 db/octave for constant amplitude recording and shows that the third harmonic distortion obtained on replay from a disc recorded with the characteristics of Fig. 5 is higher than for the constant velocity case.

OVERALL QUALITY

There are three major factors which influence the overall quality obtained insofar as the actual recording is concerned:—

(a) The linear velocity of the groove with respect to the cutting stylus.
(b) The signal/noise ratio.
(c) The cutter head performance.

Secondary effects include the type and profile of the cutting stylus, the disc base and its emulsion, and the groove spacing.

Linear Velocity of the Groove: The linear groove velocity and playing times for the standard size of record in general use is as follows:—

It is generally recognised that the groove velocity should not fall below 75 ft/min., but even at this figure, provided the amplitude of the signal is maintained within certain limits, some distortion results. A high groove velocity reduces distortion, but reduces the playing time and increases the wear of the groove wall with repeated playings. However, it is the effect of low groove velocities which will be considered here.

In Fig. 6, the profile of a typical sapphire cutter is shown with the front face angle d about 90°, which is the value most generally used, as an angle greater than this would require too great a pressure to cut the groove to the requisite depth whilst, with a more acute angle, the depth of cut would be too dependent on cutting pressure. In practice, the tip is slightly rounded for strength, but the radius is less than that of the reproducing stylus.

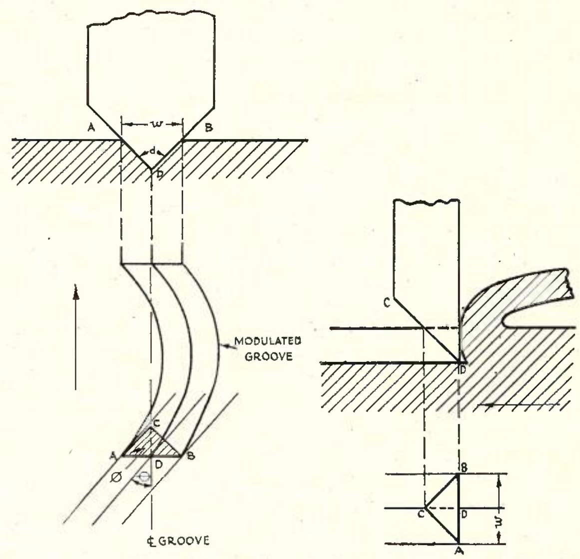

Fig. 6.—Profile of Sapphire Cutting Stylus and Limits Determining Maximum Velocity.

When a groove is being cut, the face A, D, B, should be the only part in contact with the lacquer. In the extreme case, assuming that the record material is inelastic, the maximum instantaneous velocity of the cutter is reached when the angle θ between the tangent to the bottom of the groove and the direction of motion of the record reaches the value $90-\phi$ for, at this instant, the rear edge of the cutter will be in contact with the walls of the groove just cut. Any increase in cutter velocity will prevent the cutter from faith-

Nominal Diameter	Grooves per Inch	Speed	Groove Diameters		Groove Speeds		Playing Time
			Inner	Outer	Inner	Outer	
in.		r.p.m.	in.	in.	ft./min.	ft./min.	minutes
10	96	78	3.75	9.5	77	194	3.5
12	96	78	3.75	11.5	77	234	4.7
16	112	33⅓	6.5	15.5	57	135	15.1
16	128	33⅓	7.5	15.5	66	135	15.3

fully following the signal applied to the cutter-head and the wave form of the modulated groove will be distorted. It has been assumed that the surface material is inelastic, but such is not the case, and as the cutter moves laterally, the material will be deformed under the lateral pressure and will restore itself immediately the cutter has passed. Therefore, the walls of the groove are likely to contact the rear edges of the cutter at an angle θ much less than $90-\phi$.

The distorted wave resulting from low groove velocity and high cutter velocity results in the attenuation of the higher frequencies and harmonic distortion. In addition, the reproducing stylus, because of factors discussed, is not capable of following the excursions of such grooves faithfully, and this further increases the attenuation and harmonic distortion. Fig. 7 illustrates the

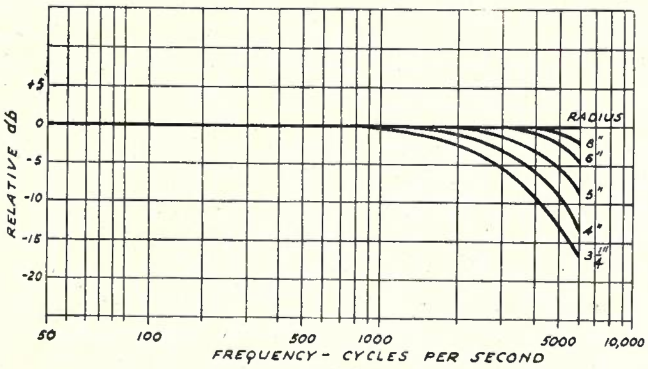

Fig. 7.—Attenuation Due to Variations in Groove Velocity; 16-inch Disc Recorded at $33^1/_3$ r.p.m. Response Obtained on Replay.

frequency response to be expected from a $33^1/_3$ r.p.m. disc cut at 112 lines/inch when replayed by a pick-up suitable for use with cellulose nitrate discs. It will be seen that varying degrees of distortion occur over an appreciable part of the radius of the disc and the problem is to determine a suitable compromise after all the factors involved have been considered.

The Signal-Noise Ratio: The inherent noise of a recording disc can be considered constant for purposes of discussion; then the factors which will determine the signal/noise ratio are the amplitude of the modulated groove determined by the recording characteristics, the efficiency of the cutting head, and the groove spacing. A method of improving the signal/noise ratio by using a characteristic of the type shown in Fig. 5 was mentioned earlier while the groove spacing is generally determined by the recorded time required, which is 15 minutes for a 16-inch disc, this being a suitable time division for programme purposes. Regarding the cutting head there is no difficulty in obtaining the modulation required for the groove spacing used with 16-inch discs cut at $33^1/_3$ r.p.m.

Cutter-head Performance: Although a cutter-head can modulate the groove satisfactorily it may introduce harmonic distortion, and, in fact, the types most generally used are difficult to maintain, both regarding frequency response and distortion. Fig. 8 shows a type in general use in Australia. It is of the balanced armature type with the armature fitted with a knife edge in a V block. Of the three adjustable springs, the centre is the retaining spring while the two outers are used to centre the armature. The pole pieces are laminated, and an extension, fitted at right angles to the armature, is centred in a soft damping medium "viscaloid" which is clamped at one edge.

With the balanced armature cutting-head, theoretically, there is no distortion, provided the air gaps are equal and the whole system symmetrical, as the only flux passing along the armature is that due to the signal currents in the coil. In practice, however, distortion may occur, depending on the incremental permeability of the pole pieces and armature and the fact that it is difficult to maintain the armature symmetrical to the pole pieces, but in any case the distortion from these causes will be uniform throughout the recording.

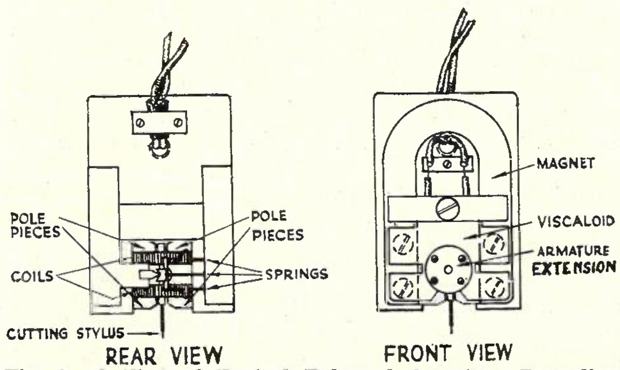

Fig. 8.—Outline of Typical Balanced Armature Recording Head.

Practical Considerations

To examine the relationship between all the factors already discussed and the practical problem of recording, the following three examples have been prepared. In each case the recording of a 16-inch disc (outer diameter of recording 15.5 inches) at $33^1/_3$ r.p.m. is considered.

Example 1: Assume the minimum programme time to be recorded is 15 minutes, the groove velocity is not to be less than 75 ft/min., constant amplitude to be used for the lower frequencies, and constant velocity for the higher. Then the inner diameter will be:—

$$d = (75 \times 12)/\pi N = 8.6 \text{ inches}$$

$$\text{and groove spacing} = \frac{TN}{D/2-d/2} = 145 \text{ grooves/inch.}$$

When T = time in minutes

N = revs/min.

D = outer diam. in inches

d = inner diam. in inches.

There are two distinct disadvantages of this scheme:—

(a) While it is possible to cut a record at 145 lines/inch, the groove depth would not be sufficient to prevent the pick-up leaving the groove if the gramophone unit were subjected to accidental vibration. This is important, for, should the pick-up leave the groove, the programme would be interrupted and the stylus would damage the record.

(b) The amplitude of the modulation would be limited by this groove spacing and the signal/noise ratio would not be satisfactory. There is the point, however, that low amplitudes produce negligible distortion on replay.

Example 2: Assume the same playing time, i.e., 15 minutes, but the groove spacing to be 112 per inch.

In this case the inner diameter will be 6.5 inches with a minimum groove velocity of 57 ft/minute, and it will be apparent that the non-linear or amplitude distortion will be excessive. There is the further point that when a recorded programme exceeding 15 minutes is replayed there will be an appreciable change in quality between the finish of one disc and the commencement of the next.

As shown earlier, one effect of the non-linear distortion is to attenuate the higher frequencies and it is possible, by means of an automatic equaliser coupled to the overhead mechanism of a recorder, to compensate for the attenuation, shown in Fig. 7, for all radial positions of the cutter. The equaliser is connected at a point ahead of the recording amplifier so that the higher frequencies are accentuated or pre-emphasised to compensate for the recording and replay losses, i.e., the inverse of Fig. 7.

At first sight it would appear that the cutting head would be overloaded, but it has been shown by Sivian, Dunn and White (4) that the peak energy for speech and music is not uniform over the frequency range and that the maximum energy is in the region of 300 to 500 c/s as shown in Fig. 9. It will be seen that the energy at 5000 c/s is lower by 15 db which is, approximately, the pre-emphasis provided by the automatic equaliser so that the cutting head does not overload, but the harmonic distortion is excessive. Pierce and Hunt (1) have shown that, under this condition, even at a radius of 4 inches, the distortion is excessive. So that, while there will not be an appreciable change in the frequency response between the inside and outside grooves, there will be an appreciable change in quality due to the high value of harmonic distortion at the inner radius.

Example 3: Record at 128 grooves/inch and pre-emphasis to improve the signal to noise ratio, as shown in Fig. 4.

The innermost groove for this condition will have a radius of 3.9 inches and the minimum groove velocity will be 67 ft/min. It is apparent that this groove velocity is less than the recommended minimum of 75 ft/min., and excessive distortion must result, accentuated further by the pre-emphasis of the higher frequencies.

DISCUSSION

In the first and the third examples, mention has not been made of the results obtained when a programme exceeding 15 minutes is replayed. If the discs are all cut to start at the inside, then there will be a serious change in quality between the finish of one disc and the commencement of the next. The effect, so far as the listener is concerned, can be reduced by cutting "inside to out" on the first disc and "outside to in" on the next, and so on. The change in quality will not be so apparent. This method of cutting has a disadvantage that unless suction equipment is fitted to the recorder, the swarf is likely to foul the cutter when recording "outside to in."

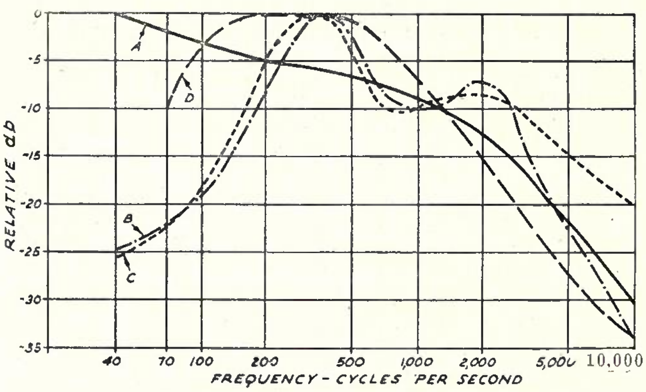

Fig. 9.—Speech and Music—Peak Energy per Increment of Frequency.

So far as the non-linear distortion inherent in the cutting head is concerned, constant amplitude recording has some advantages compared with the constant velocity type. The non-linear distortion can be due to saturation of the armature and pole pieces, or non-linearity of the control stiffness which will give rise to odd harmonics which, in the stiffness controlled frequency range, i.e., the lower frequencies, are a function of amplitude. Assume the fundamental frequency is 500 c/s, and that 1% of third harmonic distortion, 1500 c/s is produced. On replay with a constant velocity system the fundamental will be reproduced with 3% of harmonic distortion. This multiplication of harmonics by their ordinal number is even more serious in the case of intermodulation products, as the sum tones become similarly multiplied. Odd harmonics are more objectionable to the ear than even harmonics and, coupled with sum tones, the overall effect will be heard as a "shrillness," and probably accounts for the poor quality of some recordings.

CONCLUSION

This third example, then, has definite advantages which outweigh those of the other examples cited, but the change in quality between the inside and outside of the disc is serious, and an attempt has been made to reduce this effect by using a combination of examples 2 and 3, each of which has points of merit. In this case the pre-emphasis used is not as great as that for the N.A.B. standard, so that automatic equalisers can be used to compensate partially for the deterioration of the frequency response at low groove velocities. In any case, at the innermost groove, the total pre-emphasis used does not exceed the limits determined by the peak energy curves of Fig. 9. This method of recording has the following advantages when compared with the three examples given:—

(a) The pre-emphasis improves the signal/noise ratio as compared with 1 and 2, but the improvement is not as great as for 3.

(b) The use of an automatic equaliser assists to reduce the change in quality, insofar as the frequency response is concerned, between the inside and outside of the disc as compared with 1 and 3, but not to the same extent as for 2.

(c) The non-linearity on replay, due to low groove velocity, will be more severe than for 1 but better than 2 and equal to 3.

(d) The non-linearity on replay, due to high amplitude of the higher frequencies and which is a function of groove spacing, pre-emphasis and inner diameter will be worse than 1, better than 2, and will be equal to 3 at the inner radius, but may be less at the outer radius.

(e) The effect of non-linearity, due to the cutting head, will be increased on replay slightly as compared with 3, but not to the same extent as for 1 and 2.

It will be seen from the above that each system has definite advantages and disadvantages, and it is only by a careful consideration of all the factors involved that a satisfactory recording characteristic can be obtained, but even so, it will be, at the best, only a compromise.

GENERAL

So far, the use of 16-inch discs cut at $33^{1}/_{3}$ r.p.m. has been considered, but some mention must be made of the 12-inch disc cut at 78 r.p.m. Their use is limited to programmes of short duration and certain types of portable equipment. The groove velocity need not fall below 75 ft/min., but the high velocity at the outer edge, namely, 234 ft/min., is unnecessarily high and results in limiting the number of replays which can be obtained. It has been shown (5) that a recording speed of 50 r.p.m. would give a longer playing time without the extreme change in groove velocity experienced at present. It is doubtful if a change will be made now, due to economics and the fact that there are in existence millions of commercial discs recorded at 78 r.p.m.

Until recently, it was generally considered that a recording amplifier with a power capability of 10 watts would provide sufficient power for a cutting head, but the tendency now is to use amplifiers ranging in power from 40 to 75 watts. At 400 c/s, with the heads available, 500 milliwatts is all that is needed to modulate the groove fully, but an examination of Fig. 10, which shows

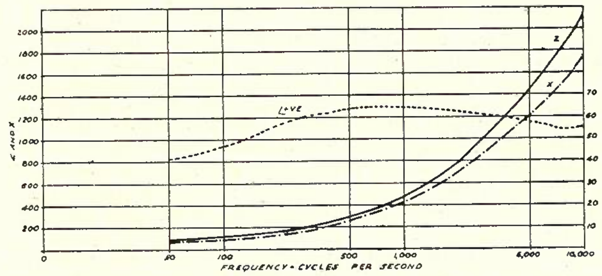

Fig. 10.—Impedance, Reactance and Angle of a Typical Recording Head.

the impedance of a typical cutting head throughout the frequency range, indicates that at the lower frequencies the current required will be high, while at the higher frequencies voltage will be the requirement. If pre-emphasis is used, then at any moment of time there is the possibility that the amplifier may be required to deliver maximum voltage and current simultaneously to the cutter. Also, there is the impedance mismatch to be considered at the extreme frequencies and, as the amplifier can only be designed to deliver the maximum undistorted power for one load condition, then it is necessary to have a large reserve of power to ensure the harmonic distortion is not exceeded under the conditions of impedance mismatch experienced.

The impedance curves of Fig. 10 also show that care must be taken that the output impedance of the amplifier is correct for the type of cutting head used. If the impedance is high compared with the design load, as will be obtained from beam power tubes without negative feedback, the frequency response will follow somewhat the general shape of the impedance curve with the higher frequencies unduly accentuated and the lower frequencies seriously attenuated. On the other hand, if the output impedance is extremely low, as obtained with beam power tubes or triodes with excessive voltage feedback, the reverse effect will be obtained. It is necessary, therefore, that a recording amplifier have a large reserve of power and that the output impedance be correctly related to the design load impedance.

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THE DROP OF POTENTIAL METHOD FOR FAULT LOCATION - APPLICATION OF FULLERPHONE

R. L. Bostock

The drop of potential method of locating faults in a telephone exchange, whereby a low resistance head receiver is used to detect the existence of a potential difference over sections of a circuit, has been in general use since the earliest days of telephony and has particular application to the location of earth and loop faults in switchboard and switch bank multiple wiring.

The general arrangement for localising a fault by this method is shown in Fig. 1. If a cross between two wires is to be found each wire is cleared from all normal connections, and a current of the order of 0.5 to 1 amp. is passed through the loop created by the fault. The limiting resistance used for this purpose may be a bank of resistance lamps connected in parallel, these being

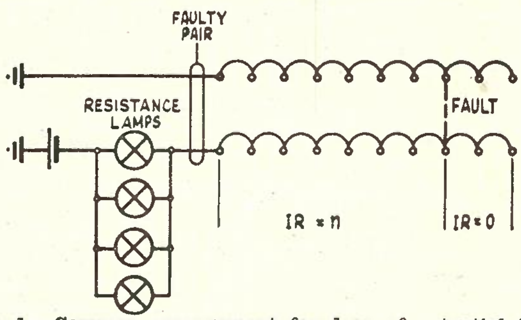

Fig. 1.—Common arrangement for drop of potential test.

unscrewed as required to adjust the current value. A telephone head receiver of low resistance (1 to 3 ohms) is tapped on to the wire to detect the drop of potential between succeeding points along one or other leg of the circuit. The strength of the "Click" heard in the receivers is proportional to the IR value of the section between the terminals of the leads from the head set. No "click" is heard when one of the test leads is connected to a point beyond the fault, which is thus localised.

When using the ordinary "drop" method for localising faults in the switchbank wiring of working exchanges there are certain practical limitations. Due to the short length and consequent low resistance of the multiple wiring between contacts on adjacent banks, only a weak click is heard in the receiver, and, at most, it is a transient of short duration. It follows that in busy automatic exchanges where the switchroom noise level is high, there is considerable difficulty in making the test unless the test current is increased to undesirable values. This limitation is particularly noticeable where the fault has any appreciable resistance.

A typical frequency versus apparent response curve for the human ear is shown in Fig. 2, and it will be noted that at low intensities the average ear is most sensitive to sounds in the frequency range 400 to 4000 cycles per second. If an AC within this range, having a current value comparable to the DC test current mentioned pre-

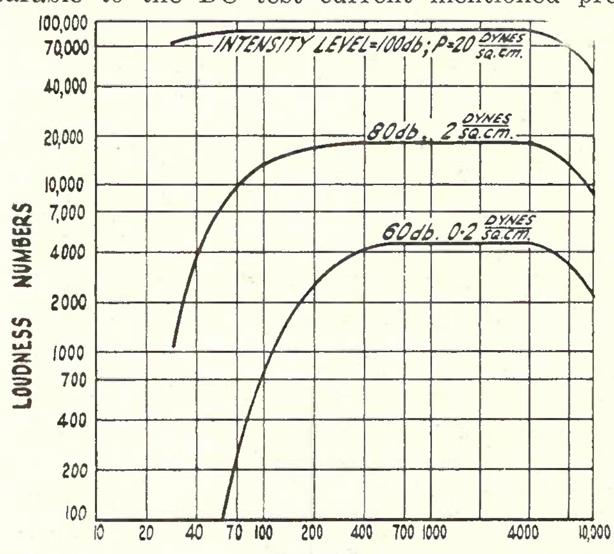

Fig. 2.—Frequency versus apparent response curve.

viously, is used, then a sustained note, having tonal quality, is heard in the headphones and the sensitivity of the test is increased considerably. The Power Buzzer facility, which is provided in the Bank Multiple Test Set as supplied by Messrs. Standard Telephones and Cables Pty. Ltd., is an example of the application of the above principle and the circuit used for generating the AC in this case in given in Fig. 3.

The buzzer or "chopper" unit of the Fullerphone, a combined simplex telegraph and telephone instrument, offers another way of achieving sensitivity without putting a high level tone over the faulty pair. This is considered an advantage in working exchanges as the risk of causing interference to adjacent working circuits is eliminated and, in most cases, the normal current from the impulsing or feed relay of the affected switch

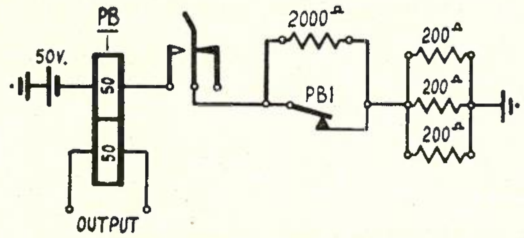

Fig. 3.—Power Buzzer Circuit.

is satisfactory for use as the test current. The actual "dropping out" of the fault can proceed without preliminary preparation or variation of the circuit current values.

The essential circuit elements of the conventional Fullerphone are shown in Fig. 4. Interrupter contact "X" is driven electrically by the buzzer circuit from battery A. When the key is depressed an interrupted current from battery B is audible in the headphones and, due to the smoothing action of the filter, a steady, direct current is passed to line (provided the condenser and inductance values are suitable). Similarly, a D.C. potential applied at the line terminals is

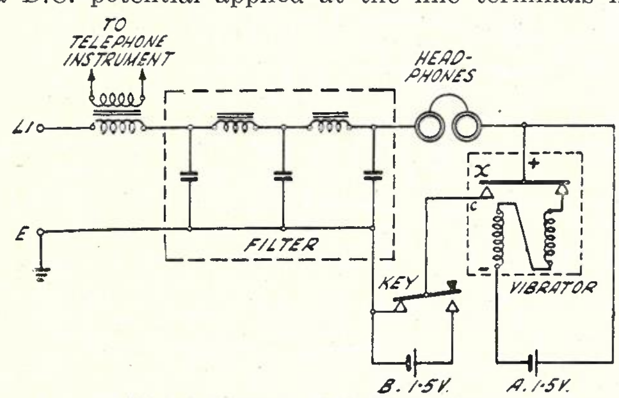

Fig. 4.—Elements of the Fullerphone.

rendered audible by the action of the interrupter contacts. For practical use as a telegraph instrument it is necessary to introduce an adjustable bias potential in the circuit to neutralise any line currents arising from differing earth potential at each end of the line. This feature is not shown in the diagram. The amount of energy required to produce an audible sound in the head-receivers is extremely small, provided the frequency is in the range previously quoted; therefore, as the line current is passed through the head-receivers with little loss, the instrument is sensitive to minute currents and, in practice, readable morse telegraph signals can be produced with a line current as low as 1.0 micro-ampere.

With the drop of potential method of fault location, low potentials and low current values are involved and it follows that the Fullerphone can be applied for this purpose. In practice it has been found quite suitable in the form depicted in Fig. 4, but, as the inductances employed in the ordinary instrument have appreciable resistance, it is desirable to dispense with the filter network and use the circuit arrangement shown in Fig. 5, which is more efficient in view of the low potentials involved. Elimination of the filter results in the introduction of tone into the circuit under test but the power is small and the risk of interference to adjacent circuits negligible.

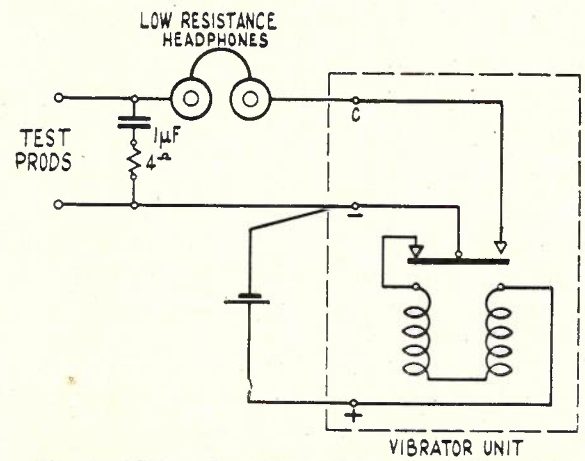

Fig. 5.—"Chopper" unit for drop of potential test.

In the several known instances in which the "chopper" method of fault location has been used, an actual Fullerphone vibrating unit has been employed, but, provided a reliable means of adjusting the contacts is available, any type of high frequency polarised vibrator unit will suffice.

As an indication of the sensitivity of the "chopper" method, it is noted that a short-circuit fault in a selector bank multiple was located with ease and rapidity, whereas with the "Click" method, and using the same test current values and head receivers, the fault could only be localised to within four bank assemblies.

FIRE AT TRUNK TERMINAL, UNDERWOOD STREET, SYDNEY, AND RESTORATION OF SERVICES

A. J. McDevitt

Fire almost completely destroyed the upper floors of a five storey building in Underwood Street, Sydney, during the night of Sunday, 15th June, 1947. The building stood on part of a site bounded by Dalley and Underwood Streets, an area acquired by the Department for the erection of a new City Telephone Exchange. As an interim measure, the building has been used to accommodate, on the ground floor, all terminal and carrier equipment associated with the Sydney-Newcastle-Maitland Trunk Cable and with aerial wire systems serving the South and South Coast Sections of New South Wales, and for this purpose certain alterations were made. These comprised the replacement of the first floor with a 3-1/2″ reinforced concrete slab to provide a fireproof ceiling for the ground floor, and the excavation of part of the ground floor to make it level, and to give sufficient height over the area to permit the erection of standard 10′ 6″ racks. This excavation resulted in one end of the ground floor being approximately three feet below the adjacent street level. The alterations were completed in 1938 and the carrier equipment was installed later in the same year. A view of the building before the fire is shown in Fig. 1.

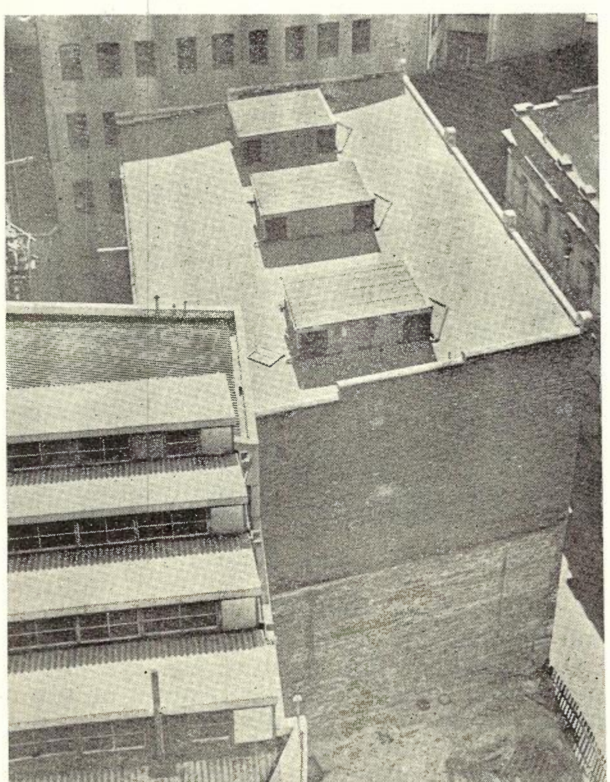

Fig. 1.—The Underwood Street building before the fire.

At the time of the fire the equipment housed on the ground floor consisted of:—

- 10 17-channel cable terminals.
- 8 9-channel cable terminals.
- 2 5-channel aerial wire systems.
- 16 3-channel aerial wire systems.
- 2 Single channel systems.
- 12 Carrier Programme channels.
- Associated equipment such as signalling relay sets, ringers, patchboards, test equipment and distributing frame, etc.
- Battery plant consisting of one 78 AH and one 316 AH 200 volt plate battery, two 24 volt 432 AH heater batteries and one 48 volt 432 AH relay battery.
- Charging equipment comprising 5 motor generator sets and two rectifiers.

The upper four floors of the building were used mainly for the assembly and temporary storage of equipment required for country works, but Transmission Laboratories, including the Standards Laboratory, were also located on these floors.

The fire was first reported to the Fire Brigade by the resident of a roof flat located on a building about 150 feet away. He reported a small, steadily burning fire visible through an upper window of the carrier building, and the time of this report has since been established at 6.25 p.m. The area above the ground floor had not been occupied after 5 p.m. on the 13th June, so that the fire actually occurred about 49 hours after this portion of the building had been vacated. The only man on duty in the building on the night of the fire (Sunday night) was a Maintenance Technician in the Carrier Room on the ground floor, and the first indication to him that anything was amiss was the arrival of the Fire Brigade. At this stage the upper floors were well alight, but before vacating the building all power was cut off and the battery and power plant was isolated from the equipment. The Fire Brigade Salvage Squad supplied and erected tarpaulins over the racks and superstructure so as to minimise water damage.

The fire spread rapidly over the upper wooden floors and falling debris built up on the concrete slab protecting the carrier terminal. The intense heat exploded two oxygen cylinders. Across a laneway another building (Morgan Chambers) caught alight. This building comprised a ground and six other floors, and was used mainly for the storage of wool and for the manufacture of woollen goods. The upper floors of the carrier building were completely burnt out within an hour but, except for a number of burnt window sashes, the ground floor of the building was not damaged by the fire. Views of the damage are shown in Figs. 2 and 3.

Water from the fire hoses, however, poured into the ground floor from all directions; down the stairway and lift well and through the concrete ceiling. When the floor was first inspected

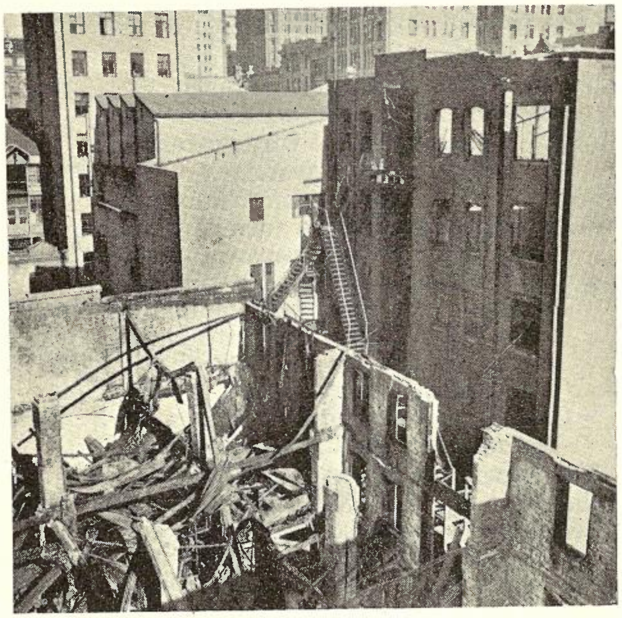

Fig. 2.—View of building after the fire from opposite direction to Fig. 1. Morgan Chambers shown on right.

in the early morning, the water coming through the ceiling had the character and intensity of a heavy rain storm. Throughout the night and early morning there was about 10 inches of water over the whole of the ground floor, but as from about 8 a.m., the rate of inflow eased and pumps were able gradually to reduce the level. As the pumping proceeded, the trench at the rear of the power board proved a useful drainage sump. Water continued to fall from the ceiling in gradually lessening quantities (and, later, at isolated spots only) throughout Monday and most of the following day.

Although an earlier inspection was made it was not possible to take staff into the ground floor until about 8 a.m. on the Monday, and even at this stage the fire was still burning in isolated parts of the building. It appeared that, although the equipment had received a thorough drenching, it might be possible to dry out some of it and bring it into service. All the battery cells had overflowed and water was still falling into them from the ceiling, but the plates appeared to be undamaged. All the power room cable and conduits were wet, but tests showed that the insulation resistance between the batteries and the power board, and between the power board and the machines, was satisfactory. One phase of the high tension leads had failed beyond the power board and was showing an earth, and one of the other phases was doubtful. It was decided to attempt to restore to service as much of the terminal equipment as possible. Squads of men were organised under leaders who had had previous experience of the plant. One squad undertook the testing out and restoration of the power plant; another was assigned to the battery room with the object of bringing one plate battery and one heater battery into operating condition; another squad was detailed to test out the discharge leads and to clear troubles between the power board and the point where the supply to the various systems was taken from the bus bars; another squad was assigned to overhaul and test out the main carrier supply bay; whilst others were assigned to line amplifier bays, 17 channel system bays, 3 channel system bays, etc. An experienced test gang was put in charge of the patchboard and to arrange the test out of the drop circuits back towards the Trunk Exchange as well as forward testing over the systems as they were restored.

It was necessary to run temporary 3 phase wiring from the point of entry into the building to the power board, and, as this was likely to take a little time, it was decided to try and start the emergency engine alternator. Although still very wet externally, the engine alternator was started within 10 minutes. Hot air blowers were directed into the motor generators and these were quickly placed in service and soon one heater battery and

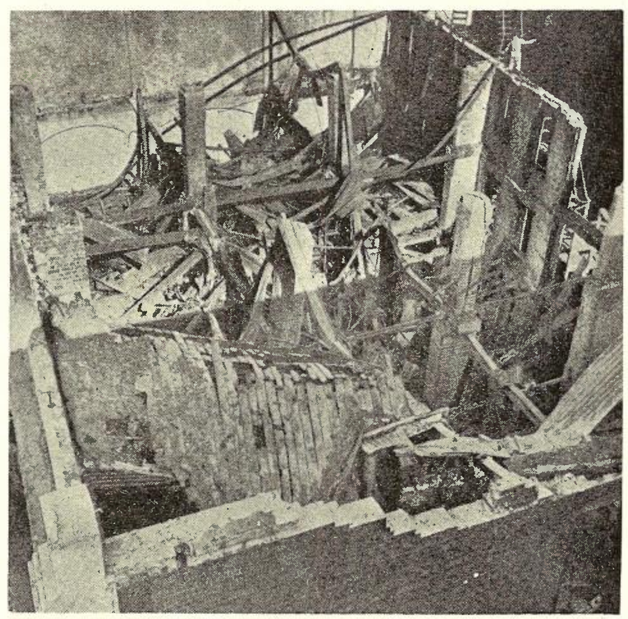

Fig. 3.—Close-up view of damaged building.

one plate battery were put on float. Power was then available to enable testing to proceed.

The equipment for most of the systems was very wet externally and the removal of a cover on any of the bays frequently dislodged water which had accumulated on the inside base of the cover. The atmosphere in the room was so moisture laden, however, that the first step taken to dry out was to arrange banks of 1,000 W. radiators around the floor with the heat directed mainly towards the equipment. Large "Air-Master" fans were used in association with the radiators to create draughts and to thoroughly circulate the hot air. Several small hot air blowers and also two large blowers, each comprising two

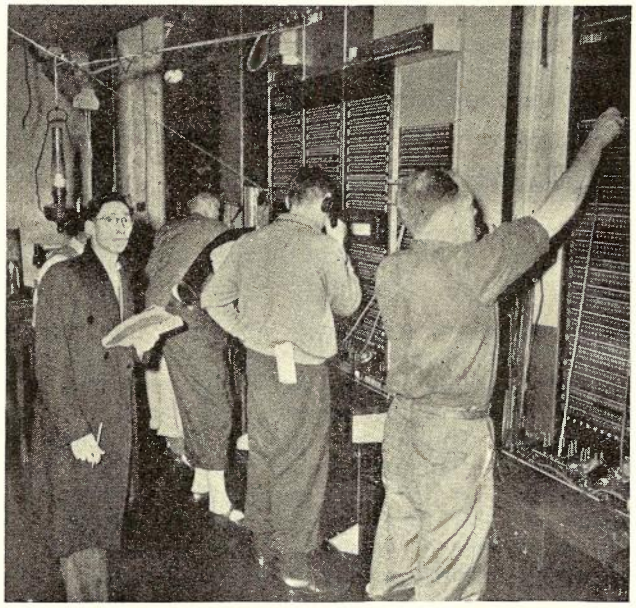

Fig. 4.—Testing in progress.

1,000 W elements with a fan mounted behind them, were also put into use and were found to be very effective for general drying out. This equipment was not satisfactory, however, for quickly drying out key sets, patchboard key shelves, relay sets and other apparatus not easily reached by main air currents, and in such cases excellent results were obtained through the use of hot air dryers normally used by hairdressers. With the commencement of the drying out it was soon evident that very little harm had been done by the water and moisture, and the carrier supply bay was tested out and supply made available within an hour of work having started on it. Drying and testing proceeded on all bays more or less simultaneously, and, although minor fireworks were experienced as power was restored to some bays, the systems were gradually restored to service and by midday on the day following the fire about 90% of all circuits had been restored to service. It was several days, however, before everything was again normal, as faults showed up intermittently during this period. As power was restored to equipment a blue-green discolouration occurred on spring sets and, after being cleaned away, returned rapidly, until the springs were treated with Methylated Spirits, which treatment stopped the action. This was the only suitable fluid available at the time and it proved quite effective. The speed with which the discolouration occurred is indicated by the fact that on 3,000 type relay signalling sets, globules of about $\frac{1}{8}''$ diameter formed on the test jack springs within 10 minutes of cleaning. A possible explanation for the trouble and the effectiveness of the spirits in dealing with it is that the moisture on the springs was acidic, due to the water dripping through the ceiling having filtered through fire debris, charcoal, etc. Methylated Spirits, being mutually soluble with water, would have diluted the acidic water during the washing process and, being highly volatile, would have quickly evaporated, leaving the springs free of moisture. The cleaning of key springs, relay springs and test jacks continued for several days. The rapidity with which the equipment was restored to service was, in a large measure, due to the cellulose acetate covered wire used at the Terminal and to the unit type assembly in use on the carrier systems. In all the cable equipment each individual unit is sealed into a can and the sealing off of these units excluded the water so that very little drying was necessary before the insulation resistance of the panels was sufficient to restore their normal functioning. The electrolyte in the batteries was replaced and the batteries re-charged over a period of three days. Some idea of the conditions in which the work was performed may be gained by reference to Figs. 4 and 5.

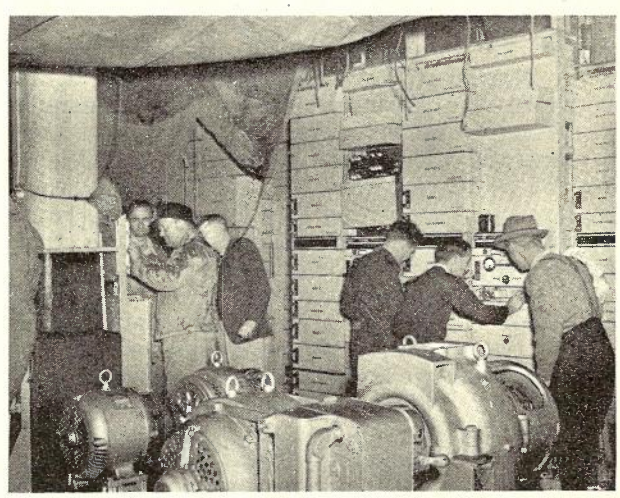

Fig. 5.—Restoration work in progress.
(Reproduced by courtesy of "The Sydney Morning Herald.")

All equipment on the 3rd and 4th floors of the building was a total loss, but, although much of the equipment which had been on the 1st and 2nd floors was heavily damaged, a fair quantity of carrier and automatic telephone equipment had suffered water damage only. There is no doubt that the existence of the concrete slab over the carrier terminal equipment was responsible for it being saved.

The day following the fire (Monday, 16th June) was a public holiday (King's Birthday), and a very pleasing feature of the restoration work was the prompt and willing assistance given by other Branches of the Department, e.g., the Stores

Branch opened up Stores and arranged transport; the Personnel Branch provided sustenance and refreshments, and the Mail Branch supplied material to be used for mopping up. Not only did Maintenance Staff attend in the early morning following the fire but, as well, Installation Staff from all Sections. It was possible to get word to some officers, but many attended voluntarily with tools ready to help. The smooth and quick restoration of service would not have been possible except for the fine spirit shown by these men, not only through their voluntary attendance, but through their zeal in working quickly and effectively under most difficult conditions.

Broadcast advice of the happening was effective in reducing public demand for service on the routes concerned, and, although the loss of the greater part of the Northern Communication System on Sunday night and Monday morning must have caused some inconvenience, there was no unfavourable public reaction, and press references were uniformly favourable.

THE SHEPPARTON INTERNATIONAL BROADCASTING STATION, "RADIO AUSTRALIA"

R. B. Mair, B.E.E., A.M.I.E.(Aust.)
A. J. McKenzie, M.E.E., A.M.I.E.(Aust.)
W. H. Hatfield

No. 3 Transmitter

The No. 3 transmitter is a 50 kW output unit designed by the Radio Corporation of America and installed by the P.M.G's Department. It delivers a power of 50 kW over the whole frequency range 6-22 Mc/sec. It comprises two complete radio frequency channels from crystal to output, and one class B modulator unit which may be employed to modulate either of the radio frequency channels at high power. The main transmitter is located in the main transmitter hall on the same side of the room as the high power stages of the transmitters 1 and 2. Two rooms in the basement below the transmitter accommodate respectively the high voltage transformers and modulation transformer and choke and the cooling system. A cubicle at the rear of the transmitter opening into the gangway accommodates the 2300/230 volt distribution transformers for supplying the power to miscellaneous parts of the transmitter, and the voltage regulators for control of transmitter input voltage.

The transmitter proper comprises the two radio frequency channels, one at each end of the transmitter. Between them is the enclosure accommodating the modulator, rectifier and relay and control equipment. Access to this enclosure is through a small passage way or power control enclosure, the sides of which are formed by the front of switchgear panels carrying the various relays and contactors operating on 230 volts. There are five doors in the front of the transmitter. Two of these when open give access to the tuning controls on the front of the radio frequency channels, and two give access to the enclosures at the side and rear of the radio frequency channels. The fifth gives access to the power control enclosure.

A sixth door gives access to the rectifier and odulator enclosure from the power control en- ure. This door, as well as the doors giving to the sides and rear of the radio fre- channel enclosures, is electrically inter- vith the control system. The other three ving access to equipment which does not carry dangerous voltages are not interlocked. Behind the doors giving access to the tuning controls of the radio frequency channels are smaller doors giving access to the earlier stages of the radio frequency channels. These doors are interlocked. The meters of primary importance are located on the front panel of the transmitter above the level of the doors, and are visible with the doors closed. Meters of less importance are located behind the doors giving access to the radio frequency tuning controls and also in the modulator unit and are visible through a window in the front panel.

A block schematic of the transmitter is shown in Figure 19. Each channel employs six stages. The crystal oscillator employs six "plug in" crystal units complete with ovens and selected by means of a small switch which carries a bank of contacts interlocked with the aerial switching system. The crystal oscillator generates oscillations at half the transmitter output frequency and is followed by a doubler stage. The crystals provided by the R.C.A. are V cut, having operating frequencies between 3 and 11 Mc/sec. Provision is also made for the use of an external master oscillator. The stages following the doubler are all push pull, the 828 tube being a pentode, is used without neutralization. The 810 type is a triode, and conventional cross condenser neutralization is employed. The 827R tube is an external anode air blast cooled tetrode, and a small amount of cross condenser neutralization is employed. The output stage employs water cooled 880 triode tubes cross condenser neutralized.

R.F. Channels

The layout of the radio frequency channels is of interest, and makes for compactness and accessibility. At the front of the channel and accessible from the front of the transmitter are three compartments vertically above one another housing the three initial stages and accessible by means of one door. The lowest stage is the oscillator and the highest the 828 stage. At the back of this and accessible from the passageways inside the enclosure and on either side of the unit are two compartments housing the 810 and 827 R tubes, the top compartment housing the 810 tubes. Below these is a compartment housing blowers and filament transformers. At the rear of these stages is a compartment extending over the full height of the channel accommodating the 880 tubes with ceramic water isolating helices, anode tuning condensers and neutralizing condensers, which comprise rectangular plates of the "book leaf" type. At the rear of the 880 compartment is a large compartment accommodating the anode tuning inductors, output inductors and tuning capacitors. These inductors are of the transmission line type employing long copper tubes with adjustable shorting bars for coarse adjustment of tuning. Mutual coupling variation is effected by raising or lowering the output inductor (by means of an operating motor) relative to the anode inductor. At low frequencies, the anode inductor consists of two turns connected in series by means of a flexible lead, and inductance is varied by a motor operated adjustment of mutual coupling between turns. The balanced tuning condenser for the output coil consists of two plates of dimensions of the order of 3 ft. 6 ins. by 2 ft., whose spacing

and low frequency output inductors. Still lower is the anode inductor bolted to the 880 anode water jackets. This inductor is replaced by another inductor at lower frequencies and this inductor is series connected to still another inductor for the lowest frequencies. This latter inductor mounted on "Steatite" insulators on a metal screening plate is at the bottom of the figure, and moves up and down under motor control. At the lower rear of the figure may be seen the plates of the "book leaf" anode tuning condensers. The overall dimensions of a radio frequency channel exclusive of passageways are approximately 13 feet deep by 4 feet 6 inches wide by 7 feet 6 inches high.

Tuning of earlier stages is effected by means of dials on the front panel of the tuning unit, a view of which is shown in Figure 21, operating the variable air condensers through shafts and universal joints. Tuning of the final stage is effected by means of small motors controlled by two-way non-locking keys on the front of the tuning unit. Position of tuning controls is indicated by means of small voltmeters on the front of the tuning unit supplied with voltage from a metal rectifier through variable potentiometers ganged to the appropriate tuning controls.

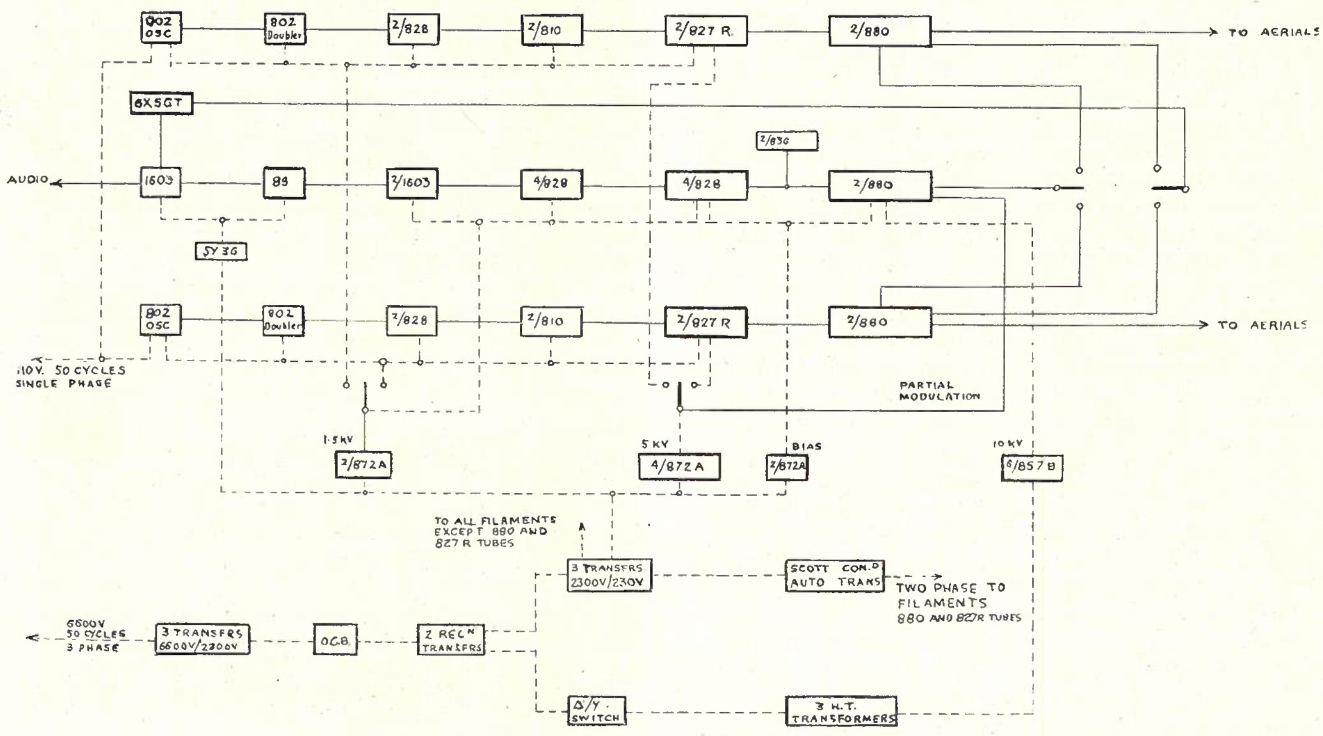

Fig. 19.—Block schematic of R.C.A. 50 kW. transmitter.

from a larger plate of dimensions about 4 ft. by 5 ft. is varied by motor operation. This condenser is shunted by mica condensers for coarse adjustment. Figure 20 shows a view of the final stage tuning inductors. At the top of the figure may be seen the two horizontal tuning plates of the output variable air condenser. Below these, mounted on "Steatite" insulators, are the high

In the lowest compartment of Figure 21 may be seen water flow meter thermometers and water control cocks. The compartments having master oscillators, 807 and 828 stages, are also visible. At the top and sides of the unit are tuning dials, and below them the five keys for tuning control.

There are 17 circuit alterations involved over

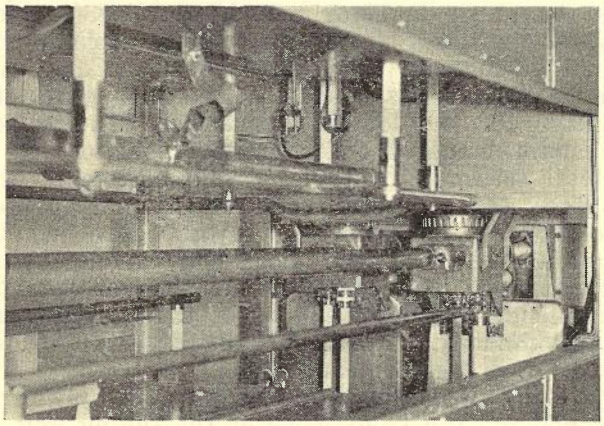

Fig. 20.—50 kW. transmitter. View of final stage tuning unit.

the frequency ranges, in addition to the above tuning adjustments. These alterations are all readily effected by opening either of the front doors of the channel which are provided with electrical interlocks to ensure safety of personnel. Change of frequency of either channel occupies only a few minutes, but, if the full channel has been pre-set to the new frequency, change of frequency with change of channel can be almost instantaneous.

It is noteworthy that no thermocouple meters are employed in the transmitter. Adjustment of output power is obtained by the adjustment of coupling to give the correct plate current (anode tuning and output tuning being successively adjusted for minimum and maximum plate current respectively). Thermocouple meters in the output circuit are meaningless as absolute indicators of power, since the input impedance to the radio frequency transmission line varies with every one of the 25 aerial conditions available to each channel of the transmitter. The thermocouple meters employed in the 100 kW transmitter are necessarily only a relative indication of power output.

A.F. Channel

The audio frequency channel comprises two push pull "class A" amplifiers, the first, two 1603 tubes, and the second, four 828 tubes, a cathode follower stage employing four 828 tubes and a "class B" modulator stage employing two 880 tubes and capable of giving approximately 40 kilowatts of audio output. A combination of resistance and choke coupling is employed in the "class A" stages. The cathode follower stage employs pentodes and it is necessary for the screen and the suppressor grid to adopt the same audio frequency potential as the cathode, while retaining their own d.c. potential. This is effected by employing a six winding balanced transformer, all windings having the same number of turns and using separate windings for cathodes, screens and suppressors, on each side of the circuit, both screen and suppressor being bypassed to cathode by means of suitable condensers, and the cathodes directly connected to the grids of the 880 tubes. This is obviously more economical in copper and iron than the alternative of using separate chokes. Two rectifier tubes, type 836, are connected between the grids of the 880 tubes. These compensate for the negative grid current in the 880 tubes, and in addition to improving the stability with regard to parasitics, they reduce the load placed on the cathode follower and enable smaller tubes to be used. In this way four tubes of total rated anode dissipation 320 watts are able to excite two tubes of 40 kW output. Feed back is applied across the audio system. Partial modulation is supplied to the 827R tubes through a resistance and condenser from the modulator output. The audio frequency channel, inclusive of modulation transformer and choke, is mounted on a frame occupying approximately 3′ 6″ x 5′ 6″ of floor space.

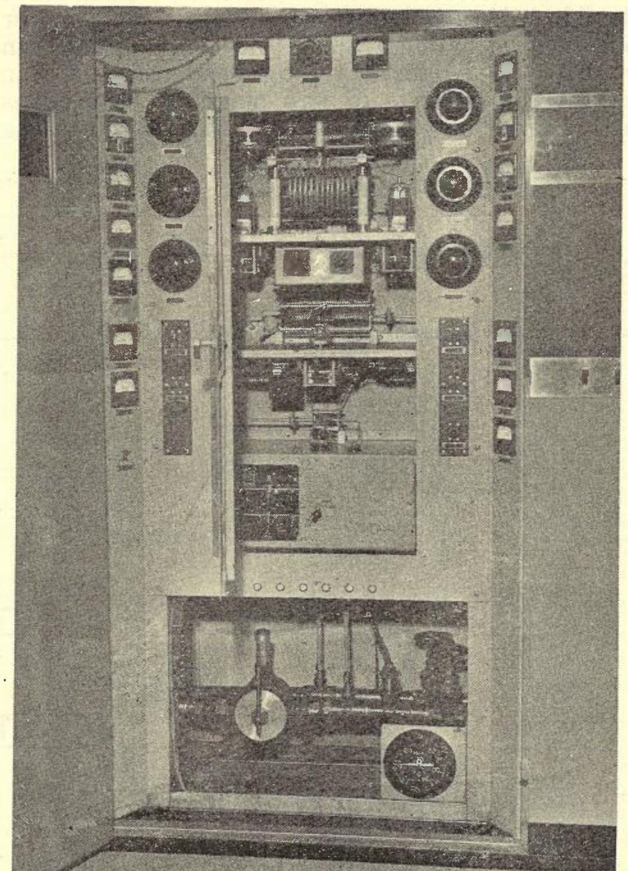

Fig. 21.—50 kW. transmitter. Front view of tuning unit.

The audio frequency amplifier is fed through a hum frequency feedback amplifier mounted in a cabinet in front of and separate from the transmitter in conjunction with monitoring equipment. The amplifier comprises two stages, a 1603 tube and an 89 tube, having approximately 40 db of degenerative feedback. In addition, regenerative feedback of rather less than 40 db from the amplifier output, and degenerative feedback through a 6X5GT rectifier from the transmitter output, are fed in parallel through a 200 c/s resistance capacity selective network to the amplifier input. The degenerative feedback from the transmitter output causes a reduction in 200 c/s noise occurring between the transmitter input and output, and the regenerative feedback compensates for the reduction in frequency response at 200 c/s which would occur if only the degenerative feedback were present. Transfer of radio frequency from the radio frequency channels to the 6X5GT diode is effected by a small relay controlled from the power control system. This is located on a small radio frequency transfer panel, together with a tuned circuit for each channel, and a meter which indicates the radio frequency level at the diode. This level must be kept the same at all operating radio frequencies.

Power and Control Equipment

Power for the anodes is obtained from three anode supply rectifiers, a 1.5 kV, a 5 kV and a 10 kV rectifier using mercury vapour tubes, the 1.5 and 5 kV rectifiers being mounted on one small rack, and the 10 kV rectifier on another. A spare 857B tube is provided for switching in place of a faulty tube in the 10 kV rectifier. Bias on all stages except the cathode follower and rectifier is provided by cathode resistances. A bias rectifier is provided on the modulator unit for these tubes. The filament supply to all tubes is A.C., being two phase for the modulator and power amplifier 880 tubes and the 827R tubes. High reactance transformers feed the filaments of these tubes, ensuring that initial current does not reach excessive values. Power is drawn through a truck type oil circuit breaker on the 6600 volt switchboard and is transformed to 2300 volts, the voltage for which the transmitter is designed, by three step down transformers in the basement. It is controlled by an oil circuit breaker in the power enclosure of the transmitter and is regulated by means of two automatic induction regulators in a cubicle at the rear of the transmitter. Power is thence fed through a set of 2300/230 volt transformers for all supplies except the 10 kV rectifier. The latter is supplied through a delta-wye switch from the 2300 volt oil circuit breaker.

The power control system is of particular interest. All power fed from the 230 volt busbars is controlled by "General Electric" thermal type circuit breakers before reaching the control contactors. These circuit breakers are operated from the power control enclosure and can be used to isolate any part of the transmitter.

The relay and contactor system is operated from 230 volt single phase busbars, supplied by the "control" circuit breaker mentioned above. Control is effected by means of toggle switches rather than push buttons, and is designed so that if all control switches are placed at the "on" position, except the initial "on" or "start" switch, operation of this switch will cause the transmitter to start up, all functions such as switching on of blowers, water pumps, filaments and anodes being effected automatically in the correct sequence.

The rectifier anode switches where repeated in different positions (the centre front panel, on each radio frequency channel, or on the control desk) are in series, so that the rectifier may be switched off at any position, but before switching on at any position, all the other switches must be closed.

The control circuit will not be described in detail, but the general features and facilities provided will be enumerated. The normal operating sequence is as follows: The start switch is closed and the appropriate cooling pump (preselected in the cooling room) and all the blowers start. An "air seal" relay closes, which keeps the pump and blowers in operation for 10 minutes after the start switch has been opened, thus allowing 10 minutes' cooling after filaments are shut off. At the same time, provided all the doors with interlocks are closed, the grounding relays earthing the condensers of the 1.5 kV and 5 kV rectifiers and the high voltage input to the channels are opened. The filament switches may be closed in any sequence and the filament contactors close, provided the appropriate air flow and water flow interlocks have operated.

Operation of the rectifier and audio filament contactor sets a 2 minute time delay relay in operation and following its closure, and provided the door switches are closed, the bias rectifier anode contactor closes, and if the bias rectifier functions properly the d.c. bias rectifier closes. At this stage an auxiliary relay operates, associated with the channel which is not to be used (as selected by the channel transfer switch). This relay replaces the ground on the high voltage terminals of the channel not to be used, and short circuits its door switches, allowing access to the channel without interrupting the sequence of operations. Operation of the anode switches now causes the 1.5 kV, 5 kV and 10 kV rectifier anodes to close as desired. Provision is made for switching on the anodes of the 5 kV and 10 kV rectifiers with surge resistors in series with the output smoothing condensers. These are short circuited about 1 second after switching on. It will be appreciated that if the doors and all switches except the start switch are closed, closure of the start switch causes the above sequence to occur automatically.

Transfer of the 1.5 kV, 5 kV and 10 kV switch from one channel to the other is effected by means of a switch on the front panel of the transmitter. If the two channels have been set up on the appropriate frequencies and aerials, and pretuned, and the filaments are operating and all doors closed, transfer may be effected by a throw of the switch which is of the non-locking "two-throw" with centre position type. The transfer sequence is almost instantaneous. It is effected through two change-over contactors of the electrically operated mechanically latched type, which change over the 10 kV and 5 kV rectifiers, and an auxiliary contactor changing over the 1.5 kV rectifier. In the unoperated position the contactors provide power to channel 1 and in the latched position to channel 2. Voltage on the operating coils of the contactors causes them to operate to the channel 2 position, at which the mechanical latch holds them until voltage applied to the trip coils causes them to release the latches and the contactors to revert to channel 1. Auxiliary relays enable the transfer sequences to be effected in the order of removing the voltage applied to the 1.5 kV, 5 kV, and 10 kV rectifier anodes, causing the transfer contactors to change over, removing the grounds from the high voltage of one channel, and placing them on the other channel, and re-applying the anode voltage to the rectifiers.

Overload protection is provided by means of adjustable solenoid type relays on all rectifiers (input and output) and in the individual cathode circuits of the 880 tubes. This is particularly important as bias on the output stage is of the grid leak type, and drive failure would destroy the tubes if no overload protection were provided. The overload relays (14 in all) are grouped on a panel in the power enclosure and are accessible without shutting down the transmitter. Each relay is provided with a flag indicating that it has operated, and reclosed by hand. The bias overload relay remains operated until reset by hand. The other relays are self restoring. In the case of the 1.5 kV rectifier, persistence of a fault causes continuous reclosure of the anode voltage, until one of the 1.5 kV control switches is opened. In the case of the 5 or 10 kV rectifiers, provision is made for the transmitter anode voltage to lockout after the first operation of the overload relay, or to reclose twice and then lockout. These facilities are selected by the 5 kV and 10 kV lockout switches on the front panel. This re-closing feature is exercised by virtue of a notching relay having an operating coil and a holding latch operating on a ratchet. Successive operation of the operating coil causes the relay to move to successive positions, and release is effected by a release coil lifting the latch. If the fault does not repeat twice, a time delay relay resets the reclosing system after 10 seconds. In the event of lockout after two reclosures, resetting is effected by means of a push button. Operation of any overload relay rings an alarm bell which is stopped by operating a push button.

In the event of a power failure occurring for less than 7 seconds, a time delay relay bypasses the normal time delay between filaments and anodes, allowing the anodes to be reclosed instantaneously. In the event of a longer power failure automatic reclosure of anode voltage occurs after two minutes. The time delay may, however, be bypassed by a push button.

The opening of any door giving access to dangerous voltages in the transmitter proper opens the anode contactors. Access to the transmitter enclosure housing the 2300 volt oil circuit breaker, the distribution transformer cubicle, and the main transformer room in the basement, is through doors provided with locks and keys. The keys cannot be removed unless the doors are closed. The three keys fit into a master key control unit, designed by the Department, and located in the main transmitter hall and which accommodates a master key as well. The master key control unit is a device employing cams which allow the withdrawal from it of either the master key, or any of the three slave keys, but not both. The master key when removed is used to unlock the 6.6 kV oil circuit breaker supplying the R.C.A. transmitter. The circuit breaker cannot be closed without the key, nor the key removed from the circuit breaker when it is closed. Thus the combination of keys prevents the 6.6 kV oil circuit breaker being closed and the three doors being opened at the same time, preventing dangerous voltages being applied to the three enclosures concerned when the doors are open.

Cooling Equipment

Air cooling to the tubes is provided by individual blowers in the transmitter units. Oil type air filters are in general use. The air flow alarms provided are small vanes carrying mercury contacts. The water cooling system is of the closed type using distilled water. The water is circulated by duplicate pumps in the cooling room, and cooled by an air blast heat interchanger in the same room. Air is drawn from inside the building, and exhausted to the outer air. Water flow meters located in each radio frequency channel and in the modulator unit, indicate the total flow in each unit. Isolating ceramic helices are used to isolate the tube anodes. Temperature and water flow interlocks are provided.

Control Desk

The transmitter is equipped with a metal control desk carrying a power control panel for high tension rectifier anode switches, an audio control panel and a v.u. meter and modulation indicator meter. A view of the desk is shown in Figure 22.

Artificial Aerial

A water cooled artificial load is provided for this transmitter, capable of dissipating 50 kW fully modulated at 6 to 22 Mc/sec. It employs woven wire and asbestos resistance mats immersed in circulating water. Matching to a 300 ohm transmitter, termination is effected by a network of air condensers and coils. A flow meter and thermometers incorporated in the unit enable the measurement of power output from the transmitter. A view of the artificial aerial is shown in Figure 23.

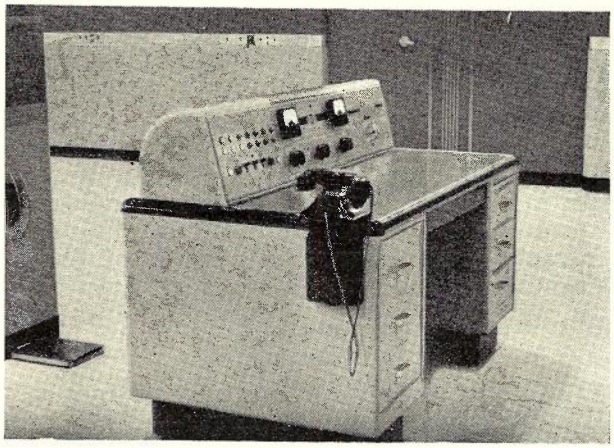

Fig. 22.—50 kW. transmitter. Control desk.

Transmitter Performance

The following details are given of the performance of the transmitters. The 100 kW transmitters are capable of giving the following outputs (guaranteed by the contractors):

6.1 - 15.2 Mc/sec.	100 kW
17.8 Mc/sec.	95 kW
21.6 Mc/sec.	80 kW

Greater power outputs are possible, but the transmitters are at present operated at these powers. At 100 kW output the total power drawn from the mains (including filaments of only one channel) under no modulation is 340 kW and rises to 480 kW at 100% modulation. The power drawn from the 400 volt mains for the filaments of one high power channel and for the driven stages (including anodes) is approximately 80 kW and the filament power for one channel, 24 kW. The distortion is of the order of 4% at 100% modulation with 1000 c/s tone. The unweighted noise level is better than 50 decibels below 100% modulation. For frequencies above 250 c/s. it is better than 58 decibels. The frequency response is within ± 3.5db from 30 to 10,000 c/s. The frequency stability is of the order of 10 parts in a million.

The 50 kW transmitter is capable of giving 50 kW output over the whole frequency range of 6 to 22 Mc/sec. The power consumption is 105 kW, including the filaments of only one radio frequency channel at zero modulation and 170 kW at full modulation. It is interesting to note that the final stage operates at an anode circuit efficiency of 71% at 21.6 Mc/sec. The distortion is of the order of 3% at 100% modulation and full modulation can be maintained over practically the whole audio frequency range. The unweighted noise level is 60 db below 100% modulation. The frequency response is within ± 1.5 db. between 30 c/s and 10,000 c/s. The frequency stability is of the order of 10 parts in a million.

Programme Control Equipment

Programme control equipment is provided to accommodate programmes for the three transmitters from the programme lines and two emergency studios located in the building. A push button switching scheme with a preset changeover facility is provided, allowing each transmitter to be modulated from its own programme line or from either studio. In addition a branching amplifier is provided which may be used to feed two or three transmitters simultaneously from any line or studio. The switching scheme is operated from push buttons on the programme control table through 3000 type relays mounted on the equipment racks.

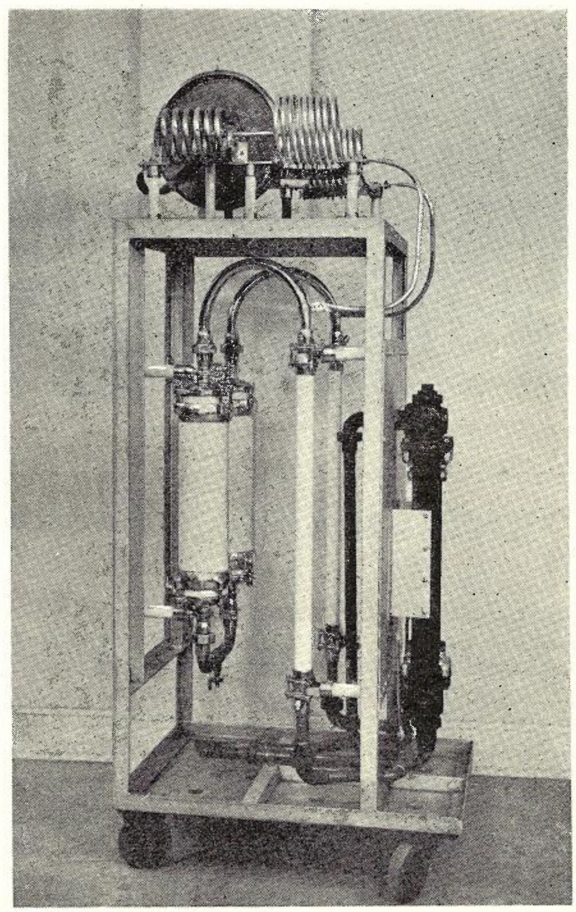

Fig. 23.—50 kW. transmitter. Artificial aerial.

Limiting amplifiers are employed in the transmitter inputs and are normally worked at 6 db of compression. Associated with each limiting amplifier is an excess level indicator, which indicates the level reaching the limiting amplifier in excess of the limiting level. The excess levels are indicated on special db meters on the control desk. The excess level indicators also light alarm lamps and operate relays indicative of excess level, when the excess level exceeds a predetermined value. Programme failure alarms are provided, which cause lamps to light in the event of programme failure.

Appropriate studio and monitoring amplifiers are provided. It is possible to monitor any transmitter input and output in the control room and in a special monitoring room and in either studio, the output of that studio or of any transmitter. Meters indicating depth of modulation of each transmitter are provided on the control room table and on the equipment racks. Testing equipment includes a beat frequency oscillator, 400 c/s low distortion oscillator, attenuator, and level meter as well as a noise and distortion meter which may be plugged to the monitoring diode output of any transmitter.

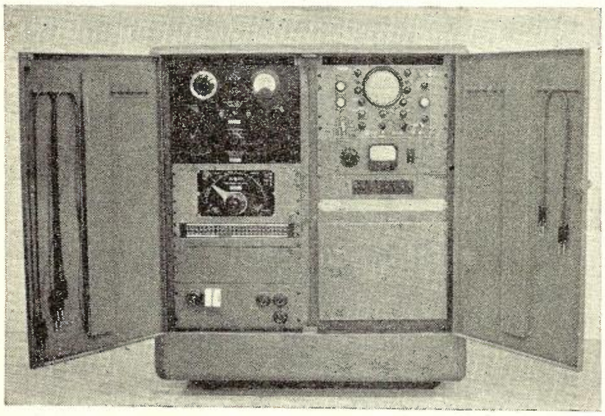

Fig. 24.—View of portable test rack.

A portable test rack is provided for use in the main transmitter room. It incorporates beat frequency oscillator, "General Radio" noise and distortion meter, cathode ray oscillograph, attenuator, and miscellaneous items of equipment. Figure 24 shows a view of the portable test rack.

In conclusion, the authors wish to express their appreciation of the co-operation received from their colleagues in the Postmaster-General's Department, and from the staff of the various contractors who carried out much of the detailed design and installation work described in this article.

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IDENTIFICATION OF CABLE CONDUCTORS

A. S. Bundle and W. C. Kemp

Introduction: In this article it is intended to set down firstly the problem of identifying underground cable conductors under practical conditions and, secondly, to outline the various methods and apparatus developed for this purpose. It will be shown that although colour codes are provided for the identification of the conductors, for various reasons they have not been fully employed in very many instances; and some method of identifying conductors by electrical means is necessary when working on most existing cables. The circuit conditions met in working cables are set out, and the various identification devices offering are considered in relation to the speed of operation, degree of interference to working lines, and general application. Methods of dealing with faulty cables are described, and some cable identification units now under consideration for adoption in Australia are discussed.

GENERAL PRINCIPLES

Types of Paper Insulated Cables: A knowledge of the types of cable used is necessary. The main types of paper insulated cable now purchased are known as twin and star quad, the names being derived from the method of twisting the wires together. A further type known as multiple twin will be met sometimes, but the general use of this form of cable has been discontinued in favour of star quad type. For this reason, no description, other than the make-up diagram, is given. Fig. 1 shows the manner in which the conductors of the three types of cable are twisted. The system of coding the conductors in star quad type cable is also illustrated.

Cable Codes: From the early days of telephone cable manufacture a means of identifying cable conductors was provided simply by using different coloured papers for wrapping the conductors, combined with their separation into layers. Some different colour codes of twin cables, selected merely as typical, and by no means covering the full range in use, are listed below:—

(a) a blue conductor with white mate as marker, and red conductors with white mates for the balance of the pairs in each layer;

(b) a blue conductor with white mate as marker, green conductor with white mate as reference, and red conductor with white

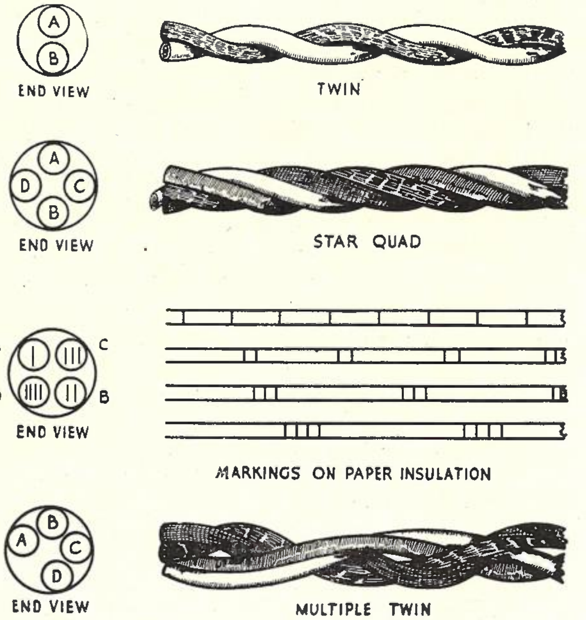


Fig. 1.—Types and make-up of paper insulated cables showing manner of twisting conductors and detail of coding the star type quad.

mate for the balance of the pairs in the layer;

(c) two orange conductors as the marker pair, green pair of conductors as reference pair, and the balance of the layer is made up of pairs marked blue, white, red, blue, white, green, red, blue, white;

(d) orange pair of conductors as marker, green pair of conductors as reference, and the balance of the conductors in the layer blue, white, red, blue, white, red, and so on;

(e) one red conductor and one green conductor as the marker pair, the balance of the pairs in the layer being made up of one yellow and one white conductor. There is no reference pair.

It will be seen that the codes vary both in colour and arrangement. In some cables the coding consisted of a special colour for marking only one pair in each layer, the identity of the other pairs in the layer being determined by the sequence and direction of counting. As there are two directions of counting, clockwise and counter clockwise, this, in itself, was confusing. To overcome this difficulty, two adjacent pairs in each layer were marked with distinctive coloured paper. One of these pairs was called the "marker" pair, being the first pair of the layer; the other pair, termed the "reference" pair, was the last in the layer. This code determined the direction of counting, but it meant that each cable length had to be drawn-in in a direction so that all sections were similar. Fig. 2 shows the usual method of numbering cable pairs or quads. The problem becomes appreciably greater when joints are made between cables with different colour codes and, possibly, with different numbers of pairs, or where twin cable, multiple twin cable or star quad cables are to be jointed to one another.

With such a multiplicity of colour codes, and in the absence of full and uniform instructions regarding their application and close supervision of their use in practice, the codes of these early cables have largely fallen into disuse and reliance

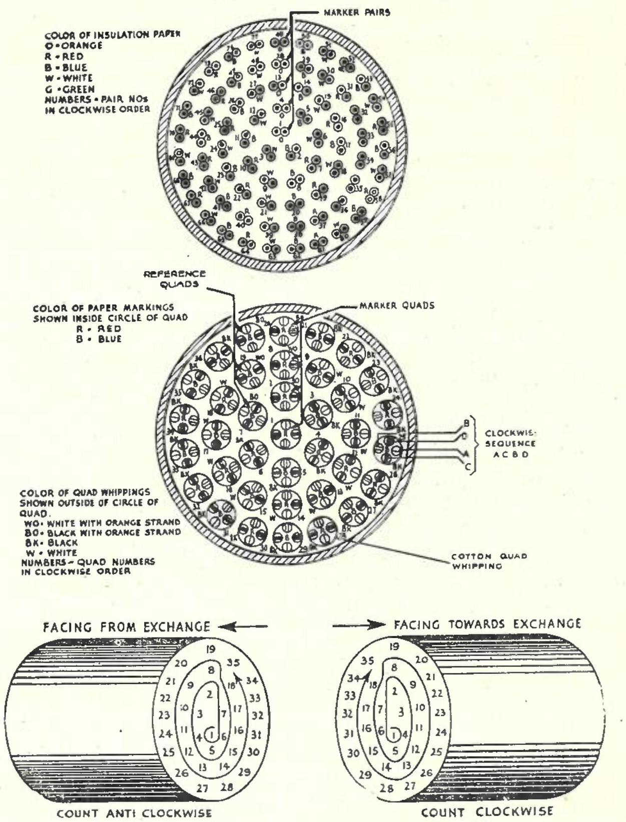


Fig. 2.—Numbering scheme for cable pairs and quads. Figures represent pairs in twin or quads in star quad type cable.

has necessarily been placed almost entirely upon identification by electrical methods. It became the practice to joint all the pairs consecutively in any layer of one cable-length to the corresponding pairs in the similar layer in the adjacent length. This established a degree of order, but it failed in the following cirmumstances:—

(a) at joints where the cables connected were of different sizes, cables with different numbers of pairs in the layers, or where the cable type differed, viz., star quad, twin, etc., and—

(b) when, subsequently, other jointers applying different methods of counting operated on the cables.

As the weakness of so many codes became apparent, a more definite stand was taken about uniformity. About 1932, because of the economies possible, the B.P.O. adopted the policy of using star quad cables almost entirely and standardised the code for this type of cable. The Australian P.O. has followed this policy fairly closely, with the result that standard colour codes now apply to practically all cables purchased, and, with proper instruction and supervision of cable jointing, it is practicable to obtain uniformly jointed cables wherein any jointer can, by reading the codes, select any given pair in the cable at sight. However, this ideal condition is not always met in practice, owing to the existence of a proportion of the earlier type twin cable in many of the cable runs, and to jointing errors.

Standard Star Quad Code: In designing the star quad cable for trunk purposes, the B.P.O. found that the amount and type of dye or ink used in marking the paper insulation had a bearing on the capacitance. The four wires of a quad are, therefore, marked with ink stripes, the stripes being either a uniform distance apart ($\frac{1}{4}$ in. for No. 1 wire) or grouped either into twos, threes, and fours. The total number of ink stripes is the same over a distance of 1 in., and the same quantity of ink is, therefore, used on the wrapping of each wire in the quad. The marking of all four wires in any quad is of the same colour, but alternate quads are marked in red and blue (see Fig. 1). This precise balancing requirement was necessary only in trunk cables, but the coding was applied also to subscribers' cables.

Each quad is "whipped" or wrapped with with several cotton strands. The colour of the cotton is different (black or white) on alternate layers, commencing with white in the central layer. That is, the centre and even layers are whipped with white cotton and the first and odd layers with black cotton. In each layer the whippings of two adjacent quads contain an orange strand. These quads are known as the "marker" and "reference" quads and are, respectively, the first and last quads in the layer. The first or "marker" quad in each layer has red markings on the conductor wrappings, and the quad whipping has an orange strand, while the "reference" or last quad in the layer is distinguished by blue markings on conductor wrappings, and an orange strand in the quad whipping.

Direction of Drawing Cables: It will be seen that to retain the star quad colour code, each length of cable must be drawn in the same direction. This requirement also applied in the case of a number of the codes for twin cable, but was frequently disregarded in favour of the greater economy and ease of drawing-in cables in either direction.

It is necessary, also, to provide some external marking on the cable sheath to indicate to the cable laying party the direction of rotation of the colour coding. The normal method of doing this is to paint a red mark on the cable sheathing at the end where the quads count clockwise and/or a green mark at the end where the count is anti-clockwise.

Circuit Conditions: In new, and non-working cables, each end can be open-circuited and, combined with the fact that the cables are jointed in an orderly manner, identification by electrical means is simple, and is necessary more to check the jointing work than to select pairs.

In working cables a variety of conditions may be met, most of which depend upon the type of exchange to which the cable connects. Figs. 3 to 7 depict some of the conditions.

In sections (a), (b), (c), (d) of Fig. 3, the conditions on idle automatic lines are shown. One leg connects to a line relay of 500, 600 or 300 ohms, and then to battery, and the other leg connects to earth, sometimes through a low resistance supervisory relay.

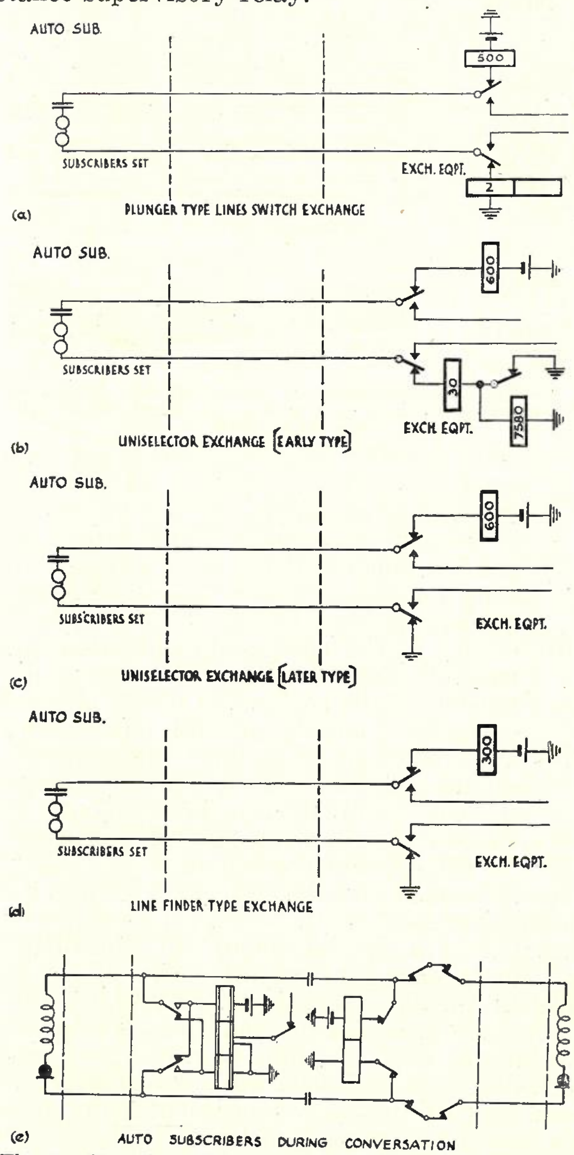


Fig. 3.—Circuit conditions on some types of automatic exchange lines when idle or in use.

Fig. 3 (e) shows the auto. line in use when one leg is connected through a 200 ohm relay winding to earth and looped via the subscriber's telephone to the other leg which is connected through a similar winding to negative battery. This provides a balanced battery condition which will be referred to later.

Loaded junction or subscriber's cable, shown in Fig. 4 (a), forms a low pass filter which limits the frequency of the current which can be used for identifying purposes to about 3400 c/s.

Sections (b), (c), (d) and (e) of Fig. 4 show morse lines which normally have one leg of the pair connected to earth to form a screen. On tele-

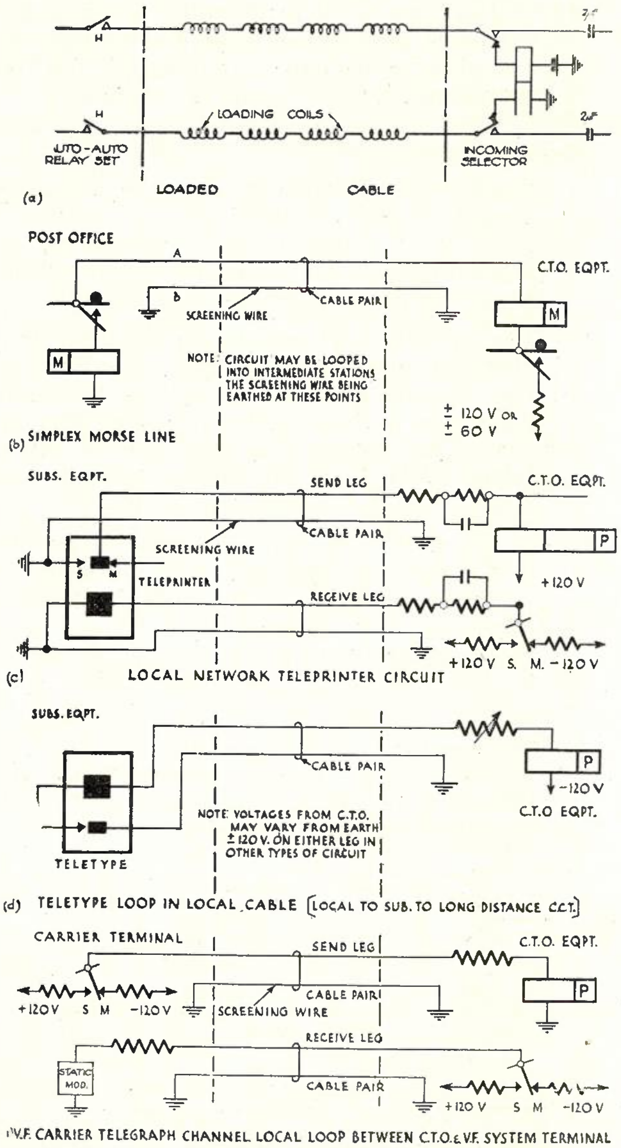


Fig. 4.—Circuit conditions on loaded lines and telegraph circuits.

printer circuits, owing to the present shortage of cable pairs, it has not been possible to continue this practice in all cases, and it has been necessary to use the one pair to provide send and receive legs without screening.

Sections (a), (b) and (c) of Fig. 5 give typical connections in C.B. exchange areas, but the circuits differ for practically every exchange.

The circuits shown in Fig. 6, (a), (b) and (c), and Fig. 7, (a), (b) and (c), are of private lines, PBX external extensions, PBX power lines, ringing leads, fire alarms, etc., some of which occur in most working cables.

Cost of Identification: From an analysis of available figures it is estimated that approximately £50,000 is spent annually in work associated with identifying cable wires. It is a field, therefore, which justifies attention with a view to improving facilities and techniques, to ensure the most efficient use of cable plant.

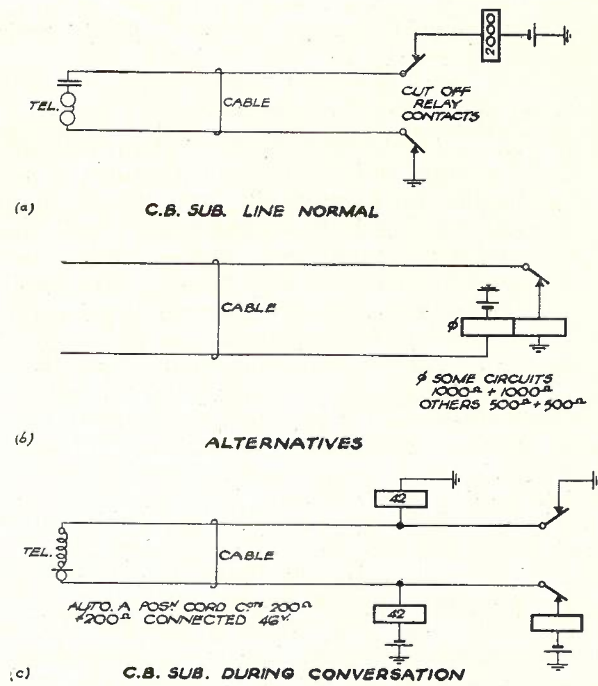


Fig. 5.—Typical connections in common battery exchange areas.

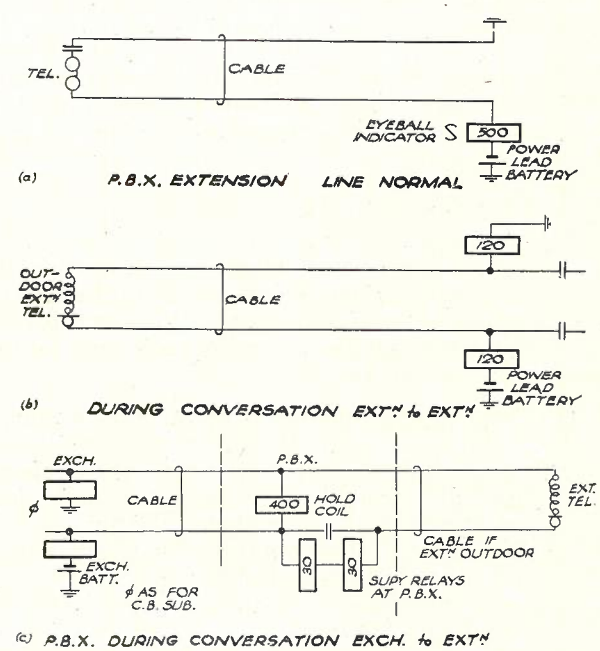


Fig. 6.—Private branch exchange circuits.

Fundamental Consideration in the Design and Operation of Identification Apparatus: The design of apparatus for general identification purposes is restricted by some practical considerations. Also, the methods to be used in operating the apparatus need to be considered in relation to the following factors:—

1. Location.

(a) To ensure accuracy, every identification of exchange or junction cables should, if practicable, be carried out from the exchange M.D.F. This is the point from which these cables are numbered, and any other point is subject to doubt, because of possible errors in marking or because of subsequent numbering changes at intermediate points. Similarly, distribution pairs should be identified from the cable pillar, distributing frame or other point where the distribution pairs will be cross-connected or "jumpered" to the main cable pairs.

(b) It is quicker to search over the terminals of the M.D.F. than through the pairs in a cable joint. Furthermore, this saves wear and tear on the paper insulation at the joint. This practice is most efficient if the majority of pairs in the cable need to be identified, but its advantages are not so marked if only a few pairs have to be found in a large cable joint. For a cable jointed in rotation, this routine simply requires the M.D.F. operator (after the first location is made) to move his tone leads step by step over successive tags in unison with the jointer.

(c) Practically every visit to a cable joint involves identification of pairs back to the M.D.F. In addition, a check is often made onward from the joint to the cable terminal or some other convenient point, particularly if the re-arrangement of cable pairs is involved.

2. Type of Signal or Tone.

(a) An audible signal for the searching operator is quicker and much less fatiguing than a visual signal, such as a milliammeter, because in the latter case the operator has to glance at the indicator each time he taps on to a conductor.

(b) Any tone transmitted must be of sufficient amplitude, and the receiving conditions such that the received tone can be clearly and distinctly heard above the noise level of trams, and other street clatter reaching the ears of the operator in the manhole, or above the switching apparatus and general noise level in the vicinity of the exchange M.D.F.

(c) If a tone is employed, providing it is of a distinctive nature, the searcher can check that his mate has the sending set functioning due to a small degree of coupling between the earthed tone circuit and adjacent pairs. The very slight induction normally involved can usually be tolerated on working pairs.

(d) If the tone is heard loudly in the head receivers at both ends only when the required wire or pair is contacted, positive operation of the system is simple.

3. Manipulation.

(a) For speedy identification, the operator should need to make only the minimum number of movements. Operating of switching keys and changing of connections should be avoided as much as possible.

(b) The operators should be in constant telephone communication, but should have their hands free to manipulate the cable pairs and perhaps a probe or pricking device. This means the provision of either telephonists' head and breast sets, or loud speakers and transmitting units.

(c) If the design of identification set enables it to function without the necessity of withdrawing fuses at the M.D.F., the likelihood of faults developing at this point on their replacement is avoided. Interruption to the subscriber's service is also minimised.

(d) Unnecessary operation of the exchange apparatus can be largely avoided if the cable identification apparatus does not short-circuit the cable pairs under test.

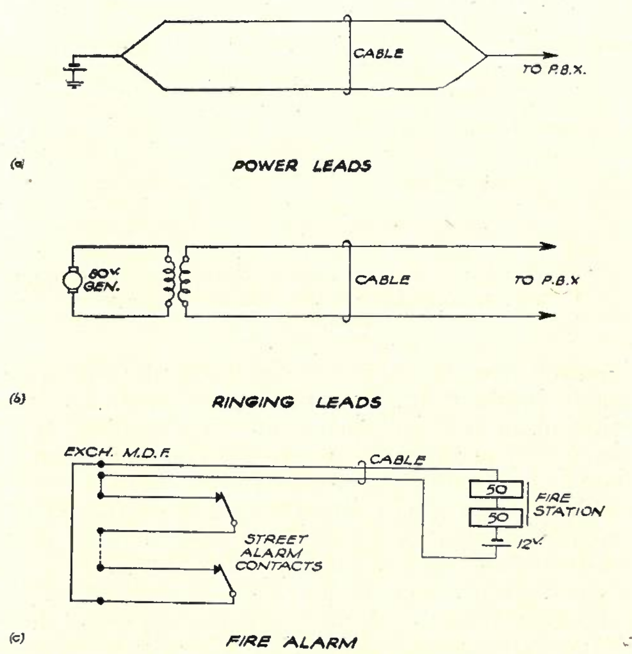


Fig. 7.—Miscellaneous circuits.

Identification in Non-Working Cables: The identification of non-working cables is not difficult and only simple apparatus is required for this purpose. A variety of methods can be used, but the arrangement shown in Fig. 8 is worthy of mention, as it enables all the tests required on a new length of cable to be made, except that for insulation, which requires a megger.

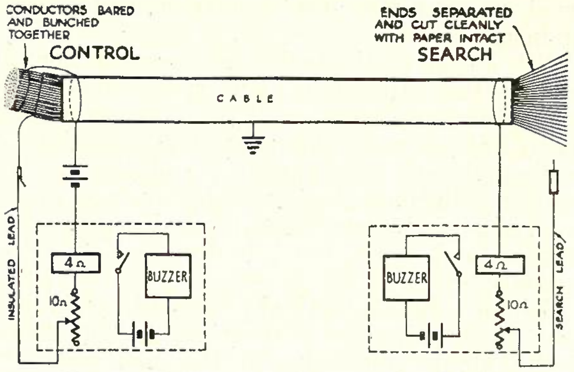


Fig. 8.—Identification of non-working cables.

All wires are bared, bunched together and connected to earth at the control end. The control operator then selects the first wire, withdraws it from the bunch and connects his lead to it. If the wire is not faulty the buzzers will operate only when the searcher connects to the particular wire (to avoid confusion from intermittent contacts a code signal of two beats is advisable; another signal often favoured is one long and three shorts). If the wire is crossed or earthed, the control operator's buzzer will give a continuous signal, and it is necessary to remove each conductor in turn from the bunch, or, alternatively, to label the wire and put it back into the bunch to deal with either when the other pairs have been identified, or when the wire or wires with which it is crossed are revealed by behaving in a similar manner. If the signal stops during this process the last wire removed will be the one with which the wire under test is crossed. If the buzz still continues when every wire is removed, then the one under test is earthed. If the wire is open circuit, no signal will be heard, even though the searcher connects to every wire.

Identification in Working Cables: Identification in working cables presents a much more difficult problem, partly because of the need to avoid interfering with working circuits and partly because of the complexity and character of many circuit conditions in such cables. The use of direct current is unsuitable for identifying circuits in working cables in metropolitan areas and large towns, because of the greater variety of terminal conditions existing on C.B., and automatic exchange lines and P.B.X. and P.A.B.X. circuits. These terminal conditions may have the effect of commoning a number of conductors to earth or causing the application of various potentials which assist or oppose the flow of the testing current in the conductors. If some form of alternating or pulsating current is transmitted, it is less likely to be upset by terminal conditions. It is, of course, desirable that such current should not interfere with the normal use of the circuits. If interference cannot be avoided, the current should be applied for the minimum possible time.

The most common circuit, and a very difficult one to deal with, is that of the idle automatic telephone line which has one side connected to ground (sometimes through a 2 ohm supervisory relay) as shown in Fig. 3 (a), (c) and (d). This low-resistance path to earth by-passes a large percentage of any low-frequency current that is sent out for identification purposes. This difficulty is further increased by the omission of heat coils from the M.D.F. protective equipment, due to the removal of the resistance of these elements from the circuit.

REVIEW OF EXISTING METHODS

B.P.O. Practice: The elements of the B.P.O. method of identifying working cables is shown in Fig. 9. In C.B. or automatic areas the control operator is required to determine first, whether the line is working by tapping on to the line with a lead connected to earth through the 50V scale of a No. 4 detector. If the line is in use, a half deflection is noted on the battery leg and a smaller

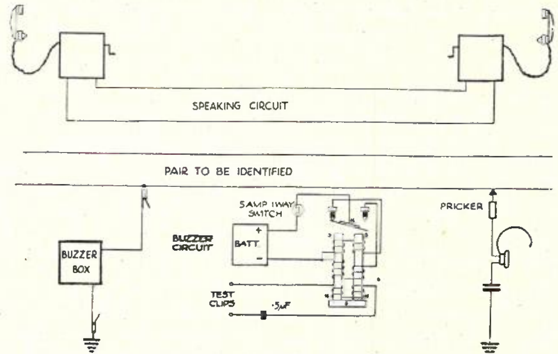


Fig. 9.—B.P.O. practice.

deflection on the other leg. If a full battery deflection is observed on one leg and not on the other, the line is not working, and the control operator then sends an earthed tone over one leg of the line and the searcher goes over all the pairs until he hears the tone. If he is at an exchange, he runs his lead over the M.D.F. terminals, or, if in a manhole, pricks into each conductor through the paper insulation. The instruction states that the circuits shall not be disconnected at the M.D.F. while identification is being carried out. It will be noted that separate telephones are used, and it is necessary for the searcher to change telephones when he desires to converse with his mate.

War-time necessity has demanded speedier methods, and a description is available of two new devices which were to be introduced, although there is no later information to indicate the extent to which they have actually been used in practice.

The first is referred to as a "swiffer," and is essentially a search coil which makes use of the magnetic field surrounding the conductor, over which the identifying current is flowing, to give a signal (amplified if required) to head phones. The signal is provided by a convenient portable buzzer of standard type with predominant frequency of 400 to 500 c/s connected between the wanted wire, pair or quad and earth as the return circuit.

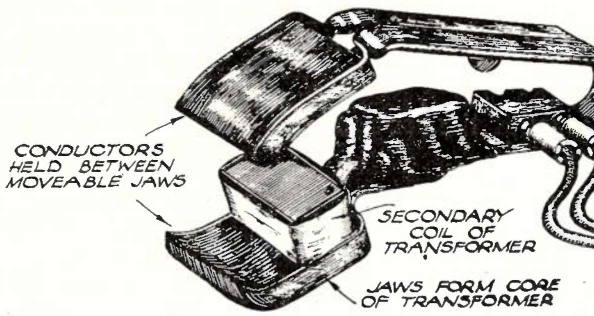


Fig. 10.—Tongs for use with swiffer.

The "swiffer" principle is similar to the clip-on ammeter used to measure current in A.C. busbars. The energised conductor acts as the primary of a transformer, and is clamped within the jaws, which form part of the magnetic circuit of the core. An alternating magnetic flux is set up in the core and results in an E.M.F. in the coil which forms the transformer secondary and which connects direct to head phones or to the input of an amplifier. Fig. 10 shows a sketch of the tongs used.

The second device, known as a capacitance probe, uses the electric field around the conductor set up by the identifying current. An insulated metal probe at the searching end, coming within this field, receives an alternating potential above earth, and this is transferred by an insulated wire to the grid of an amplifier, the cathode of which is earthed. The tone is thus heard in head phones connected to the output of the amplifier. Fig. 11 shows the schematic circuit of the amplifier, which is used with both the "swiffer" and the capacitance probe.

In practice, the identifying tone is connected between the two wires of a pair and not to earth. This is done to reduce the risk of interference

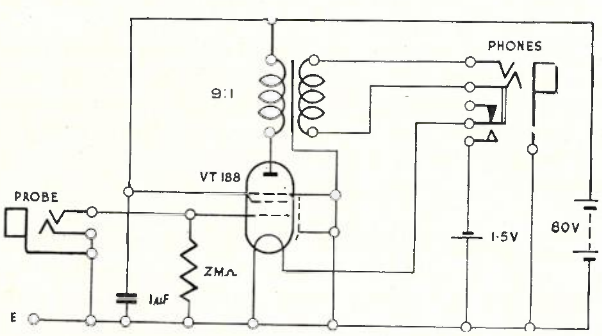


Fig. 11.—Amplifier for use with capacitance probe and swiffer. Schematic circuit.

in other pairs. The two wires of the pair having similar capacitance to earth take up equal voltages to earth and set up an electric field at all nearby points, except in a plane bisecting the line joining the two conductors. The probe is never wholly in this plane for any noticeable interval, so that this does not represent a serious handicap.

With either of these devices a search round or through the cable joint will give some idea of the approximate location of the pair carrying the identifying current. Alternatively, the pairs can be divided into two bunches, and the probe or "swiffer" will indicate in which bunch is the pair required; this bunch is again divided into smaller bunches, and so on, until finally the pair or wire is isolated.

Although such a method represents an improvement in speed of identification, the application of the identifying tone to the pair renders it unusable while it is being identified, and also makes necessary the operation of checking each pair to ascertain whether it is in use before identification proceeds.

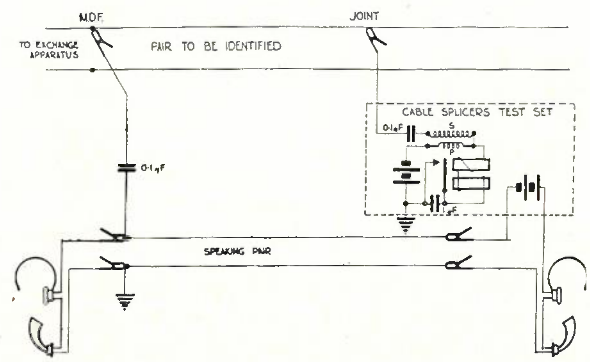


Fig. 12.—Bell system practice for identifying working cables.

Bell System Practice: This is shown in Fig. 12, and is somewhat similar in principle to the B.P.O. method, but shows an improved technique, in that both operators can hear the signal when connection is made to the right pair. Also, they are in constant communication and can speak to one another without need for the searcher to change head receivers. It might be noted that a special cable jointer's test set is used which can provide all the circuit conditions required when working on cables.

Australian Practice: In Australia, with the exception of the Standard Identification Set, which is identical in principle to that shown in Fig. 14, a standard practice has not yet been established. However, as shown later, considerable progress has been made in the development of equipment suitable for standardisation.

Probably the best system in use to date is one somewhat similar to that of the Bell System Practice, as illustrated in Fig. 13. Special "send" and "search" sets are provided. Until recently, it was the practice to disconnect the exchange side of the pair being identified, but later sets have been provided with an improved circuit that permits satisfactory identification on a line connected to the exchange apparatus.

At the exchange, tone is sent out momentarily over every line in turn by rapidly running over the terminals of the M.D.F. When connection is made to the pair to which the jointer at the manhole has his lead connected, both the exchange tester and jointer hear the tone. Thus a circuit is interrupted only momentarily.

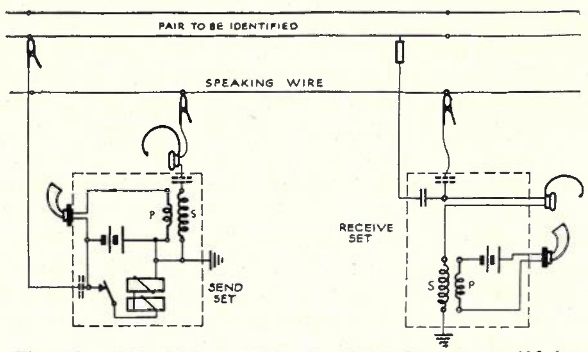


Fig. 13.—One method used in Australia for identifying cable pairs.

Identification in Faulty Cables: In general, cable failures can be classified under three headings:—

(1) Where water or moisture has penetrated the sheath and has reduced the insulation of the paper wrapping.
(2) Where a cable has been cut completely through.
(3) Where a hard object has penetrated the cable sheath and mutilated both conductors and insulating wrappings.

Case (1) is the one most commonly met in practice. The insulation is so reduced that an audible tone transmitted over one circuit can be heard with equal volume in the other faulty pairs, and it is thus impossible to distinguish the pair required. There are two methods of dealing with such a fault after locating the position of the fault between manholes. Either the faulty spot is found and the sheathing opened, the conductors dried out, and a sleeve wiped over the sheath, or else a new length of cable is cut in to replace the faulty length which is later drawn out or abandoned. In the former case no identification is required. In the latter case, it is necessary to identify between the two points where the cable is being cut in, so as to be sure that the pair in the length on the exchange side of the faulty section is cut into the same pair in the new cable as the corresponding pair on the distant side of the faulty length. The way of doing this is to identify the pairs in the faulty cable just prior to cutting them over into the new cable. In such cases a device known as the "Page" buzzer (named after its inventor) has proved to be the most suitable. The circuit and arrangement is shown in Fig. 14.

The insulation resistance between wires in a saturated cable is reduced to a figure of the order of 50 ohms, and may possibly be as low as 30 ohms. In such cases, reliable identification can be made between the cutover points, i.e., the manholes, provided that the test circuit used will discriminate between the resistance of a metallic conductor and a conducting path through the faulty section of the cable. That is to say, the jointer must be sure that the connection is made via the cable conductor and not through the resistance of the fault. This is achieved by using a marginal relay (adjusted to operate on 180 mA) and a rheostat which is adjusted so that the relay will just operate with its local battery when working over the cable conductor. If the identifier pricks into the wrong wire, the resistance of the fault will prevent sufficient current flowing to operate the relay and so no signal is heard and the identifier will pass on to the next wire.

Consider an example. Given that the operating battery is 4.5 volts provided by three dry cells, and that a 100-yard length of 10 lb. conductor cable is to be replaced, assume that the 10 ohm resistance is adjusted to zero and the relay battery removed in the second Page set at the distant end.

Data:—

The 4 ohm relays are adjusted to operate on 180 milliamps. Maximum resistance of circuits, in ohms:—

	Ohms
10 lb. conductor, 100 yards (faulty cable)	5
Pair in new cable 100 yards	2.5
Relays (Page sets)	8
Rheostat	10
Miscellaneous, leads, milliammeter, etc.	1
Total	26.5 ohms

Current flow = E/R = 4.5 × 1000/26.5 = 170 mA.

The rheostat at the near end only is next adjusted until the current flow is about 190 mA. This current will operate the 4 ohm marginal relays and thus the new value of the circuit resistance

$$R = E/I = 4.5 \times 1000/190 = 23.7 \text{ ohms.}$$

Therefore the resistance cut out by the rheostat

$$= 26.5 - 23.7 = 2.8 \text{ ohms.}$$

Referring to Fig. 14, it will be seen that, should the operators at each end tap on to different wires, the resistance in the Page circuit would be increased by at least 30 ohms, the resistance between adjacent wires, and the resistance in the relay circuit would now be:—

$$30 + 23.7 = 53.7 \text{ ohms.}$$

The resulting current would now be:—

$$E/R = 4.5 \times 1000/53.7 = 84 \text{ mA.}$$

This would not be sufficient to cause the relays to function, and the relay buzzer units thus discriminate between a good conductor and a circuit through the fault.

Procedure: If available, two buzzer units are used, one being set up at each end. The jointer at the distant end should turn his rheostat to cut out all the resistance, and possibly remove the dry cell battery dependent upon the resistance in the circuit arrangement.

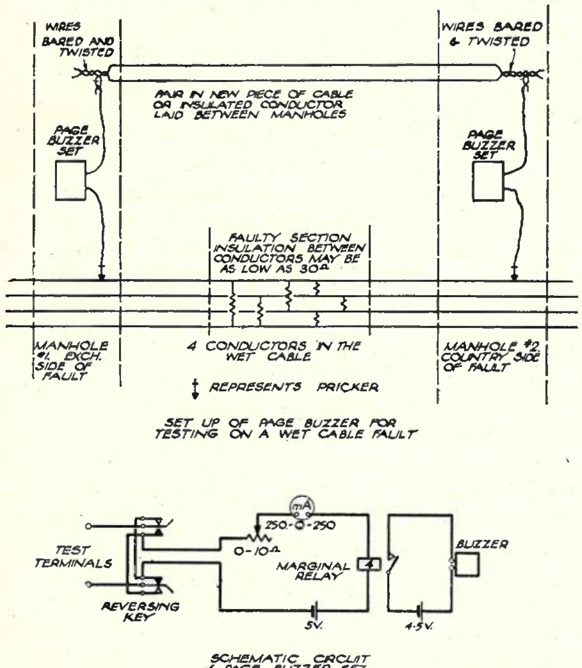


Fig. 14.—Wet cable identification using Page buzzer set circuit and arrangement.

The usual method adopted is as follows:—

(a) The operator at the exchange side of the fault acts as the control party. He selects a conductor of a pair in the working cable, cuts it, and then connects his identification set to the faulty side of the cut conductor. Precautions: It is essential that only one wire be identified and jointed at a time, for the following reasons:—

(i) One or more pairs may have been transposed in other joints.

(ii) On junction, public telephone and telegraph circuits the polarity of the working battery must not be reversed.

(iii) It is not always possible to select a pair of wires visually, and cutting two wires on a supposition that they are a pair may lead to an error.

(b) The other jointer at the distant end searches through the cable until he connects to the wire being identified. In such circumstances, the sets obtain sufficient current over the line to actuate the relays, the contacts of which close the local buzzer circuits and so produce audible signals. The milliammeter readings should then be checked to see that the correct value of current is flowing.

Note: In the event of exchange battery not having been removed from all pairs in the cable (this is not always practicable), stray currents of this "foreign" battery may be picked up which, by causing the Page relay to operate, may confuse the identification. As a check on the readings the reversing key may be thrown. If the reading on the meter is due to the local Page battery, no difference in the deflection will show. If the reading is due to "foreign" battery the deflection will change on reversal of the key and indicate the fact.

(c) The control operator connects his identification set to the other wire of the pair and his mate checks to ensure that an audible signal is obtained on this wire.

(d) The control operator then makes a similar identification of the selected pair in the new length of cable and proceeds with the cutover.

The Page unit does not provide communication facilities. Until the recent addition of the reversing key, it did not provide a ready means of detecting exchange battery, which may cause the relays to operate when the unit is actually bridged across a pair of wires. In such instances, the difference of potential across the pair may be sufficient to cause errors in identification.

Theoretically, it should be possible to operate from a point on either side of the fault and, by reference to colour codes only, cut-in a new piece of cable simply by rotation jointing. It is essential for both jointers to work carefully and take extra care to see that they both start off by selecting (by colour code) the same pair in the faulty cable length as the first to cut into the new cable, and that they both select the same pair in the new cable. After this it should be only a matter of careful rotation jointing.

Under the conditions which occur in practice at the time of a cable fault, it seems to be extremely difficult to achieve this care and accuracy, with the result that some mistake may occur. Once a mistake has occurred, the whole of the remaining lines will probably be incorrectly connected and confusion will result, with the wrong subscribers being connected to the exchange equipment. Such a condition requires a lot of time to rectify, and experience has usually shown that it is better to identify each wire in both the new and old cables as each pair is cut-over.

LATER DEVELOPMENTS

In recent years, various units have been developed, using thermionic valves, with the object of enabling the identification of working lines without interrupting them. These new methods have been based on one or other of two principles:

(a) Earthed tone is sent over the cailho and received by induction.

(b) A current of a frequency above the audible range is transmitted over the pair and is detected at the searching end after it has been picked up by induction.

Bell Voice Frequency Method: This American method consists of transmitting an audible tone over the phantom of a quad and using the capacitive coupling between a blunt-pointed probe and the conductor to enable the operator to hear the tone. An amplifier with three valves is used, giving a gain of approximately 50 db. It was designed primarily for use on trunk cables but can, of course, be used in some types of exchange cables.

Bell High Frequency Method: Another and somewhat later development consists of transmitting a tracing current of frequency of 250 kc/s modulated with 500 c/s. The current is picked up by means of a probe, is amplified, demodulated and fed to a loud speaker, thus enabling the searcher to work in greater comfort. The probe contains a tiny coil with many turns of wire so as to enable an equal pick-up to be obtained by electro-magnetic coupling or capacitive coupling. This is necessary because of the possibility of standing waves occurring at points along the line with such high frequency currents.

This set was designed essentially for identifying over short sections of trunk cables, in such instances as the cutting-in of a new length of cable when the gas pressure alarm system has indicated that a fault has developed in the sheath in a section of the working cable. The high frequency is used to provide a safe margin above the highest frequencies of the carrier systems operating over the cable. The sharp attenuation of currents of this frequency limits, to a few hundred yards, the length of cable over which the system will work.

Modulated Carrier Method: This system consists of transmitting, over the pair to be identified, a current consisting of 15 kc/s, modulated with 400 c/s, the modulating current being suppressed. Searching is done by means of a circuit using copper oxide rectifiers to detect the modulated high-frequency tone and produce a 400 c/s tone in the searcher's receiver.

A feature of this method is that the current sent over the line should be inaudible to anyone using the line. It has also been combined with the technique of search over the exchange M.D.F. instead of through the cable pairs in the joint, but this practice has its limitations in such circumstances as a case where, say, 24 pairs are to be located in a joint in an 800 pair cable.

The oscillator-modulator unit was designed for use in the exchange, the current being sent over a pair to the jointer in the manhole, who then connects this pair in turn to the pairs he requires identified, or to each pair in the cable until the pairs required are all identified. The man at the M.D.F. searches over the lines terminals with head receiver and copper oxide rectifier circuit until he hears the tone, and then advises the distant jointer of the pair number.

With proper co-operation between the exchange and outdoor staffs, this method can be put to considerable use, but has certain limitations in such matters as identifying over loaded cables and the length of line over which it can operate. Furthermore, owing to contact resistances, capacity unbalances and the like, rectifying effects can occur on the line which cause some of the transmitted tone to be demodulated and to become audible to a subscriber using the circuit.

High-Frequency Heterodyning: Experiments carried out in South Australia have resulted in the development of a system of transmitting a 20 kc/s current over the line and heterodyning it with an amplifier-oscillator unit at the receiving end, using a current of a frequency 1 kc/s different from the sending current. The current is picked up at the receiving end by magnetic coupling, using a tuned coil for the purpose. The objection to the use of these high-frequency methods is the rapid attenuation which occurs with such currents. Transmission through V.F. loaded cables is impossible. Costly and complex apparatus at the receiving end is also required. It also depends upon magnetic coupling and, consequently, upon current flow and is, therefore, less efficient on pairs terminating at, or close to, a joint.

As completely developed and produced, this equipment forms a very satisfactory method of identification under most practical conditions. However, because of the various controls, etc., it is best handled by selected personnel, and loses some of its value in this way. Provision of such sets for general use would be extremely costly and their bulk and fragility would also combine with their complexity to render them unsuitable for general use by cable jointers. In short, they are rather too elaborate for the general case.

(To be concluded in next issue.)

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 give information which a candidate should have to enable him to give answers which would secure high marks.

EXAMINATION No. 2643—ENGINEER TELEGRAPH EQUIPMENT

R. D. Kerr

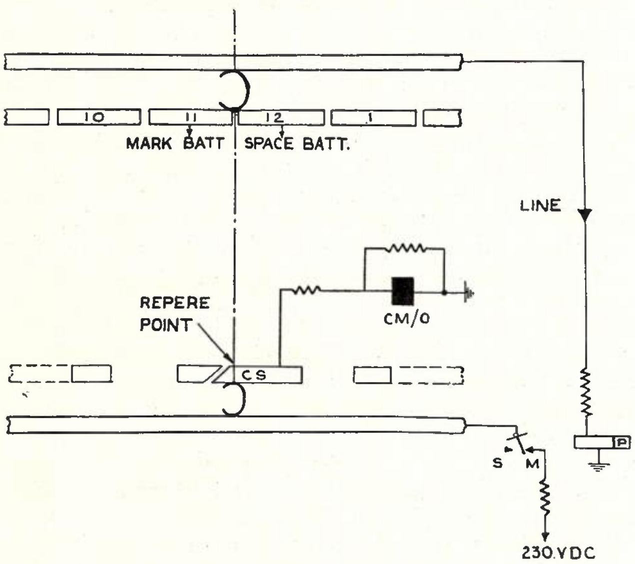
GROUP 2

Q. 3.—(a) Describe, with the aid of sketches, the sequence of operations both electrical and mechanical, in the transmission of a correction signal on a multiplex system.

(b) Describe a multiplex "run-in" to synchronism.

(c) How frequently should the correction of the brushes take place? Give reasons.

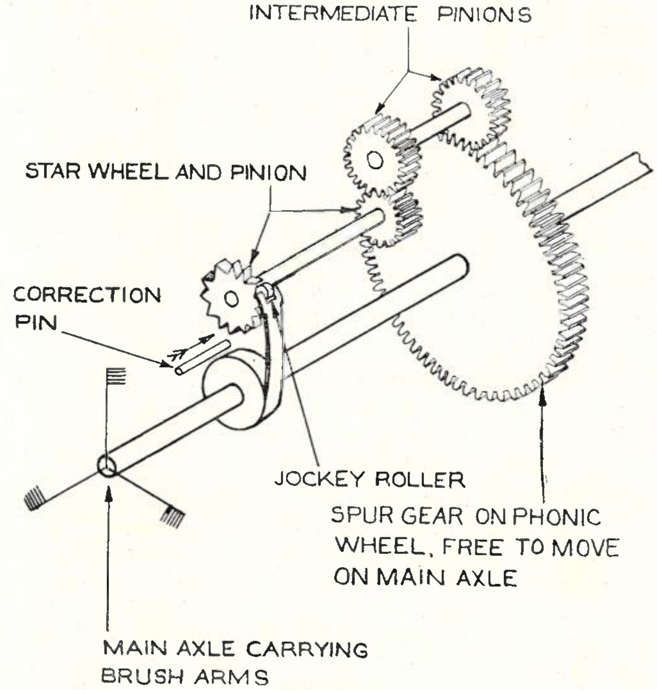
A.—The synchronisation of sending and receiving distributors necessary for the operation of a Murray Multiplex circuit is achieved by arranging for the receive distributor to run slightly faster than the send, and regularly retarding the advance of the brushes on the receiving or corrected stations distributor. A correction signal is transmitted with each revolution of the brushes of the sending distributor, two segments (11 marking and 12 spacing in a Double multiplex) being provided for this purpose in addition to the five signalling segments for each channel on the send ring of the plateau.



Q. 3, Fig. 1.

At the receiving distributor the correction signal is received, in the normal working condition, as the receive brushes traverse the correction segment at 12 o'clock on the plateau. With perfect synchronism the receive brushes theoretically reach the correction segment as the send brushes pass the gap between segments 11 and 12 in the case of a double multiplex. Thus the marking correction impulse has just ceased as the receive brush touches the correction segment so that no current flows to the correction magnet connected to this segment. (See Fig. 1.) As the receive brushes advance on the position of the send brushes during a revolution they will commence to traverse the correction segment whilst the send brushes are still traversing the marking segment 11.

This impulse of marking current will operate the correction magnet if prolonged sufficiently; i.e., if the receive brushes have advanced so far on the segment as to make correction possible. Actually, the correction segment is slightly advanced on its theoretical position and the point of operation of the correction magnet (repere point) delayed by a corresponding amount. This is necessary to compensate for the actual delay in operation of the correction magnet due to its electrical and mechanical inertia. This delay is artificially increased, with a resistance network about the correction magnet, to stabilise correction by permitting the receive brushes to stop bouncing, after hitting the leading edge of the correction segment, before a correction signal is actually registered.



Q. 3, Fig. 2.

The mechanical operation of correction is shown by reference to Fig. 2. The operation of the correction magnet armature causes the correcting pin to be thrust into the path of a star wheel which is normally fixed in relation to the distributor main axle and rotating with it in space. The star wheel does not normally rotate about its own axis as it is held by a jockey roller engaging in its teeth.

In this condition the epicyclic gearing between the spur gear (fixed to the driving phonic wheel of the distributor but both free to rotate on the main axle of the distributor), intermediate pinions, and star wheel pinion is locked so that the rotary motion of the phonic wheel is transmitted to the main axle carrying the brushes. When the correcting pin is thrust into the path of the star wheel it is forced to rotate on its axis, the jockey roller "jumping a tooth" on the star wheel when it does so. This occurs approximately 120° after 12 o'clock.

This rotation of the star wheel on its axis is transmitted through the gearing to the phonic wheel and results in the setting back of the brushes on the main axle with respect to the phonic wheel. Actually, a small negative angular velocity is interposed for a short time between the continuous positive angular velocity of the phonic wheel and the brushes normally rotating at this latter velocity. In this way compensation is made at the receiving brushes for the receiving phonic motor's slightly greater velocity than that of the sending terminal.

A cam on the gearing carriage throws the correcting pin out of engagement of the star wheel at each revolution of the distributor, this occurring at approximately 240 degrees after 12 o'clock. The ratio of gearing and the number of teeth in the star wheel are such that the brush arms are displaced 1½ degrees with respect to the phonic motor at each correcting impulse.

(b) A full description of the Murray Multiplex Run-In is given in an article having that title in the Telecommunication Journal, Vol. 5, No. 1, of June, 1944.

(c) The normal frequency of correction is once every second revolution of the distributor. The frequency of correction depends on the difference of speeds of sending and receiving distributors. The limiting maximum speed is such that the receiving distributor advances on the sending distributor's position by no more than 1½ degrees at each revolution, i.e., the brush on the receiving distributor turns through 361½ degrees for a 360 degrees revolution of the brush on the sending distributor. The limiting minimum speed is such that the receiving and sending distributors have the same speed. The maximum tolerance of speed variations is obtained when the receiving distributor speed is set mid-way between these limits and consequently gains ¾ degree for each revolution, or correction occurs on an average once for each two revolutions.

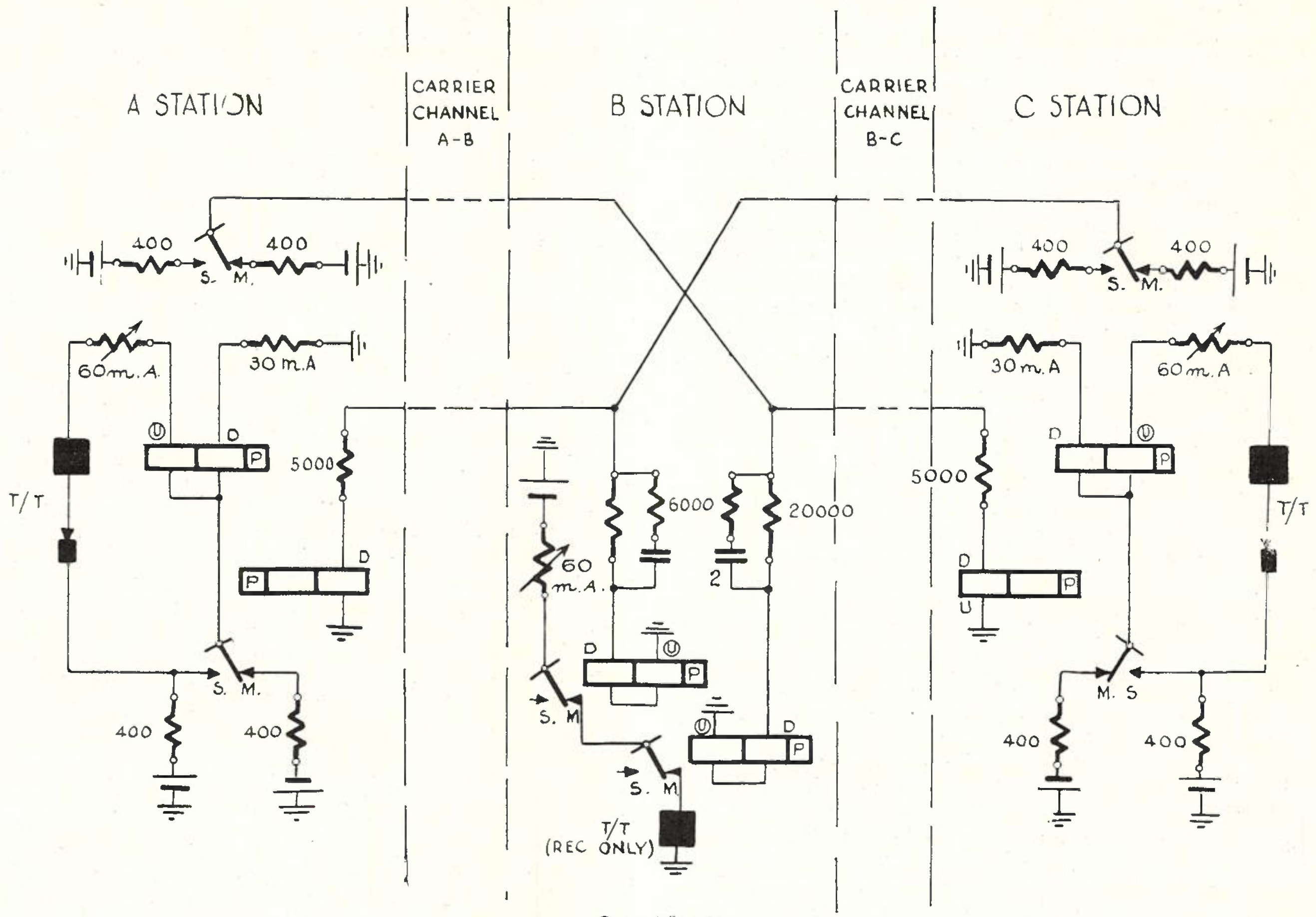
GROUP 3

Q 1.—A simplex service using Model 15 teletypes is required between stations "a" and "c" over two V.F. carrier channels in series. Drop copy receiving facilities are required at intermediate station "b" midway between the two series carrier channels. Show in a diagram the telegraph circuits required at the three stations and explain the operation. Explain what is meant by "orientation" as applied to a Model 15 teletype and explain the functioning of the device to achieve the desired orientation.

A.—(a) Fig. 1 shows the schematic connections of the telegraph equipment on the drop copy Model 15 teletype service between the three points A, B and C.

A and C Stations.

At the telegraph offices adjacent to terminals A and C the relay sets are standard teletype long distance to local circuit repeaters. These function as follow:—



Q. 1, Fig. 1.

The carrier receive circuit is normally marking. The local loop circuit is normally closed and 60 m.a. marking current flows from the mark contact of the receive relay (— battery) through D circle to U circle winding of send relay, local loop and limiting resistances to the space contact (+ battery) of the receive relay.

Simultaneously, a 30 m.a. spacing current flows from the mark contact of the receive relay (— battery) through U to D winding of send relay. Since the loop current of 60 m.a. marking preponderates over this 30 m.a. spacing current the send relay contacts normally send marking battery into the carrier send circuit.

The teletype signals open and close the local loop, the 60 m.a. loop current falling to zero and restoring while at zero the 30 m.a. spacing current takes control of the send relay and it sends spacing battery into the carrier send circuit, thus repeating the signals from the local loop.

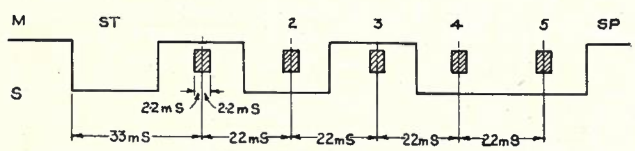
Should signals be received on the carrier receive circuit, the receive relay will move to space feeding positive battery out through the send relay to the local loop whilst the return of the loop is to the same positive battery. Thus the loop current falls to zero, and the teletype magnets release. In this way, marking and spacing signals are sent from the carrier receive circuit to the local circuit.

When the carrier receive circuit is spacing, the 30 m.a. current from the receive relay contacts through the U to D winding, the send relay will be reversed from the normal spacing current so that, whilst the local loop current is zero, the send relay is kept to mark by the reversed U to D winding current.

B Station.

The two long distance channels on either side of the intermediate station B are connected, carrier send A side to carrier receive C side and vice versa so that the two wire unidirectional connection between the two terminal stations over two long distance channels in tandem functions in the normal manner. At B the passing signals from A to C and C to A are repeated by the leak relays connected to each of the two unidirectional double current legs of the through connected channels.

The leak relays' mark and tongue contacts are connected in series, and key a 60 m.A. local circuit to the intermediate stations printer magnet. Normally there is a marking potential on both the legs of the through connection so that the local circuit through the mark contacts and tongues of the leak relays is closed. The signals in either direction operate the associated leak relay (since the through circuit is operated "simplex" transmission only takes place in each direction alternately) and each repeats the signals to the local circuit and intermediate station printer magnet.



Q. 1, Fig. 2.

(b) The "orientation" of the Model 15 teletype consists of setting the selection intervals of the receive mechanism with respect to the start transition so that they are most favourably placed to follow the signals received over the circuit.

Normally, the selection interval is not longer than 20% (i.e., 4.4 milliseconds) of a code element and these are normally set to the middle of the code elements each of duration 22 milliseconds. From Fig. 2 showing letter S in teletype code it will be seen that by placing the centres of the selection intervals at the centres of the code elements, the greatest tolerance of advancement or retardation of any transition is obtained.

The orientation device of the teletype mechanically shifts these selection intervals towards or away from the stop arm of the teletype receiving cam cylinder and in this way advances or retards the selection intervals with respect to the start signal.

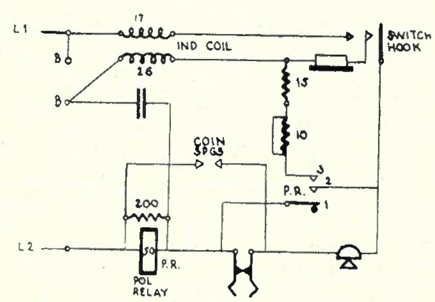
EXAMINATION No. 2643—ENGINEER, TELEPHONE EQUIPMENT

W. King.

Q. 7.—(a) With the aid of a circuit diagram, describe the operation of the telephone apparatus normally installed in a public telephone cabinet in an automatic exchange area.

(b) What circuit alterations, if any, would you suggest if the induction coil No. 14, installed in the standard automatic public telephone, were replaced by an induction coil No. 27, now provided as standard equipment in an automatic handset type telephone instrument?

A.—(a) A circuit of the standard automatic public telephone is indicated in Fig. 1, and a description is as follows:—

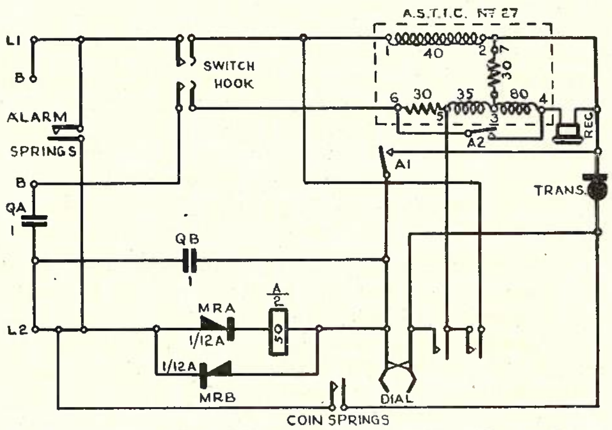


Q. 7, Fig. 1.

When the receiver is lifted from the switch hook a loop is completed to the automatic exchange and the number required can be dialled in the usual manner. The polarized relay PR will not operate if the lines are not reversed. When the called subscriber answers, however, the direction of the current through the PR relay is reversed, and this relay operates. PR springs 1 and 2 short circuit the transmitter, and PR springs 2 and 3 connect a low non-inductive shunt across the receiver. The calling party cannot speak to the called party, as the transmitter is short circuited and the shunt across the receiver prevents its effective use as a transmitter. The shunt, however, does not prevent the calling party hearing, and when the called party speaks the caller presses the button holding the coins at the top of the chute. This allows the coins to drop and operate the coin springs. These springs short circuit the polarized relay PR, which restores. The short circuit is removed from the transmitter and receiver, and conversation may proceed. When the receiver is replaced on the switch hook at the end of the call, the coins pass into the coin tin.

(b) The circuit alterations necessary with the induction coil No. 14 replaced by an induction coil No. 27 are indicated in Fig. 2.

It will be observed that the polarized relay has been replaced by an ordinary relay and rectifiers, and alarm springs which short circuit the lines when the coin tin is removed have been included. These modifications are not essential; but additional switch hook



Q. 7, Fig. 2.—Public telephone, automatic, with induction coil No. 27.

springs and the other modifications indicated would be necessary if the induction coil No. 14 was replaced by coil No. 27.

Q. 8.—(a) Explain, with reference to a diagram of the essential circuit elements, the operation of a subscribers' uniselector circuit of the homing type designed for positive battery metering, and which is fitted with L and K relays of the 600 type.

(b) What steps are necessary in the design of the circuit or its component parts to ensure satisfactory operation with subscribers' loops with a resistance not in excess of 1200 ohms, when the uniselector trunks to first group selectors of the standard 2000 type?

(c) Can you suggest any modification to the first group selector which would permit operation with a subscribers' loop in excess of 1200 ohms?

A.—(a) The circuit has been given in Vol. 4, No. 1, June, 1942, page 53, and the following explanation of the A.P.O. homing type Uniselector has reference thereto:—

Outgoing call: Relay L operates over the subscribers' loop and L1 makes early to prevent the operation of K relay at this stage. Earth via L2 completes the circuit of the drive magnet via the home contact of the private bank and the interrupter springs, and the switch steps from the home position to the first trunk. The stepping of the switch is now dependent on the conditions on the private bank contacts. If the first trunk is busy, relay K will be short circuited, and earth on the private bank steps the switch to the next contact. When a free trunk is found, relay K operates in series with the drive magnet and switches the subscriber through to the selecting switch at K2 and K3 contacts. If all trunks are busy, the switch rotates to the 25th contact. Relay K operates from earth at L2 as no trunk is connected to the 25th private bank contact, and relay BT operates on its 25 ohm winding via the subscribers' loop. Relay L remains operated in this case, as the 25th negative trunk is connected to the L relay. Busy tone is connected to the 150 ohm winding of BT relay via BT1 operated, and this is induced into the 25 ohm winding and returned to the calling subscriber.

Metering: When the called subscriber answers, a positive battery pulse is sent back over the private, and this operates the subscriber's meter via the rectifier in the trunk.

Release: Relay K is held by earth on the release trunk from the switch ahead, and when this earth is removed by opening the calling loop, relay K restores. With L1 and K1 normal, earth from the homing arc drives the switch via the interrupter to the home position.

Step over open trunk feature: If a trunk is open, relay K will not hold, and relay L, being slightly slow to operate, maintains a stepping circuit for the drive magnet from earth via the homing arc L1 and K1 normal and the drive magnet interrupter. The switch therefore steps over the open trunk.

Incoming call: Earth on the private of the final selector multiple operates relay K via the homing arc home contact, and K2 and K3 contacts remove the line relay and earth from the line. As the uniselector wipers are standing on the home contact, relay K can fully operate as there is no trunk connected.

(b) To ensure satisfactory operation with high-resistance subscribers' loops it has been found necessary to reduce the spring load on the L relay by substituting 12 mil springs for the standard 14 mil springs. As the resistance of the loop increases, the current through the L relay decreases, and consequently the release lag of the relay is reduced. By reducing the spring load, L relay is maintained until earth from the selector is returned to hold K relay.

(c) For subscribers' loop exceeding 1200 ohms it would be necessary for a fast guard earth to be returned from the selector. Normally, the selector A and B relays must operate before earth is returned on the release trunk. By returning a fast guard earth on the release trunk after the operation of A relay in the selector, the holding time of the subscriber's L relay can be reduced considerably without the danger of this relay restoring before the K relay is held by earth returned on the release trunk.

Q. 9.—During a period of very heavy traffic, the main discharge fuse in the main battery supply lead of a main automatic exchange of the 2000 type is operated due to momentary short circuit accidentally caused to the main discharge bus bars.

Assuming that you are in the exchange, adjacent to the fuse when operation occurs, and that there is a spare fuse of rating similar to the blown fuse immediately handed to you, describe in detail the action you would take when restoring the exchange to full service once again with the fuse installed in the normal manner.

Give reasons for any steps taken in meeting the particular emergency envisaged by the question.

A.—As the main fuse was operated during a period of heavy traffic, it would be necessary, before the main fuse could be replaced, to take certain precautions to prevent the operation of group section fuses and rack fuses. During heavy traffic a very large proportion of the switches would be in use, and these switches would remain off normal when the main fuse operated. If an attempt was made to restore the main fuse without reducing the load, all switches would tend to restore to the home position simultaneously, and the very high current demand for the driving magnets of uniselectors and the rotary magnets of bimotional switches would, in all probability, cause the operation of group section fuses and also the smaller rack fuses which feed current to a number of switches.

The procedure to restore the exchange to service would be as follows:—

(i) Open all group section fuses supplying battery to uniselector, line finder, group selector and final selector racks; those feeding repeaters need not be opened.

(ii) Restore the main fuse.

(iii) On each Line Finder, Group Selector and Final Selector rack, check that at least 50 per cent. of the switches are normal; if not, restore by hand, taking care that a proportion is restored on each shelf.

(iv) Restore each group section fuse to normal in the following order—

(a) Final Selector Racks;
(b) Local 3rd and 4th Selector Racks;
(c) Incoming Junction Selector Racks;
(d) First and Second Selector Racks;
(e) Line Finder or Uniselector Racks.

On all except uniselector racks the fuse should be tapped momentarily on the fuse clips several times; this allows the switches still off normal to restore without a sustained load on the small shelf fuses. When all switches in a group are normal, the group section fuse may be permanently restored.

If homing type uniselectors are installed, the group section fuse or fuses supplying battery to these racks should be restored last. If battery cut-off keys are provided for emergency purposes, these should be operated on the racks before the section fuse is replaced. When this fuse is restored the battery cut-off keys may then be restored to normal one at a time so that the battery drain may be eased.

(v) Should any shelf fuses have operated, these should now be replaced.

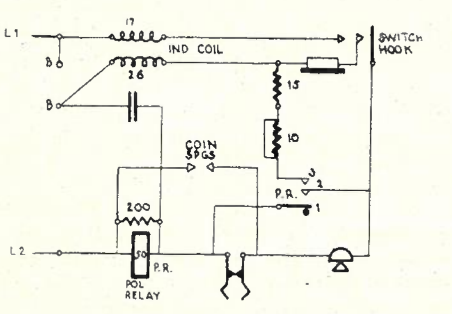
EXAMINATION No. 2633—TECHNICIAN TELEPHONE

A. N. Birrell.

Q. 6.—Draw a schematic circuit of a unit fee automatic public telephone and describe its operation.

A.—The schematic circuit of a unit fee automatic public telephone is shown in Fig. 1. The dial off-normal springs not shown in this diagram are across both the transmitter and the receiver.

The caller places two pennies in the coin head, lifts the receiver and dials the required number. When the called subscriber answers, the direction of current flow is reversed and the polarised relay operates. Springs PR. 1 and 2 short-circuit the transmitter, so preventing the transmission of the caller's speech. Speech through the receiver is rendered difficult by the placing of a shunt across it as a result of the operation of springs PR. 2 and 3. The resistance of the shunt is 15 ohms for lines under 200 ohms and 25 ohms for lines above 200 ohms. The caller is still able to hear the voice of the answering party, however, and releases the pennies into the coin chute by pressing the coin head button.



Q. 6, Fig. 1.

The coin springs, which now operate, short-circuit the polarised relay, so restoring the transmitter and receiver circuits to normal. Conversation proceeds with the circuit in this condition.

When the receiver is replaced on the hook at the end of the conversation, the coins are released from the chute and pass into the coin tin.

On calls to an information desk or the operator at a manual exchange, no reversal of polarity takes place, and conversation can proceed without the insertion of coins.

Q. 7.—What effect would the following have on the performance of a 3,000 type relay:—

(a) Copper slug on armature end;
(b) Copper slug on heel end;
(c) Short-circuit on auxiliary winding;
(d) Condenser across coil;
(e) N.I. resistance across coil;
(f) Increased residual;
(g) Nickel iron sleeve on core;
(h) Fitting of isthmus type armature?

A.—(a) Slow operation and release.
(b) Slow release.
(c) Increased operate and release lags, since a short-circuited winding is equivalent to a copper slug.
(d) Increased operate and release times, the delay depending on the capacity of the condenser.
(e) Increased release lag.
(f) Faster armature release.
(g) Higher impedance to audio frequency currents.
(h) Fast armature operation and release (providing the loading imposed by the spring-set is low). Uniform operation over a wide range of current values.

Q. 8.—(a) Describe briefly the facilities provided by a standard 100 line P.A.B.X.

(b) Explain how selected extensions are prevented from obtaining direct access to the public exchange.

A. — (a) The following facilities are provided by a standard 100 line P.A.B.X.

1. Extension to extension calls dialled direct.
2. Outgoing calls dialled direct by prefixing the directory number with the digit "Y."
3. Any extension may be barred direct access to the main exchange. Should this extension desire to call an outside subscriber, the connection must be set up via the P.A.B.X. telephonist.
4. An extension may hold an incoming exchange call and make an enquiry call to another extension.
5. An extension dials "9" to reach the telephonist.
6. Incoming calls are received at the manual board and switched to the desired extension.
7. Reversion of exchange calls set up by the telephonist to any extension.
8. The telephonist can offer an exchange call to a busy extension. If required by the subscriber, a warning tone can be provided to indicate when the telephonist is across the connection.

9. Night switching of exchange lines to selected extensions.
10. Direct lines from important extensions to the manual board.
11. Conference facilities, allowing up to six extensions to be connected together simutaneously.
12. Staff locator system.
13. Group hunting for extensions. Several extensions in close proximity are allotted the one number and the final selector, in hunting, seizes the first disengaged line of the group.
14. Tie lines (both way working) to other P.B.X's and P.A.B.X's.

(b) To prevent certain extensions gaining direct access to the main exchange, the following additional equipment is provided:—

1. Each group selector or selector repeater possesses 10th level off-normal springs and a marginal relay Z.
2. A 500Ω resistor is placed across the K relay of each uniselector connected to a line denied exchange access.

When "0" is dialled from any extension the tenth level contact springs are operated and the Z relay is inserted in the P wire. If the calling extension is one denied exchange access, Z operates on the increased current flowing via K and the 500Ω resistance in parallel. Z places an earth on the P wiper of the selector, causing it to step to the 11th contact and give the engaged signal to the caller. If an extension allowed direct access to the exchange dials "0," the wipers come to rest on the first disengaged exchange line, because insufficient current flows to operate Z, owing to the absence of the 500Ω shunt resistance in the uniselector circuit.

Q. 9.—(a) Draw a schematic diagram of the exchange and extension line circuits of an A.X. cord type C.B. P.B.X. used in an automatic exchange area.

(b) For which of the following connections is the speaking battery supply obtained from the power leads (or local power supply) at the P.B.X.?

(i) Exchange to extension;
(ii) Extension to extension;
(iii) Exchange to P.B.X. telephonist;
(iv) Extension to P.B.X. telephonist.

A. — (a) For the schematic diagrams of an AX cord type C.B. P.B.X., the reader is referred to the Course of Technical Instruction, Telephony II, Paper 6.

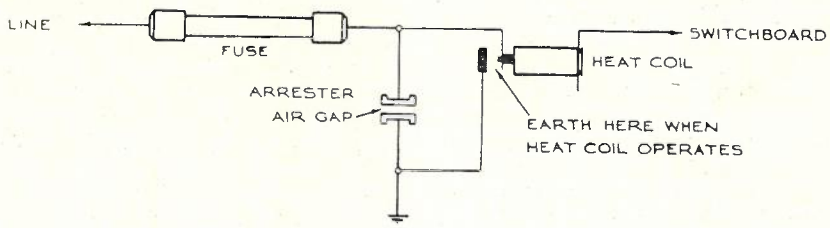
(b) The speaking battery is supplied by the local P.B.X. for:—

(ii) an extension to extension call.
(iii) a call from the exchange to the P.B.X. telephonist.
(iv) a call from an extension to the P.B.X. telephonist.

Q. 10.—(a) Draw a schematic circuit showing the arrangement of the protective devices provided at the M.D.F. in an automatic or manual exchange and explain briefly the reason for the provision of each.

(b) Which of the devices shown in (a) would be provided at the exchange on the following classes of external circuit:—

(i) Subscriber's line entirely in U.G. cable;
(ii) Subscriber's line entirely in open wire;
(iii) Junction line entirely in U.G. cable;
(iv) Ringing leads entirely in U.G. cable;
(v) P.B.X. power leads entirely in U.G. cable.



Q. 10, Fig. 1.

A.

(a) The devices shown in the schematic circuit are provided to safeguard the exchange equipment against damage by excessive voltage or current. The reasons for their provision in each case are:—

Arrester. The spark gap of the arrester is designed to break down when the difference in potential between the carbon blocks is from 500 to 750 volts. Should the line become charged to a high voltage due to the effect of lightning, a spark will therefore pass between the blocks, discharging the line. Continued discharge arising from extreme lightning effects or a contact with high voltage power lines will cause an accumulation of carbon dust in the gap, thereby lowering its resistance. The higher current then passing will operate the fuse.

Fuse. The purpose of the fuse is to disconnect the external line in the event of excessive current. Generally it will function after the operation of either of the other protective devices.

Heat Coil. This protects the exchange apparatus against excessive currents which, although not of a sufficiently high value to operate the fuse, could cause considerable damage to exchange apparatus if allowed to flow for some time.

(b) (i) Arresters, heat coils and fuses.
(ii) Arresters, heat coils and fuses.
(iii) Arresters, fuses and dummy heat coils at terminal exchanges. Fuses only at an intermediate exchange if the junction is routed via the M.D.F.
(iv) Arresters, heat coils and fuses.
(v) Arresters, dummy heat coils and fuses.

EXAMINATION No. 2643—ENGINEER, LINES CONSTRUCTION

F. R. McNicoll, B.Sc.

Q. 1.—Owing to heavy development in subscribers' services, it is necessary to instal a cable in existing ducts from an Auto Exchange to a point about 1 mile distant. The longest lateral will terminate 1¼ miles from the Exchange.

The survey figures are:—

Present	650
8 years	950
20 years	1,800

The areas are served at present by an 800 pair cable and 1 spare duct is available.

State:—

(a) What size cable you recommend and the reasons therefor?

(b) What gauge conductors should the cable contain and the reasons for your selection?

(c) Describe the method of drawing the cable into the duct and the precautions to be observed.

(d) In what manner would you design the distribution system to provide for the maximum number of pairs being available for services?

A.—(a) The position could be met by installing a cable of sufficient capacity to meet the 20 year requirements. For example, a 1,400 pair cable could be drawn into the spare duct, but as this would not leave any duct available for emergency purposes, it would be advisable also to provide an additional duct initially. However, since many pairs in the proposed new cable would be lying idle for a long period, the expenditure involved in providing such a cable and an additional duct immediately would not be justified.

Since the development rate is high, the best method would be to make provision for cable relief in two stages. The two stage provision would have to be designed to conform with the economic planning period. Initially, two additional ducts could be laid and a 600 pair cable drawn in. This would enable development for about 10 years to be met. The advisability of installing cross connecting cabinets at important distributing points would also be examined, as these may permit a reduction in the size of the relief cable, due to increased flexibility and, consequently, greater occupancy of the cable being obtained. At a later stage a second cable would be laid, the size being governed by the development figures then existing, but, on existing figures, at least an 800 pair cable would be necessary. As mentioned before, the size of the cable would be governed by the improvement in main cable occupancy obtained by the provision of cross-connecting facilities.

(b) The conductor gauge to be provided would depend on transmission requirements. Since the longest lateral will terminate only $1\frac{1}{4}$ miles from the exchange, $6\frac{1}{2}$ lb. conductors would be suitable.

(c) (i) The duct is first rodded and then a wire, to which a brush and a further draw wire are attached, is pulled through the duct. Any obstructions encountered are investigated and removed.

(ii) Preferably all lengths of cable should be drawn in, in the name direction, so that the direction of rotation of the pairs is the same for all lengths. This direction should be the same as that of the other cables in the exchange area.

(iii) The drum of cable should be set up ready for drawing in so that it will enter the duct with an easy curve and without kinking.

(iv) The flexible steel rope is pulled into the duct by means of the draw wire previously inserted. The steel rope is attached to the cable by means of the cable grip, swivel and steel link.

(v) The winch is set up at the next manhole and the steel wire attached to the drum.

(vi) The cable sheath is completely covered with cable pulling compound as the cable is drawn into the duct. When sufficient cable has been drawn into the further manhole to allow for correct setting up and jointing, the cable is cut in the first manhole and all ends sealed.

(vii) The length drawn into the duct is pressure tested.

(viii) When setting up the cable drum and the winch, care should be taken to avoid damage to the roadway or danger to the public.

(d) In order to permit the maximum availability of pairs, it would be desirable to instal distribution pillars with an inter-pillar multiple to allow relief to be given at a later stage with minimum jointing. In some cases it may be found desirable to allow for link pairs between pillars.

To obtain maximum availability of main pairs it would be desirable to adopt the more recent practice of installing large cross-connecting cabinets at locations determined after a careful examination of the area in order to establish regions of greatest anticipated development. These cabinets may be located at several points on the main cable run and a suitable multiple between them could be designed. Each cabinet would serve a group of distribution pillars, the combination of pillar and cabinet multiples ensuring greatest flexibility and highest occupancy.

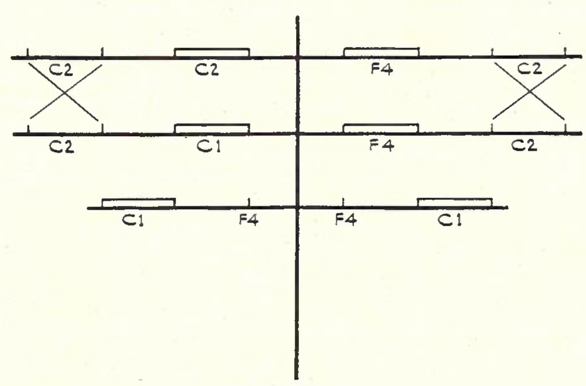
Q. 2.—A main Telephone and Telegraph route with a pole configuration, as shown on the diagram hereunder (Fig. 1), is to be reconstructed.

One 12-channel carrier telephone system is to be installed in the near future and a second at a later date.

Prepare a pole diagram for the reconstructed route and give reasons for any changes considered necessary.

What precautions would you take to ensure that existing channels are not interrupted during the reconstruction work?

A.—Limited Reconstruction: To reconstruct this route to provide for 12-channel carrier telephone working it will be necessary to re-bore cross-arms in some places to 9″-19″-9″ spacing between wires, and to untwist the existing rolled groups. The separation between arms 1 and 2 should be increased to 28″, but the 80″ arm, if retained, could remain at 14″ spacing from the arm above it. If practicable, it would be advisable to replace the 400 lb. iron and 100 lb. copper wires on arms 1 and 2 with 200 lb. H.D.C. in order to obviate replacement difficulties at a later date, and to standardise construction. This would also warrant reboring for



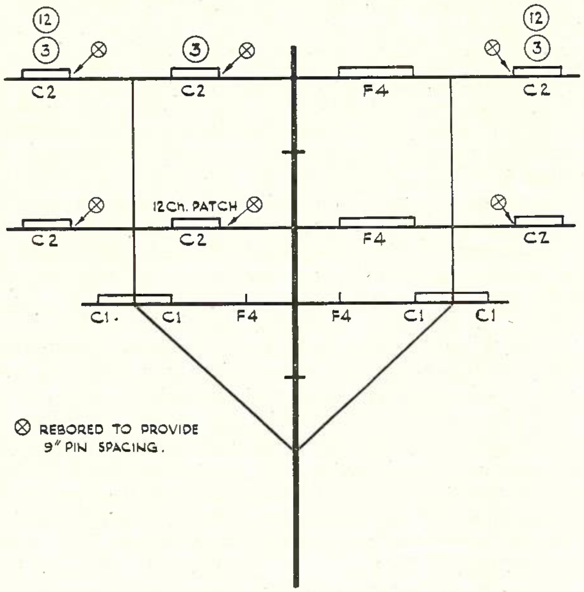
Q. 2, Fig. 1.

NOTES

1. X represents wires on the roll or twist system.
2. Arms 1 and 2 are 108″/14″ spacing. Arm 3 is 80″/14″ spacing.
3. Each twist group carries a 3-channel carrier telephone system and a third system operates on the pair in pin positions 1.3-1.4.
4. The circuits on arm 3 consist of two minor trunks and two telegraphs.

9″ spacing of the new wires. The justification for this would depend on future requirements, and is not necessary within the limits of the present question. However, it is considered advisable to provide a patch circuit for 12-channel working, and, for this reason, the 100 lb. H.D.C. wires on the second arm would be replaced with 200 lb. H.D.C. and the spacing reduced to 9″.

Fig. 2 is a suggested pole diagram for limited construction of the route to provide for immediate requirements and for an additional 12-channel system in the near future.



Q. 2, Fig. 2.

Here, three new holes have been bored in the top and second arms, these arms now occupying positions 1 and 3 on the pole. The 80″ arm has merely been lowered. The existing 3-channel systems on the rolled groups now operate on arm 1, and the 3-channel system on pin positions 3 and 4 of the top arm is unchanged except for pin spacing. However, reconstruction in this manner will have the disadvantage of introducing difficulties in replacing the iron wire at a future date without undue interference to existing circuits.

Recommended Reconstruction: Consequently, it is considered most desirable to replace the 400 lb. iron wire with 200 lb. H.D.C. wire now, if no financial or other restrictions prevented this being done. The reconstruction should be planned for the estimated ultimate channel requirements, provision also being made for cross-arms to carry subscribers' wires.

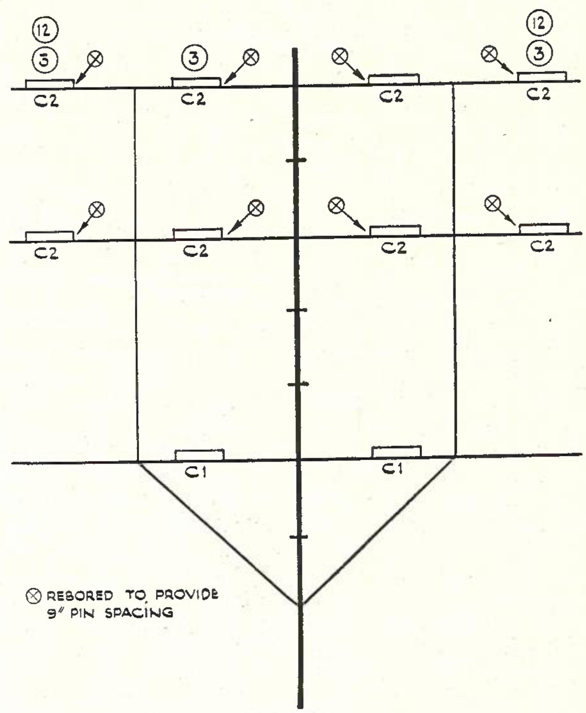
It will also obviously be preferable to replace the 80″ arm with a 108″ arm, and it is considered that this should be done on the present reconstruction, if possible. It could then be lowered to the final position on the pole which it will occupy during the life of the route. This may be position 4 or even position 6.

The existing 100 lb. H.D.C. wires on the 80″ arm could then be re-erected in pin positions 3-4 and 5-6 of the new 108″ arm, thus facilitating the erection of later wires in pin positions 1-2 and 7-8. The 400 lb. iron wires could be dismantled and any telegraph circuits operated as a cailho.

Assuming that reconstruction could be carried out to this extent the new pole diagram would be as shown in Fig. 3.

In this case, four holes have been re-bored in each of the two upper arms, giving a pin spacing of 9″-19″-9″ throughout.

It will be necessary to carry out any pole re-spacing for 12-channel transposition requirements, and to re-transpose the unrolled 3-channel circuits. Combiners should be fitted as shown.



Q. 2, Fig. 3.

To ensure that existing channels are not interrupted during the reconstruction, interruption cable could be used as work is being carried out on each section of route. Sections of interruption cable up to ¼ mile in length would enable the 3-channel systems to continue operating satisfactorily. In any 3-channel repeater section, up to 2 miles of interruption cable can usually be operated when the correct matching transformers are used.

Reasons for Changes: Rolled groups are not a suitable arrangement for carrier operation from considerations of crosstalk and impedance irregularities. To make fullest use of the available pole height, the use of flat transposed pairs is necessary. Iron wire has too steep an attenuation V frequency characteristic curve for satisfactory carrier operation.

Alteration to the wire and arm spacing is required to give the better coupling conditions between pairs for high frequency working.

The replacement of the 80″ arm by a 108″ arm is desirable from the point of view of uniformity of construction and enables additional minor trunks per arm to be provided.

Q. 3.—It is proposed to install multiple ducts for the accommodation of large size underground cables in a metropolitan area. Describe the various processes from the commencement to the completion of the job, with particular reference to:—

(a) The selection of the route.

(b) The method of opening the ground.

(c) The method of laying the conduits.

(d) The type of manholes and approximate distance between each.

(e) The various materials required.

A.—Preliminary Survey: Preliminary and detailed surveys are necessary when designing a conduit route. The purpose of the preliminary survey is to determine the route to be followed after examination of alternatives and generally outline the work required.

(a) **Selection of Route:** In selecting the route the following should be taken into account:

(1) The route should be as short as practicable, provided other requirements are met.

(2) The opening of streets with expensive pavements should be avoided where satisfactory alternatives exist.

(3) It is preferable to lay conduits in footways rather than roadways, because—

- (i) Excavation and reinstatement costs are lower.
- (ii) Less depth of cover is required.
- (iii) Less expensive types of manholes can be used.
- (iv) Under present-day traffic conditions, roadway manholes constitute a danger to traffic and workmen.

(4) Presence of obstructions, e.g., cellars, sewers, subways, underground mains. Any known obstructions likely to affect the choice or practicability of a route should be taken into account.

(5) Wet, unstable or made-up or broken ground should be avoided, where practicable.

(6) Future road or street alterations which may later necessitate shifting or altering the conduits.

(7) Facilities for drainage of manholes and ducts.

(8) Crossings under railway and tramway tracks should be avoided as far as possible.

(9) In the case of trunk or junction routes, their suitability also for subscribers' distribution purposes.

After examination of possible routes in the light of the above, it should be practicable to fix the most suitable route. In special cases, however, it may be necessary to prepare comparative costs for alternatives.

(b) **The method of opening the ground.**

It is a good plan to sink pilot or test holes before commencing excavating along any route where there is any possibility of unmarked obstructions necessitating an alteration to the intended location of the conduits. The pilot holes should be at least six inches deeper than the proposed trench, and the bottom and sides should be well probed for foreign bodies. Having fixed the location of the trench, the sides should be marked out before operations are commenced. Generally, to enable the conduits to be conveniently laid the trench should be not less than 3 ins. wider than the conduits. To facilitate repair of the pavement, care is necessary in cutting the surface in the first instance. Asphalt cutters or a mattock should be used for cutting asphalt. Pneumatic concrete breakers operated by an air compressor should preferably be used for cutting concrete. Where this equipment is not available, medium or large cold chisels and a 2 lb. hammer can be used.

Trenching machines can be used under most soil conditions, viz., loam, clay, gravel, etc., but are not usable in solid stone or rock, or in very soft soils in which the trench walls are not self-supporting. They can be used along the nature strip in suburban streets.

The pneumatic tools in general use for conduit excavating work are:—

Paving Breaker (or Road Ripper).
Rock Drill (Jack Hammer Type).
Spader (or Clay Digger).
Pick.
Back Fill Tamper.

Excavation will generally be finished by hand in order to obtain an even and level surface at the bottom of the trench, or an even gradient where necessary.

During excavation it is desirable for surface soil to be laid at one side of the trench and sub-soil at the other, in order to lessen reinstatement difficulties.

(c) Method of laying conduit. The most suitable form for the multiple ducts will be 4 or 6 way self-aligning earthenware type. In some cases these could be laid directly along the bottom of the trench, the alignment being checked with some form of mandrel. Alternatively, the ducts could be laid on a specially prepared bed of sand or fine earth.

The levelling and ramming of the bottom of the trench is most important. In jointing E.W. self-aligning conduits, the spigot and socket linings are coated with a molten mixture applied hot, which sets to form a firm joint. The mixture should be liberally applied and preferably hot enough to soften the bitumastic lining, thereby forming a welded joint. A final application of compound is made to the exposed surface of the joint. As an alternative method, the bitumastic linings of the duct sockets should be heated until the compound is soft, and the two sections of conduit then firmly driven together to form a good welded joint between spigot and socket. The bitumastic linings must not be damaged prior to laying as the joint might otherwise be impaired.

(d) Type of Manholes and distance between each.

For a multiple duct run, concrete manholes built in situ are suitable. They should be large enough to accommodate comfortably the maximum number of cables to be carried by the ducts and to enable jointing operations to be carried out with maximum efficiency. The manholes should be dry, and provision should be made for adequate drainage. In most cases it will be necessary for manholes to be constructed on both sides of a street crossing in order to obtain sufficient depth for the ducts under the roadway. On normal conduit runs along the footpaths, 400 feet is considered to be a desirable maximum distance between manholes, the average distance being 330 feet.

(e) The materials required are:—

- (i) Multiple ducts and drain pipes.
- (ii) Excavation and miscellaneous tools.
- (iii) Acetylene cylinder for use when softening bitumastic linings.
- (iv) Cement, sand, screenings, etc.
- (v) Manhole covers and frames.
- (vi) Reinforcing material.
- (vii) Cable bearers, anchor irons, Lewis bolts, etc.

Note: For further details see a series of articles entitled, "The Design and Construction of Underground Conduits for Telephone Cables," by A. N. Hoggart, B.Sc., Telecommunication Journal of Australia, Vol. 4, No. 6, Vol. 5, Nos. 1, 2, 3, 4, 5 and 6, Vol. 6. Nos. 1 and 2.

Q. 4.—Describe a gas pressure alarm system used with underground cables.

Explain briefly the method of fitting and the components used.

What pressures are normally adopted and what types of gas are used?

In what circumstances would such a system be used and for what purposes?

A.—Gas pressure alarm systems are installed on underground cables in order to provide indication of a failure in the cable sheathing. When a failure does occur, the pressure in the cable will drop, and, when a predetermined critical pressure is reached, an audible or visible indication is given at a repeater or terminal station.

As long as a sufficient reservoir of gas is available (either in the cable or cylinders), the escape of gas from the cable will assist in preventing the entry of moisture.

Components

(i) **Gas Tight Seals:** These are placed at the cable terminations in the exchanges, or at other points such as in lateral cables leaving a main cable. They can also be used for dividing the cable into small sections, for fault location or to prevent large quantities of gas from escaping if work on any section has to be carried out. These intermediate seals can be by-passed with a by-pass valve to obtain the benefit of a large reservoir of gas.

(ii) **Contactors:** These are used at intervals along a cable, not exceeding 2 miles, and, when the pressure in the cable drops to a predetermined figure, a pair of springs operates to short-circuit the alarm pair in the cable. The position of the operated contactor is determined by a resistance measurement from a terminal or repeater station. A contactor consists of a sealed Bourdon tube inside an airtight metal container. The movement of the ends of the Bourdon tube operates the contact springs.

(iii) **Terminal Blocks:** These are required to provide access to the alarm pair when checking operating pressures, and to allow the alarm pair to be disconnected while this is being done. Facilities are also provided for the connection of a telephone for conversation between the alarm point and the exchange.

(iv) **Contactor Gauges:** These are mounted at the ends of cables in buildings and consist of a standard 6″ dial Bourdon gauge fitted with a pair of contacts. Their advantage is that the pressure of gas in the cable is continually indicated, and indication of a slow leak in the cable can be obtained by regular reading of the gauge.

(v) **Valves, Flanges, etc.:** For making connection to the cable for routine pressure readings or during fault location, a flange is sweated to the sheath. A valve holder containing a standard Schrader valve is screwed into the flange. Valves are only left in permanently at points where regular maintenance pressure readings are taken or where gassing of cable is to take place. All other flanges are sealed with a screw, the thread of which is coated with gasket cement.

Fitting

Gas Tight Seals (Pressure filled type): An opening is made in the sheath and a large flange sweated on. Mixture of 2 parts mexphalte, 1 part resin, and 1 part paraffin is heated to a temperature of 360°F, placed in a grease gun screwed into the flange, and then blown into the cable by compressed air. Pressure is kept on while the seal solidifies. The position of the seal is indicated by painting the sheath red.

Contactors and terminal boxes are screwed to the wall of the manhole where there is least chance of damage, and are connected to the cable by ½″ diameter lead tubing.

Flanges are fitted where necessary for fault location and at all places where routine measurements are required. They are sweated to the sheath, and a hole is then made in the sheath with a special cable boring tool.

Gas and Pressures

Commercial dried compressed air is used. Normal pressure is 10 lbs./sq. in., with the alarm operating between 5 and 6 lbs., but on carrier cables the pressure is 15 lbs./sq. in., with the alarm operating between 10.5 and 11.5 lbs./sq. in.

Use

(i) On all carrier cables.
(ii) On all trunk entrance cables, joining separate cables at a station together through by-pass valves in order to obtain the benefit of a large reservoir.
(iii) Junction networks.
(iv) Important subscribers' cables such as Police, Fire, etc.
(v) Paper insulated submarine cables where the depth of water is not too great.

Precautions

(i) Care is necessary in making gas-tight seals to prevent accidents to operators.
(ii) Regular maintenance inspections of the cable route and checking of contactors is necessary to keep the alarm system in order.
(iii) The cable should never be charged at a greater pressure than 20 lbs./sq. in., the gas being applied at a point midway between contactors if possible.

Q. 5.—It is proposed to erect a new trunk and telegraph aerial wire pole route between towns about 50 miles apart, as an extension of an existing route.

The wires are to accommodate immediately four 3-channel and two single channel carrier systems. Describe the steps you would take and the principal factors to be noted in designing and pegging out the route. Name the type and class of line materials required.

Draw a rough sketch showing one of the poles and the relative positions of the arms and wires.

A.—Design of Route: The route should be surveyed in order to arrive at the best location from the point of view of provision cost, accessibility, immunity from washways, etc., best holding ground, long straight sections and even gradients, proximity to existing or projected power lines, necessity for any road, rail or river crossings, and directness between terminal towns.

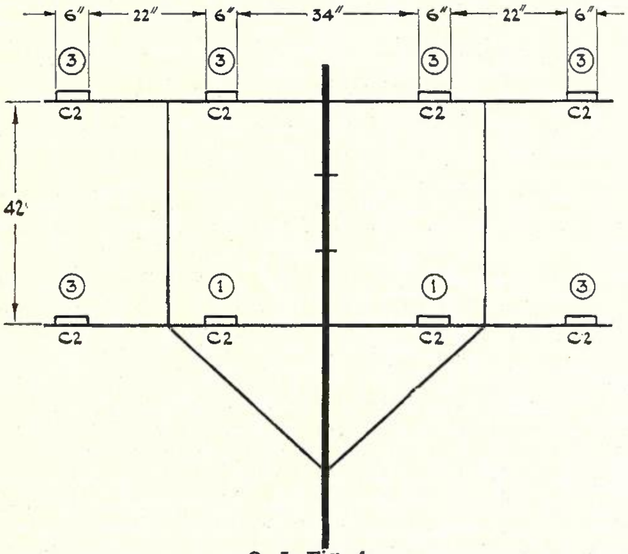
Following the survey of the route to be adopted, it should be pegged out for 2 chain pole spacing. Survey of levels with theodolite will enable drawings to be made, from which pole lengths to give most even pole to pole gradient for the wires, can be ascertained. Pole heights should be calculated to provide sufficient clearance at all points for the ultimate estimated number of trunk crossarms required for the life of the route, allowance being made for any anticipated subscribers' wires.

Field book notes of all staying, etc., and any other features such as rock excavation, crossings, etc., can be made and a firm estimate prepared.

The design of transposition sections in accordance with the standard types must receive consideration during preparation of the estimate, and the lengths of any terminal trunk entrance cable will be a governing factor in their layout. It would be advisable to design the route on a basis of eight E sections, each of 6.25 miles, so that in the event of future requirements for 12-channel systems, no pole re-spacing or alteration to length of E sections will be necessary.

Since the importance of the route is such that immediate requirements are four 3-channel and two single channel carrier systems, it is most likely that further development will necessitate the provision of 12-channel carrier telephone systems at a future date during the life of the route, and, consequently, in the proposed poling diagram, 42″ spacing in lieu of 28″ has been left between the two trunk arms required immediately.

A pole diagram showing a suitable layout of circuits is shown in Fig. 4. It is considered that at least one patch circuit is necessary, and, in order to balance the lower arm, two patch circuits have been provided. Standard 6″-22″-6″ pin spacing has been adopted on the basis that the two towns involved in the route extension will eventually be 12-channel repeater stations.



Q. 5, Fig. 4.

Material: Whether wooden poles or steel beams would be used will depend on the economics of the particular case, relative costs and procurement considerations being deciding factors. Assuming that steel beams are used, associated line material would include:—

- Pole, steel beam, 7″ x 3½″. } Assorted lengths.
- Pole, steel beam, 6″ x 5″. }
- Plate, foot, steel (base), 12″ x 8″.
- Bolt, U shape (square end), ½″ x 3⅝″ x 8″.
- Bolt, U shape (square end), ⅝″ x 5⅛″ x 7″.
- Plate, foot, steel (surface), 18″ x 9″.
- Plate, foot, steel (surface) 24″ x 12″.
- Stay rod, 1″ x 8′ (terminal poles).
- Stay rod, ⅝″ x 6′.
- Plate stay, steel, 12″ x 12″.
- Wire, S.S., gal., 7/14 and 7/12.
- Band, transposition, bent (attaching transverse angle stays and overhead stays to steel beams).
- Thimble, ⅝″ (on stay wire).
- Bolt, G.I., ⅝″ x 2″ (for overhead stay attachment).
- Washer, spring, ⅝″.
- Eyebolt lug, ⅝″ (for longitudinal stays).
- Eyebolt, straight, ⅝″ x 9″ (for aerial stays).
- Plate transposition, PL, 6″.
- Spindle, transposition.
- Insulator, TK P.LS or TK G.LS.
- Tape, copper, 100/237.
- Arm, wood, terminal, 108″.
- Bolt, G.I., ⅝″ x 9″.
- Bracket, terminal.
- Spindle, TK., ⅝″, J. LS.
- Arm, wood, 108″/8-6″, W.S.
- Arm, wood, 108″/8-6″, S.S.
- Bolt, G.I., ⅝″ x 6″.
- Bolt, G.I., ⅝″ x 7″.
- Washer, flat, ⅝″.
- Brace, arm, long.
- Block, steel, 1¼″, U shape. } Gain blocks.
- Block, steel, 2″, U shape. }
- Block, steel, ⅝″, flat. }
- Bolt, G.I., ⅝″ x 3½″.
- Bolt, G.I., ⅝″ x 4″ (for combiners).
- Spindle, TK, wood, LS.
- Spindle, TK, ⅝″, LS.
- Wire, copper, H.D., 200 lb.
- Sleeves, wire jointing (press type), C.200.
- Wire, copper, soft, 50 lb.
- Sundries—stay guards, paint, etc.
- Combiners.

Q. 6.—How would you conduct an electrolytic survey? If the survey proves the existence of excessive current leakage from underground cable sheathing, what means would you adopt to eradicate or minimise this effect? In what manner does the nature of the material of the pipe or conduit containing lead covered cable affect the electrolytic problem?

A.—The information required to prepare a typical answer to this question has already been published in the Examination Section of the Journal. The following previous answers are given for reference:—

Examination No. 2194—Q. 8—Vol. 2—No. 5 October, 1939, page 332.
Examination No. 2377—Q. 6—Vol. 4—No. 6 February, 1944, page 382.
Examination No. 2050—Q. 2—Vol. 1—No. 5 June, 1937, page 244.

Q. 7—(a) Discuss the conditions and reasons for erecting Trunk aerial wires on a long Trunk and Telegraph pole route with 9″ and 6″ spacing between wires of each pair.

(b) What are the span lengths between poles you recommend for each, and the reasons therefor?

(c) What is meant by 64, 128, interval basis for transpositions and the circumstances in which each would be adopted?

(d) What checks would you make to ensure that transpositions have been correctly inserted?

A.—(a) On Long T and T routes 9″ spacing is the standard for operation up to 30 kc/s. A normal span length of 2½ chains is desirable, and 4 chains for isolated spans is considered the maximum where 9″ spacing is used. For operation at frequencies above 30 kc/s, it is necessary to consider reduction of wire spacing, for the following reasons:—

Crosstalk = Length of circuit in miles x coupling co-efficient x transposition type unbalance.

The type unbalance is a function of the transposition type used, and, with operation up to 143 kc/s, a restricted number of types having low values of type unbalance is available. Therefore, to obtain satisfactory far end crosstalk to 143 kc/s between all pairs over a long route, it is necessary to consider reduction of the coupling co-efficient by reducing the spacing between wires to 6″, with increased spacing between pairs and crossarms. This reduced wire spacing requires a normal span length of 2 chains and a maximum of 2.5 chains for isolated spans. In addition, the difference in sag between wires of a pair should not vary by more than ½″.

(b) Span lengths for 9″ and 6″ spacing are as stated in (a). The normal span length is determined by the provision of 256 spans for E sections and sub-multiples of this for other section types. A wire spacing of 6″ is used only with 6.4 mile E sections and proportionately smaller sections of other types. The maximum span length permissible is determined by the possibility of contact between the two wires of a pair during high winds.

The Threshold of Contact Wind Velocity is taken as 55 m.p.h. normal to the line and is given by the following empirical formula:—

$$V_n = 22.4 \ (L^{0.1} \ S^{0.3}/d^{0.25})^{2.1}$$

Where V_n is the threshold of Contact Wind Velocity (miles per hour)

L is the maximum span length (feet)

S is spacing between the wires (inches)

and d is the sag at rest (inches).

(c) 64, 128 interval basis refers to an E section, which is the basic section of a transposition layout. A 64 interval basis means that there are 64 transposition intervals in the E section; i.e., every fourth pole is a transposition pole. Similarly, for 128 interval basis, where every second pole is a transposition pole.

A 64 interval basis is adopted where the most frequently transposed pairs are transposed to single extra types, and a 128 interval basis when double and triple extra types are used.

(d) To check that transpositions have been correctly inserted:—

(i) Carry out an independent check of transpositions by recording them in a field book and then checking them against the transposition drawing.

(ii) Check if the wires come out in the correct positions at the end of the transposed section.

Q. 8.—It is proposed to establish a trunk cable between towns about 100 miles apart. Assume that the traffic requirements are 500 speech channels in 20 years. Describe:—

(a) What precautions, tests, etc., you would take in the design of the route, and the factors which would guide you in the selection of the actual route.

(b) The type of cable or cables you would recommend and the reasons therefor.

(c) The tests you would apply during and after the cable or cables have been laid.

(d) The size of cable or cables you would recommend for adoption to provide the ultimate number of channels when required, and the reasons for your choice.

A.—(a) The route should be as short as practicable in order to conserve cable and, possibly, save the provision of one repeater station. A survey should be carried out and the general route for the cable selected, repeater sites being determined, having regard to the overall route length and the type of carrier system to be adopted. Initial repeater sites, and ultimate sites which may be required when higher carrier frequencies are used, should be selected. The route should, where practicable, pass through country suitable for cable installation, using a mole plough, and sufficiently removed from possible sources of interruption, such as road deviations or other public works which might cause interference.

A soil resistivity survey should be made along the proposed route, mainly to determine where remedial action, from an electrolysis viewpoint, may be required at a later date. A power supply will be required for repeater stations and this must be considered during survey. The route of the cable should be generally accessible for maintenance. After considering all factors, selection of the best route can be made.

(b) Two 24/40 P.I.L.C. star quad carrier type cables should be laid, one as "go" cable and one as "return" cable.

Carrier cable is necessary because of the very large number of speech channels involved and their length.

By operating 12-channel carrier systems initially and 24-channel systems subsequently on each pair, the 24 pairs will cater for at least 500 channels.

When two cables are used, all low level circuits can be kept in one cable entering repeater stations, and near end crosstalk eliminated. 24 pr./40 lb. is the standard size used for carrier cables.

Through towns, where the cable will normally be in ducts, armouring is not necessary, but cable laid with mole plough should be tape armoured. At river crossings or places where additional strength is necessary, a lead-antimony sheathed, single wire armoured cable should be used.

(c) Drums of cable delivered from the manufacturers are under gas pressure. This pressure should be read on receipt of cable and both before and after laying.

Electrical tests: These include tests for continuity of pairs and I.R. tests, wire to wire and wire to earth. Capacity unbalance characteristics and resistance unbalance should be measured. Distant end admittance unbalance tests should be made at the centre point of repeater sections. Overall distant end admittance unbalance tests are then made and far end unbalance networks adjusted. Attenuation, crosstalk and impedance measurements on the cable are made as required.

(d) The cables recommended are two 24/40 lb. carrier type, the Departmental standard. Using 12-channel carrier-on-cable systems operating to 60 kc/s frequency, we may obtain $12 \times 23 = 276$ circuits. (One pair is used for gas pressure alarm system.)

Later, when required, 24-channel systems operating from 60-108 kc/s may be installed, so providing an additional 276 channels.

Alternatively, we could use 17-channel systems operating to 72 kc/s, giving $17 \times 23 = 391$ channels, additional systems operating to 150 kc/s being installed as required to meet development.

EXAMINATION No. 2643—ENGINEER—NATURAL SCIENCE

E. Palfreyman, B.E.

PART 1

1. State and prove the remainder theorem and use it to solve the equation—

$$2x^3 + 3x^2 - 11x - 6 = 0.$$

A.—Statement: If f (x), a polynomial in x, is divided by (x — a) until the remainder is clear of x's then this remainder will be f (a).

Proof: Assume that, when f (x) is divided by (x — a), the quotient is Q and the remainder is R. Then $f(x) \equiv (x - a)\,Q + R$ identically and being an identity it is true for all values of x, and if we put x = a then we will have $f(a) = 0 \times Q + R = R$.

An obvious corollary of the remainder theorem is that if f (a) = O, i.e., the remainder is zero, then (x — a) is a factor of f (x) and x = a is a root of f (x) = 0.

In question $f(x) = 2x^3 + 3x^2 - 11x - 6 = 0$ and since factors of — 6 are ±1, ±2, ±3 and ±6

Try $f(1) = 2 + 3 - 11 - 6 \neq 0$,

thus x = 1 is **not** a root

$f(2) = 16 + 12 - 22 - 6 = 0.$

Hence x = 2 is a root.

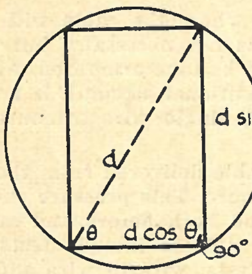
dividing out by x — 2 gives

$$f(x) = (x - 2)\,(2x^2 + 7 + 3)$$
$$= (x - 2)\,(x + 3)\,(2x + 1).$$

Hence roots of f (x) = 0 are x = 2, — 3, — 1/2.

2. The strength of a rectangular beam varies as the product of the breadth and the square of the depth of the beam. Find the breadth and depth of the strongest

rectangular beam that can be cut from a cylindrical log, the diameter of the cross-section of which is "d" inches.



Q. 2, Fig. 1.

A.—

In fig. breadth $= d \cos \theta$

depth $= d \sin \theta$

and since S varies as breadth x depth^2

$\therefore S = K d \cos \theta \times d^2 \sin^2 \theta$

$= K d^3 (\cos \theta - \cos^3 \theta)$

Giving $dS/d\theta = K d^3 (-\sin \theta - 3 \cos^2 \theta (-\sin \theta))$

$= K d^3 \sin \theta (3 \cos^2 \theta - 1)$

S has a max. or min. when $dS/d\theta = 0$, i.e., when $\sin \theta = 0$ giving $\theta = 0°$ for min. or when $3 \cos^2 \theta - 1 = 0$.

giving $\cos \theta = 1/\sqrt{3}$ and $\sin \theta = 2/\sqrt{3}$ for max.

Thus breadth $= d \cos \theta = d/\sqrt{3}$

depth $= d \sin \theta = d\sqrt{2}/\sqrt{3}$.

3. (a) Write down the integrals with respect to "x" of the following expressions:—

x^n, $1/x$, e^{kx}, sin x, cosh x.

In the case of x^n, indicate the value of "n" for which your solution does not apply.

(b) Evaluate the integral $\int \frac{dx}{x(1 + x^2)}$.

A.—(a)—

$x^n + 1/n + 1$ $(n \neq -1)$, Ln x, e^{kx}/k, $-\cos x$, sinh x.

(b)—

$$I = \int \frac{dx}{x(1 + x^2)} = \int \frac{x\,dx}{x^2(1 + x^2)}$$ (Note that numerator is now d.c. of x^2.)

Put $x^2 = u$ then $2x\,dx = du$

and $$I = \int \frac{\frac{1}{2} du}{u(1 + u)}$$

$$= \tfrac{1}{2} \int \left(\frac{1}{u} - \frac{1}{1 + u} \right) du$$ by partial fractions.

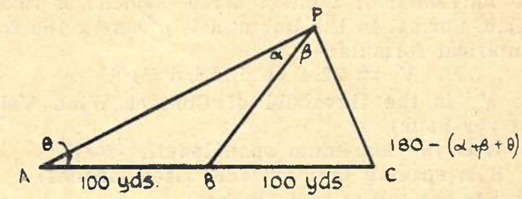
$= \frac{1}{2} \text{Ln } u - \frac{1}{2} \text{Ln } (1 + u)$

$= \text{Ln } u/(1 + u) = \text{Ln } x^2/(1 + x^2)$

4. A, B and C are three telephone poles on a straight road and AB = BC = 100 yards. A man at a Point P, in a field, observes the horizontal angles APB (α) and BPC (β). Show that the horizontal angle PAB (θ) is given by the equation:—

$\sin \alpha \sin (\theta + \alpha + \beta) = \sin \theta \sin \beta$.

If $\alpha = 30°$ and $\beta = 60°$ calculate θ and the distance AP.



Q. 4, Fig. 1.

Equation can be put in ratio form:

$$\frac{\sin \alpha}{\sin \theta} = \frac{\sin \beta}{\sin (\theta + \alpha + \beta)}$$

i.e., AB/BP = BC/BP by sine rule which is true since AB = BC .... QED.

If $\alpha = 30°$ and $\beta = 60°$ then $\sin 30° \sin (\theta + 90°)$

$= \sin \theta \sin 60°$

i.e., $\frac{1}{2} \cos \theta = \sin \theta \times \sqrt{3}/2$

i.e., $\tan \theta = 1/\sqrt{3}$

Hence $\theta = 30°$ .... ans.

Also $$AP = \frac{AB}{\sin \alpha} . \sin (180 - \alpha + \theta)$$

$$= \frac{100}{\sin 30°} \sin 120° = \frac{100 \times \sqrt{3}/2}{1/2}$$

$= 100\sqrt{3} = 173.2$ yards .... ans.

PART 2

5. The following particulars are taken from the magnetic circuit of a relay:—

Mean length of iron circuit	**20 cm.**
Length of air gap	**2 m.m.**
Number of turns on core	**8,000**
Current through coil	**50 mA.**
Permeability of the iron	**500**

Neglecting leakage, what is the flux density in the air gap?

If the area of the core is 0.5 sq. cm., what is the pull exerted on the armature?

A.—

Reluctance = Rel (Iron) + Rel (Gap)

$= l_i/u_i A_i + l_g/u_g A_g$

$= 20/(500 \times 0.5) + 0.2/(1 \times 0.5)$

$= 0.48$ rels.

M.M.F. = magneto magnetic force = 0.4 NI

$= 0.4 \pi \times 8000 \times 50 \times 10^{-3}$

$= 160 \pi$ gilberts.

ϕ = Flux = M.M.F./Rel. = 160/0.48

= 1000/3 Lines.

B = Flux density $= \phi/A = 1000/3 \times 16/0.5$

= 2094 Lines/Sq.cm.

F = Magnetic Tractive force $= B^2 A/8 = \phi^2/8$ A

$$= \frac{1000^2 \times 2}{9 \times 8 \times 0.5} = \frac{2}{36} \times 10^6 = 87{,}300 \text{ dynes.}$$

ERRATA

In Vol. 6, No. 4, June, 1947, on—

Page 207—For "column 7," read "column 6," and on page 209—Alter (b) under Test Results to read—

"(b) 8 tests per quad, lowest reading 66 mmfds."

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