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The

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of Australia

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CONTENTS

This Journal is issued three times a year by the Telecommunication Society of Australia. A year's subscription commenced with the June issue; succeeding numbers are published in October and February. A complete volume comprises six numbers issued over two years, and a volume index appears in No. 6 of each volume.

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THE TYPE 801 TELEPHONE

*R. J. KOLBE**

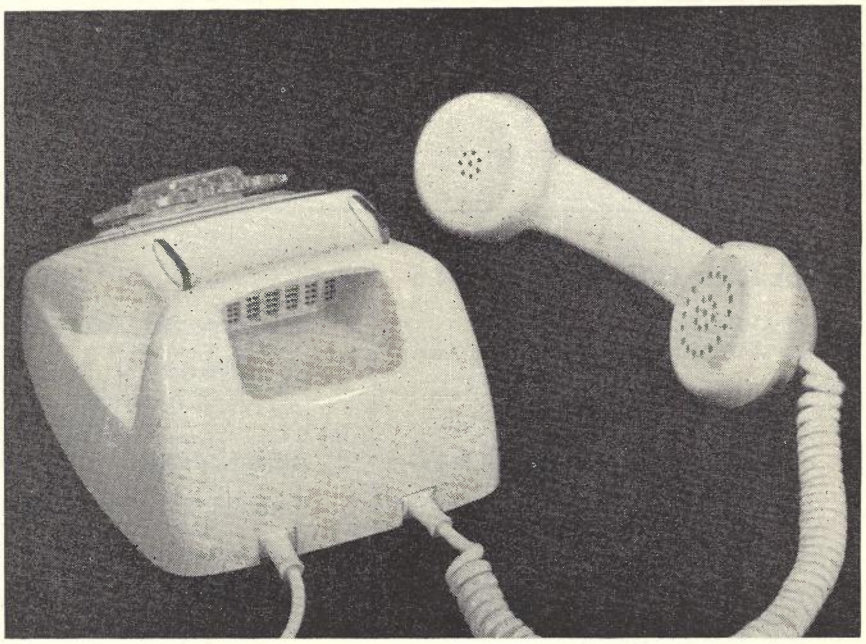


Fig. 2.—Rear View with Handset Off.

INTRODUCTION

In January, 1963, a new type of coloured telephone having a pleasing appearance and advanced technical features was made available to the Australian public. It was the first type in the 800 series to be released and is known as the 801 type telephone. This telephone is designed for use in automatic exchange areas and incorporates automatic regulation of transmission performance. The general features of the design of the 801 telephone, together with its circuit and transmission performance, are discussed in this article. In future issues of this Journal, the various components of the telephone will be dealt with in greater detail.

Shortly after the candlestick telephone gave place to the moulded handset telephone, designers realised that plastics offered the opportunity to make durable telephones in colours other than black. Although coloured telephones were introduced into service in the Australian network during the 1930's, only the ivory instrument achieved any degree of popularity. Since World War II, a great many new plastic materials have become available commercially and many of these are very suitable for the manufacture of telephones in the full range of colours from strong reds, greens and blues to pastel shades.

The Australian Post Office has been well aware of the need for a range of coloured telephones which would harmonise with colours used in modern interior decorating schemes. Accordingly, after calling tenders throughout the world, it was decided in September, 1961, to develop a new Australian coloured telephone as a joint project of Australian manufacturers, that is, Standard Telephones and Cables Pty. Ltd. (S.T.C.), and Amalgamated Wireless (A/sia) Ltd. (A.W.A.), and Australian Post Office engineers. For the first time the Post Office had control over all design features. Information about telephone design had been accumulated for the past 15 years with a view to the eventual design of an instrument for the Australian network and it is clear that the 801 type telephone is at least as far advanced as any other available at present on the world market.

The new telephone instrument is a development from the "Assistant" telephone designed by the Bell Telephone Manufacturing Co., Antwerp, Belgium, with which S.T.C. is associated. However, the design details, both external and internal, have been modified considerably to produce the Australian instrument.

* See page 502.

Fig. 1.—Face View of 801 Telephone.

GENERAL FEATURES

The objectives in the design of the new telephone were a high standard of performance throughout the service life, an aesthetically pleasing appearance, and economy in both installation and maintenance consistent with the requirements for economic manufacture. Particular attention was given to the design of components to ensure that they could be manufactured to the quality level required to give a high probability of a long trouble-free service life. The unit construction principle is employed to simplify manufacture and maintenance. Individual components are grouped and arranged in sub-assemblies which are the fundamental units from which the complete telephone instrument is built.

The case and handset are moulded in a toughened polystyrene injection moulding material, acrylonitrile butadiene styrene (A.B.S.), which combines light weight with high impact strength. The surface has good resistance to scuffing, marking, abrasion and scratching, and is easily cleaned. In addition, A.B.S. resists aggressive chemicals such as acids, alkalis, and many solvents and is

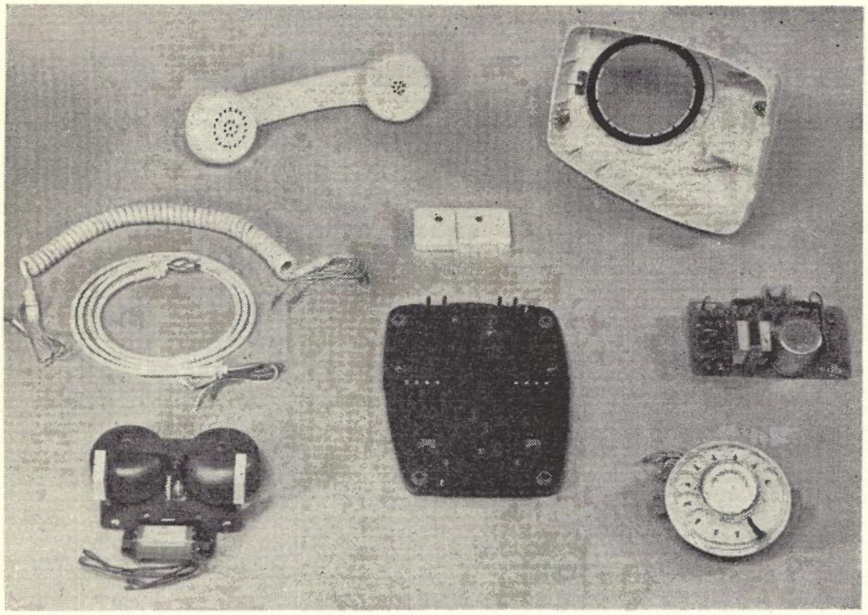


Fig. 3.—Component Assemblies.

not adversely affected by substances normally used for household cleaning.

The five colours chosen for the first order of the new telephone are light ivory, mist grey, fern green, topaz yellow, and lacquer red. These are shown in the photograph on the front cover of this issue of the Journal. Further details of the external appearance can be seen from Figs. 1 and 2.

The case functions primarily as a cover for the component assemblies and not as a mounting unit. It has therefore been possible to design it as a relatively thin, mechanically elastic shell with smooth contours. This case shape, together with the design of the gravity switch plungers (Fig. 2), almost eliminates the danger of accidental operation of the gravity switch by the cords. The handset, when replaced, is directed into its correct position on the gravity switch plungers by a self-aligning action. It is nearly impossible to accidentally balance the handset on the telephone case in any position near the plungers without operating them. A built-in carrying handle in the form of a recess in the case is provided (Fig. 2), which makes it easy to grasp the telephone and carry it in one hand.

The sub-assemblies and components which make up the telephone are shown in Fig. 3. With careful design of the layout, it has been possible to mount the induction coil, capacitors and gravity switch on a printed circuit card to form a compact printed circuit assembly as shown in Figs. 4 and 5. The "wiring" side of the printed circuit card (Fig. 5) is tropic-proofed after soldering, in order to prevent leakage currents between conductors due to "creepage" in moisture films on the card surface. The use of "quick connect" sleeves and studs allows easy and reliable connection of the component assemblies to cords and flexible links without the need for screw fastening or soldering. "Parking" studs for flexible links provide for possible variations of the basic circuit.

The handset is supplied in the same colour as the case. It is a shell moulding approximately half the weight of the previous standard handset. A convex transmitter cap without projections is provided, and the small mouthpiece horn on earlier handsets has been eliminated to improve the appearance without greatly affecting the efficiency of the instrument. The handset is slightly curved to bring the transmitter into the correct speaking position. Adaptor inserts in the handset cavities allow the use of alternative types of receiver and transmitter capsules. An acoustic shock absorber "click suppressor" is mounted on the back of the receiver to protect the user from noises loud enough to cause discomfort.

The dial is adapted to the telephone case by use of a dial adaptor ring which also serves as an enlarged number ring. Placing the numbers away from the fingerplate reduces wear and obliteration of the numbers and makes identification more certain. By the substitution of alternative adaptor rings any modern dial can be accommodated. No letters or numerals are provided on the dial label and this allows adequate space for the subscriber's telephone number and the prefix of the national dialling code, when subscriber trunk dialling is introduced. Special numbering stamps are being developed so that the number can be printed on the label in a uniform manner by the installing technician. The dial mechanism and springsets are enclosed in a clear polystyrene dust cover. On the 811 telephone (the equivalent C.B. manual table telephone), a dummy dial is used to replace the dial and adaptor ring.

The bell has a single coil, polarised by a permanent magnet inside the coil, and will operate satisfactorily with ringing frequencies of $16\frac{2}{3}$ c/s to 50 c/s. A bell loudness control device, which can be operated by the subscriber to vary the loudness between a loud clear ring and a low level buzz, protrudes through the base plate of the telephone. To guard against the subscriber unintentionally placing himself out of call, the control does not silence the bell completely in the minimum position. The telephone base plate provides ventilation by pressed-out louvres and is equipped with four rubber feet which have been designed to give the telephone a firm grip on the table surface.

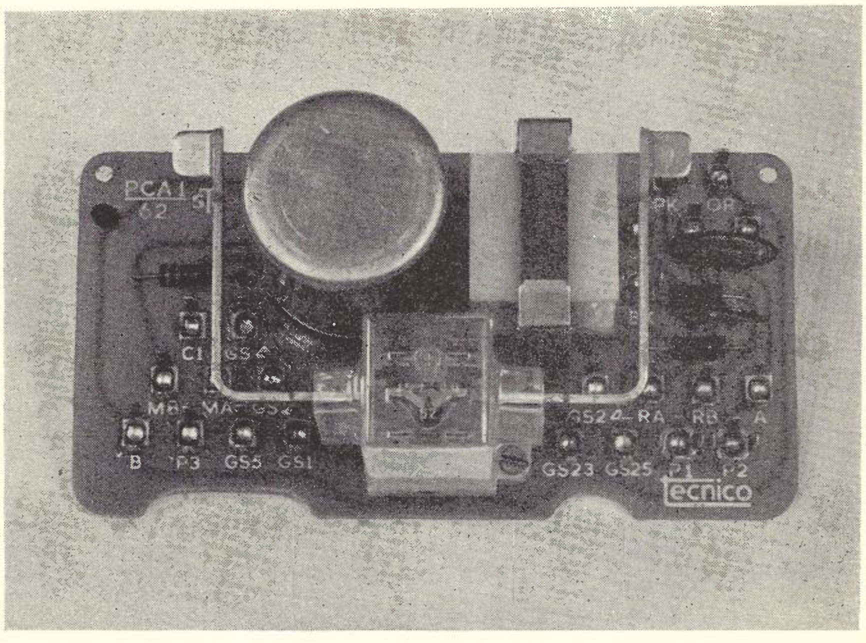


Fig. 4.—Printed Circuit Assembly.

The handset cord is retractable, coiled, covered with P.V.C., and coloured to match the case mouldings. The cord was designed to have a retractile force much lower than the force required to make the telephone slip on all normal surfaces. The small pull created by the cord together with the light weight handset makes the telephone very comfortable to use. The cords are fitted with "quick connect" sleeves which plug on to the studs on the printed circuit assembly, the instrument plug, and the transmitter inset. The cord pull is taken by grommets which are securely welded to the sheath instead of by strain cords. The conductors are also welded to the sheath at the ends to stop them being drawn in when a strong pull tends to stretch the sheath. The instrument and handset cords, which enter the telephone through separate openings at the rear, can be interchanged without disconnection of the terminations, to cater for those instances where a telephone instrument is used mainly on the right-hand side of the table.

The connection between the instrument cord and the fixed wiring is made through a flat plug and socket unit which has been designed for minimum protrusion from the surface on which the socket is mounted (Fig. 1). Provision is made for the plug to be made captive by changing one of the wood screws used to mount the socket. This is done by using a longer screw which passes through a tongue on the plug as well as through the base of the socket. Both long and short screws will be provided with each socket supplied. Plug pins and socket points provide for a maximum of six conductors from the telephone. Normally a three conductor cord is used. Provision is made for the connection of an extension bell by removing a strap in the socket. No alteration to telephone instrument, cord or plug is required. Contacts on socket springs 3 and 4 "make" when the plug is removed. This facilitates the standardisation of cable connections to instruments in plan number working.

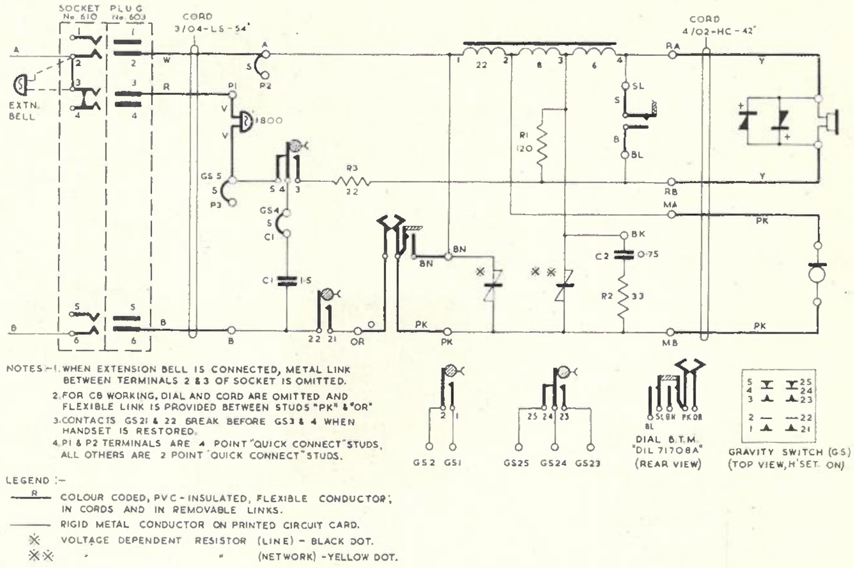


Fig. 6.—Circuit of 801 Telephone.

The electrical circuit provides the following improvements compared with circuits used previously:

(i) Transmitting, receiving, and side tone levels are automatically regulated within standard limits by using two voltage dependent resistors, more commonly known by the trade name "Varistors", as control devices.

(ii) The provision of a "click suppressor" across the receiver has made possible the sequencing of the gravity switch contacts to spark quench the contacts in the line circuit. In earlier circuits the gravity switch contacts had to be sequenced to short out the shock pulse which occurred when the gravity switch was operated; this contact sequence did not provide a spark quench.

(iii) The bell is disconnected from the line by the gravity switch while the handset is lifted.

Provision is made for the addition of push buttons at the front corners of the angled surface of the case. These will be bought with the telephones or added in the workshops or in depots as required. Push buttons are secured to the base plate connected to the circuit assembly by flexible conductors fitted with "quick-connect" sleeves and remain in position when the case is removed.

Ventilation of the interior of the instrument is provided by a ventilator grille at the rear of the case in the carrying recess. This, in conjunction with the fixed louvres in the base plate and the slots between the case and base plate, provides an adequate flow of air over the components to avoid condensation under humid conditions. It also allows sound-waves caused by the bell operation easy egress from the case.

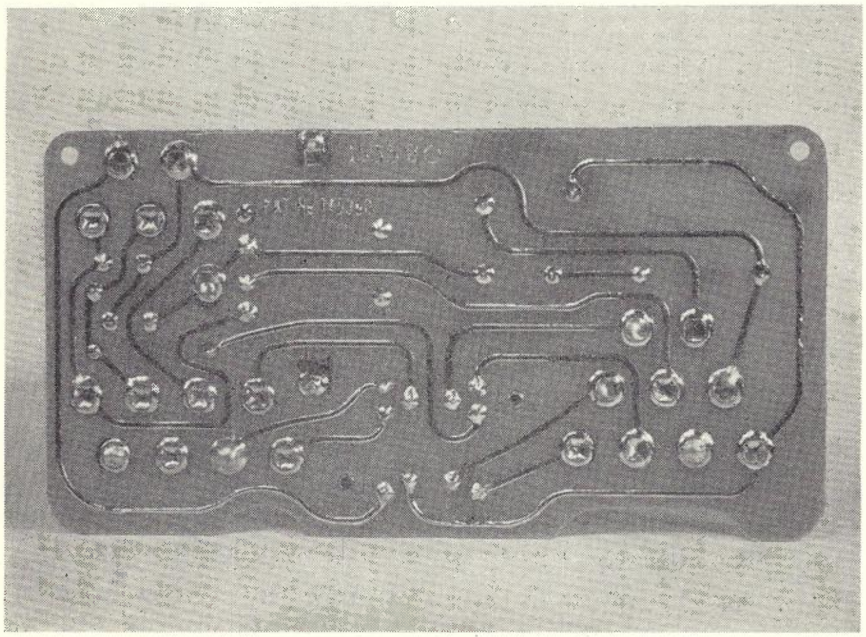
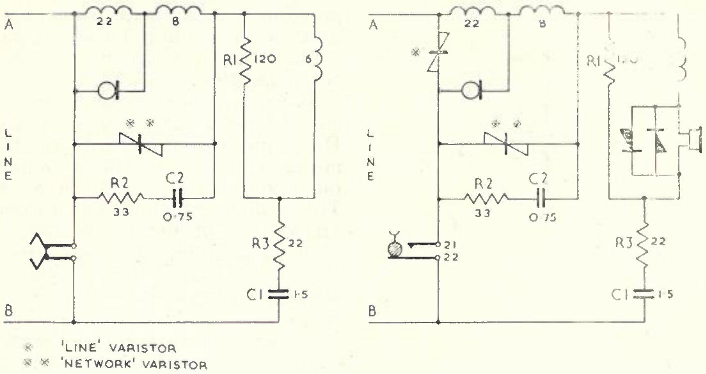


Fig. 5.—Printed Circuit Card after Soldering.

CIRCUIT.

The complete circuit of the telephone is shown in Fig. 6.

The gravity switch contacts of the earlier 400 type circuit, which normally "made" when the handset was lifted to connect the bell circuit capacitor as a spark quench across the dial contacts, have been replaced by a changeover springset GS3, 4 and 5, so that the bell circuit is opened when the handset is lifted. This eliminates the high impedance shunt to speech current of a bell connected across the line. The "break" side of either of the two changeover contacts provided on the



(a) Dial Impulse Springs. (b) Gravity Switch Contacts.

Fig. 7.—Spark-Quench Arrangements.

gravity switch, may be used to disconnect external capacitors connected in parallel with C1 for ringing purposes. The capacity across the impulse springs can thus be controlled in these instances and the impulse distortion that occurs with excessive capacity avoided.

The gravity switch contacts previously in series with the "A" line, have been moved so that they are in series with the "B" line. This has two advantages:

(i) The "B" line potential is isolated on one side of the 1.5 microfarad capacitor and GS.22 contact when the handset is cradled. This enables maximum separation of conductors of opposite polarity in the design of the printed circuit card layout.

(ii) On "hanging up" the gravity switch contacts GS.21 and 22 open the D.C. loop and this causes a high transient voltage across the contacts in a similar manner to that caused across the dial impulse contacts when dialling. In the 400 type telephone these contacts were only partly quenched by the bell coil and series capacitor. In the 801 telephone, however, the new circuit uses the elements of the dial spark quench circuit, slightly re-arranged, for a second function as a spark quench on the gravity switch contacts.

Fig. 7(a) shows the spark quench circuit applied to the dial impulse springs and Fig. 7(b) shows the spark quench circuit applied to the gravity switch contacts GS.21 and 22. In order to achieve this quenching it has been necessary to sequence the contacts GS.3 and 4 to break after contacts GS.21 and 22 as the handset is restored. The sequencing of the gravity switch contacts in this telephone is therefore opposite to that provided in the 400 type telephone. This is possible due to the provision of the shock absorbing rectifiers across the receiver which make sequencing for click suppression in the receiver unnecessary.

The dial spark quench circuit has been adjusted to an optimum value by insertion of R3 (22 ohm) between the gravity switch spring GS.3, and the RB terminal; the influence of R3 on the receiving transmission efficiency is negligible because of the relatively high impedance of the receiver.

The series connection of straps and links has been reduced to decrease fault liability at connecting points, but the inherent potential for circuit modifications has not been impaired.

TRANSMISSION PERFORMANCE.

The circuit of the 801 telephone is based on the transmission circuit used in all modern instruments and first used in the Western Electric 500 telephone some 20 years ago.

The transducers used in the 801 telephone are the present standard transmitter No. 13 and receiver 4T. The dimensions of the handset which determine the position of the transmitter cap relative to the receiver cap and have a big effect on the transmission performance, are in accordance with standards widely used in Europe.

The induction coil design minimises iron and copper losses and the magnetic reluctance of the air gap is chosen for maximum transmission efficiency under the "long loop" condition, consistent with adequate control of saturation by "zero-loop" feed current.

When receiving from the line, the signal divides between the transmitter and receiver and the ratio:

$$\frac{\text{Audio signal power into transmitter}}{\text{Audio signal power into receiver}} = y$$

is known as the "y" ratio. When transmitting, the audio signal output of the transmitter is divided between "Line" and "Balance Network" and the ratio:

$$\frac{\text{Audio signal power to Line}}{\text{Audio signal power to Balance Network}}$$

is also equal to y. The value of y is determined by the ratio of coil windings, together with related line and balance network impedances.

Theoretically, maximum overall efficiency is obtained when y is unity but, to be compatible with an existing network in which receivers of low sensitivity such as type 1L are used, a telephone using a receiver with high sensitivity such as type 4T has to bias the "y" ratio to favour the transmitter. The departure from the 1 : 1 ratio introduces additional copper and iron losses in the induction coil, and the value of y chosen is a compromise which best fits the present transmission levels required in the Australian network. The winding ratios of the induction coil (ICO-1) used in the 801 telephone are identical with those of British Post Office Coil No. 31 and almost the same as those of the British Post Office Coil No. 30 which was used in the 400 type telephone. The relevant winding turns of these coils are shown in Table 1.

TABLE 1. COIL TURNS

Coil	Line	Network	Receiver
ICO-1; B.P.O. No. 31	900	540	315
B.P.O. No. 30	1220	666	420

As a result of the gain in transmission by the use of more efficient transducers, modern telephones when connected by short lines have uncomfortably high "receive" volume and sidetone. On P.B.X. working an extension telephone may be connected to the local feeding bridge by a very short loop in the case of an internal call, but on a call over the exchange line the loop distance from the feeding bridge may be several miles. Automatic regulation of transmission levels on "send" and

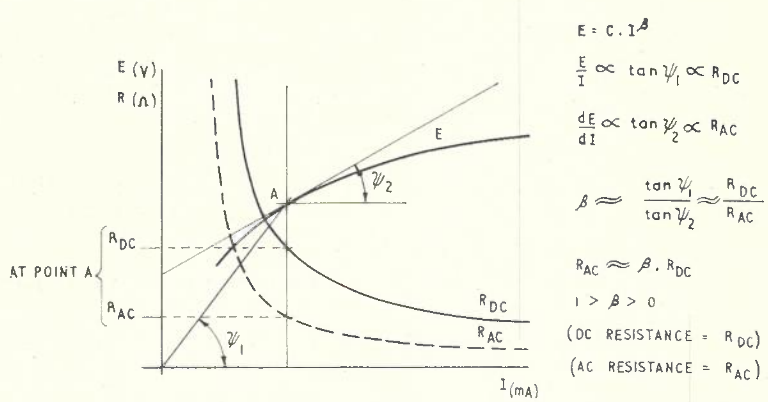


Fig. 8.—Characteristics of a Voltage Dependent Resistor (Varistor).

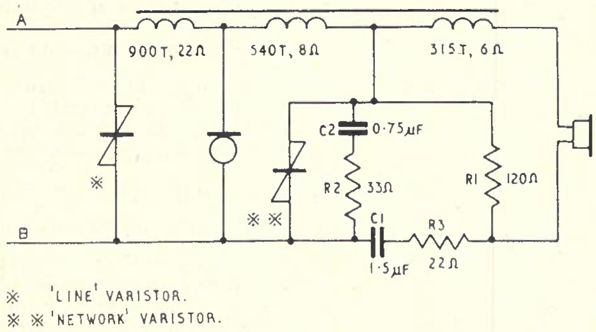


Fig. 9.—Schematic of Transmission Circuit.

"receive" and improved sidetone suppression on short loops is therefore desirable.

The values of components in the balance network were chosen so that high values of sidetone attenuation could be obtained under medium and long loop conditions when the influence of the varistors is small. The automatic regulation in the 801 telephone is controlled by two varistors. They consist of a multitude of silicon-carbide crystals, bonded with a ceramic binder into a disc. The contact resistances between the various crystals form a complicated network of series and parallel paths giving the voltage dependent characteristics of the unit.

The characteristics of a voltage dependent resistor are shown in Fig. 8 with voltage and resistance plotted against D.C. current on a linear scale. At the operating point A the apparent D.C. resistance of the unit is a function of the angle ψ_1, while the incremental A.C. resistance is a function of the angle ψ_2. For direct current, the voltage-current relationship of the unit is of logarithmic nature. When plotting on a logarithmic scale it approaches a straight line, thus demonstrating that β is almost constant over the range of operation.

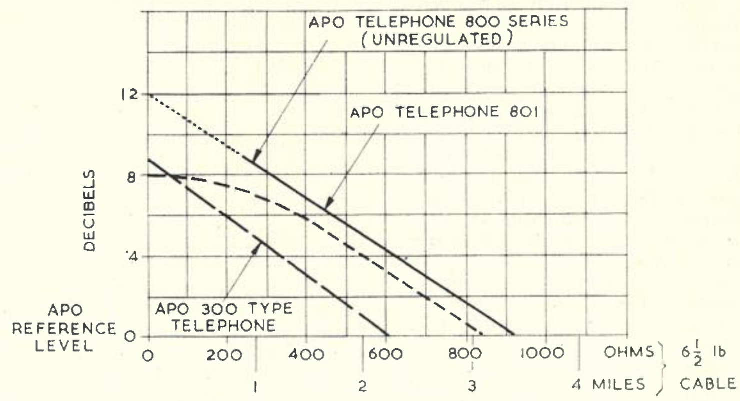
Two varistors are used as shown in Fig. 9. The "line varistor" acts as a shunt across the line and the "network varistor" as a shunt across the balance network.

The main effect of the line varistor is to produce the desired regulation of "send" and "receive" efficiency by shunting audio frequencies under the control of the D.C. voltage across the line terminals. A comparison of transmission ratings between "regulated" and "unregulated" Australian Post Office telephone circuits is shown in Fig. 10. These ratings are based upon transmitter characteristics typical of a No. 13 transmitter midway through its useful life.

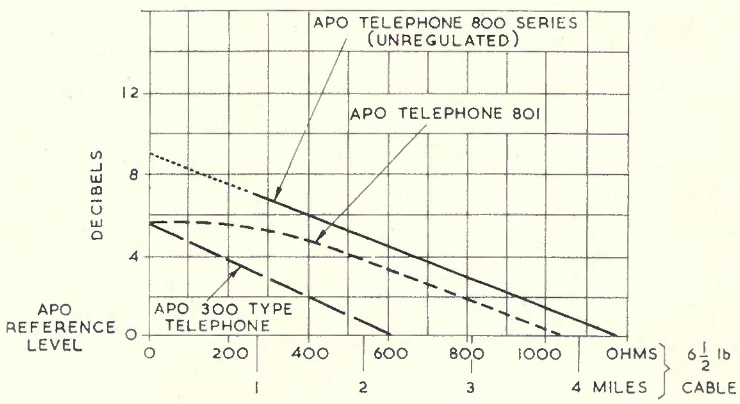
The main effect of the network varistor is to produce an improved sidetone suppression, shunting the network so that a balance with the combined impedance of the line and line varistor is achieved. This gives the desired improvement in sidetone attenuation on short loops. Sidetone attenuation of the 801 telephone has been determined as the average ratio of "Receiver Voltage" to "Transmitter E.M.F." at the frequencies of 0.5, 1, 2 and 3 Kc/s. At zero loop the sidetone suppression is 7 db better than that of the unregulated circuit. This is of particular value when a telephone is used in a noisy location.

The use of the varistors also provides an additional benefit as their combined D.C. shunting effect reduces the transmitter current by approximately 20% on a zero loop, as shown in Fig. 11. This reduces "frying" and increases the service life of the transmitter.

In determining the subscribers' local line transmission limits for the 801 telephone, cognisance was taken of the progressive deterioration of transmission efficiency of carbon transmitters, because of reduced depth of modulation and an increased "speaking resistance" (dynamic resistance) during their service life. As varistors regulate by shunt control, the transmission loss on long loops, which is due to the presence of regulators, also increases with higher "speaking resistance". The limit loop conditions make allowance for this fact.



(a) Efficiency Rating "Send".



(b) Efficiency Rating "Receive".

Fig. 10.—Relative Ratings of A.P.O. Telephones.

TABLE 2. LOCAL LINE TRANSMISSION LIMITS, 801 TELEPHONE.

	4 lb. Cable	6½ lb. Cable	10 lb. Cable	20 lb. Cable	40 lb. CC Open-Wire	70 lb. CC Open-Wire	100 lb. HDC Open-Wire
Ohms	1150	920	770	610	1320	1155	1078
Miles	2.62	3.41	4.37	7.0	25.4	38.5	61.3

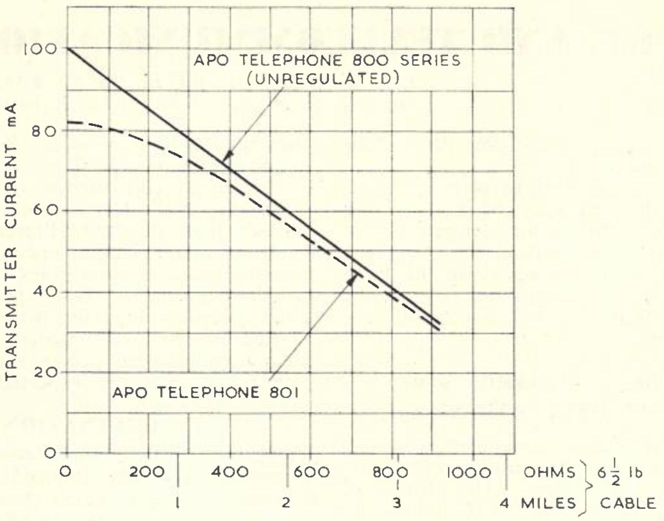


Fig. 11.—Control of Transmitter Feed Current by Varistors.

TABLE 3. CONVERSION FACTORS.

	4 lb. Cable	6½ lb. Cable	10 lb Cable	20 lb. Cable	40 lb CC Open-Wire	70 lb. CC Open-Wire	100 lb. HDC Open-Wire
Conversion factor — Ohms	.67	.84	1	1.26	.58	.66	.70
Conversion factor — Miles	1.7	1.3	1	.62	.17	.11	.07

The transmission limits are shown in Table 2.

The conversion factors for use when composite loops with conductors of different weight are provided are shown in Table 3.

CONCLUSION.

The introduction of the 801 telephone has brought automatic subscribers instruments in Australia up-to-date by world standards, and plant in this field will now match the new types being introduced in the switching equipment and other fields. It is expected that this modern instrument will appeal widely to the general public as well as giving improved transmission performance and maintenance facilities.

ACKNOWLEDGEMENTS.

The author is indebted for the help given by his colleagues in the Telephone Equipment and other Sections of the Engineering Division at Headquarters, and in particular those in the Research Laboratories. A number of valuable contributions to the design features of the new instrument were made by S.T.C. and A.W.A., and significant contributions were made to the design of components by other Australian manufacturers, particularly Transmission Products Pty. Ltd., makers of the 6-pin plug and socket, Blys Industries Pty. Ltd., makers of the cords and grommets, J. J. Hoelle Pty. Ltd., makers of the "quick-connect" terminations, and Rola Co. (Aust.) Pty. Ltd., makers of the sintered ceramic permanent magnets. The assistance given by the Training Section in the preparation of this article is also acknowledged.

TECHNICAL NEWS ITEM

NEW INTERNATIONAL TELEPRINTER EXCHANGE

The new exchange for the international teleprinter (TELEX) service opened at the Overseas Telecommunications Terminal, Paddington, Sydney, on December 31st, 1962. This service is provided by the Overseas Telecommunications Commission (Australia). The initial international telex exchange was established at O.T.C. House, Sydney, in October, 1958 to give service to four countries; today, it is open to 50 countries and the volume of traffic exceeds the volume of the international telephone traffic. To meet the demands of the future, it has been necessary to transfer the exchange to the Paddington terminal and to increase its capacity. Direct connection is available on demand to many countries of the world, and the majority of other countries are accessible by indirect connection.

Telex transmission channels at present are almost exclusively provided by high frequency radio circuits. Complex automatic error detecting and correcting terminal equipment is provided on these channels so that the quality of telegraph communication is of a high standard. On completion of the Commonwealth Pacific Cable (COMPAC) project in late 1963, a large increase in the number of telex circuits available to Canada, United States of America, Britain and Europe will be possible. This is expected to give rise to an added impetus to the rapidly expanding volume of telex traffic already offering.

To meet this further development a semi-automatic international telex exchange will be installed at Paddington in 1964. This new exchange will enable the telex operators in distant countries to select telex subscribers automatically. On present planning, it is probable that direct subscriber to subscriber switching (without the intervention of operators) may be provided for inter-continental telex calls to and from Australia by 1966.

CO-ORDINATION OF POWER AND TELECOMMUNICATION SYSTEMS IN AUSTRALIA**

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and H. T. DAVIS, B.Sc., A.M.I.E.Aust.†

INTRODUCTION

Australia is a country of great distances, the centres of population being separated by long stretches of land with little development. As a result the telecommunication trunk network and the systems of power transmission and distribution both rely heavily on aerial construction and most of the co-ordination work performed in Australia has been associated with the avoidance of noise and dangerous conditions in aerial trunk lines exposed to high voltage power lines.

As power networks have extended further into the lightly loaded rural areas, various forms of single phase high voltage systems have been used to reduce costs. These systems present problems of co-ordination not found in conventional three phase systems.

The trunk network has expanded similarly and it is possible to establish connections over aerial lines up to 4,000 miles in length, under which conditions the signal-noise ratio becomes very important. Noise from power lines must therefore be closely controlled at all points in the network.

This article contains a broad description of the way in which the various aspects of co-ordination have been handled in Australia in the hope that this information will be of value to countries facing a similar situation.

THE ORGANISATION SET UP FOR CO-ORDINATION

The protection of telecommunication plant against injurious effects from power systems depended in the first instance on the legal powers contained in the Federal Post and Telegraph Act and supplementary regulations. As power systems grew it was realised that restrictive measures which acted to the detriment of the power systems could not be rigorously applied to protect the telephone system. The solution to the problem of interference lay in the co-ordination of the two systems, and to achieve this end, Joint Committees of two telecommunication and two power engineers each were formed in each of the six States of the Commonwealth, with a similarly constituted Central Joint Committee to co-ordinate their activities.

The Joint Committees have advisory functions, and operate under the guidance of joint conferences of the Postmaster-General's Department and the Electricity Supply Association of Australia which meet at approximately four-yearly intervals. Recommendations on general co-ordination principles and practices must be ratified by these two bodies.

The work of the Committees falls into two categories:

(a) The preparation of codes of practice for the guidance of both power and telecommunication engineers in matters of co-ordination.

(b) The giving of advice to the Postmaster-General's Department and the power authorities on aspects of co-ordination.

BASIC STANDARDS FOR CO-ORDINATION

The standards of engineering design for co-ordination generally follow the C.C.I.T.T. Directives. The limit of maximum longitudinal e.m.f. induced in telecommunication lines under earth fault conditions is 430 V, increased to 650 V for power lines of high security. The limit of 60 V induced electromagnetically under normal conditions in the power line is observed, together with a maximum of 15 mA flowing from line to ground when electrostatic induction is present.

A maximum value of .006 for the telephone form factor for power lines is found to be satisfactory, together with a coefficient of sensitivity of telephone lines of .025. The co-ordination design is finally based on a maximum psophometric e.m.f. of 0.78 mV appearing across the subscriber's instrument. This represents a noise level of 60 db below one milliwatt (— 60 dbm).

High standards of construction are important in safeguarding against contacts between power and telecommunication lines and in preventing excessive induction at crossings. The standard of construction of power lines is controlled by government legislation.

The aerial construction of the Postmaster-General's Department is of comparable high standard. Present practice is to use full length pressure treated wooden poles or steel poles and treated wooden crossarms. Only plastic insulated telecommunication wire or cable is used on joint use construction and the clearances between power and telecommunication wires are inspected annually.

CO-ORDINATION

Protection of Plant and Personnel from Excessive Voltages Induced at Power Frequency under Earth Fault Conditions on a Power Line.

Long exposures of aerial trunk lines to power lines are common in Australia, and considerable experience has been obtained in the measurement of induced voltages, and in protection against them. Recently long distance trunk cables have been placed close to power lines and experience in assessing shielding factors is now being gained.

Values of induced voltage are calculated from the power line earth fault currents by the methods described in the C.C.I.T.T. Directives and other texts (1). If the induced voltage exceeds 430 V, or 650 V for high security lines, consideration is given to the provision of adequate separation, or the installation of protective devices, to keep the residual voltage below 430 V.

If the earth resistivity appropriate to the exposure is not known, a value of 50 ohm-metre is assumed if the terrain is relatively flat and not of a rocky

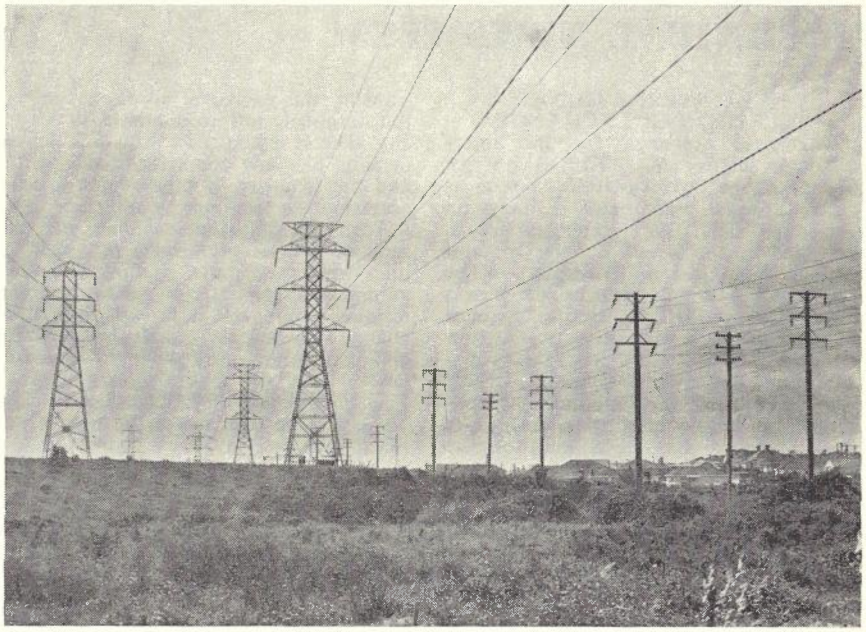

Fig. 1.—High Voltage Transmission Lines Approaching Melbourne.

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* See page 503.
† See page 502.

** This article was presented by the authors as a paper at the May, 1962, Session of the Conference Internationale des Grands Reseaux Electriques a Haute Tension, Paris.

Fig. 2.—High Voltage Lines Flanking Both Sides of Warrigul Road, Melbourne. Such lines introduce the hazard of low frequency induction into the underground telephone cables under earth fault conditions.

nature, or 1,000 ohm-metre in mountainous or rocky country. Measurements of soil resistivity indicate wide variations from place to place and also with depth. Surface measurements do not usually agree with values calculated from tests for induced voltage. In a typical example, surface resistivity was 20 ohm-metre and 100-300 ohm-metre values were obtained from induced voltage measurements. In a few instances, however (clay soil in a coastal plain area—30 ohm-metre), there was no difference. The most common values of resistivity, from all induced voltage tests, fall in the range 100-300 ohm-metre. Extreme values are 35 ohm-metre for deep, damp soil and 1,000 ohm-metre for rocky country in high rainfall areas.

A suitable factor is applied for the shielding effect of earthed conductors such as power line earth wires, cable sheaths, metallic pipes, etc. Wherever possible, and particularly if there is doubt about appropriate values of earth resistivity and shielding factor, induced voltage is checked by test. Since the test current is usually smaller than fault current, allowance must be made for the possible saturation of shielding elements.

The assessment of individual shielding elements is usually complicated by the presence of a number of such elements. Typically, in an open wire exposure where railway tracks and large water pipes ran close to the exposure, the measured voltage was half the calculated voltage. This reduction supports findings by the C.C.I.T.T.

Measurement of the mutual impedance between lines is carried out by passing a measured current through the power line and earth return. The telephone line is normally earthed at one end and the voltage to earth at intervals along it is measured.

In practice, other effects must sometimes be allowed for. In an exposure of 7.1 miles between an aerial telephone line and a 220 kV power line, the presence of a 22 kV unbalanced single phase power line which paralleled the telephone line at a separation of 120 ft. caused 46 V to earth to appear on the open circuited telephone line through electrostatic coupling, making the determination of electromagnetic effects by voltage measurements difficult. However, a satisfactory determination was made by earthing the telephone line at both ends and measuring the current in the earth loop. The value of the electromagnetic voltage was calculated using the measured impedance of the earth loop. The voltage between telephone line and ground was measured at half mile intervals along the line, to determine the residual voltage on the line after operation of the protectors at each end.

If the magnitude of the extraneous voltage on the telephone line can be measured and its phase angle determined with reference to a fixed voltage, the resultant voltage, with test current flowing in the power line, can be measured similarly. The electromagnetically induced voltage is the algebraic difference.

The telecommunication circuits are protected by arresters which will discharge to earth when excess voltage is applied. The arresters are so selected and located that, when they discharge, the residual voltage at any point on the line will not exceed 430 V.

If the calculated induced voltage is above the 430 V limit, all exposed pairs are normally fitted with protectors at each end of the exposure to avoid the appearance of potential differences between the wires on the route when the protectors have operated. For this reason a "turn off" pole within an exposure is usually selected as a protection point.

The residual voltage between line and ground depends on maintaining a small value of earth electrode resistance with respect to the line impedance, and low earth resistances are therefore necessary. This may influence the selection of protector locations in some cases. It should be noted that, with varying separations, the maximum residual voltage does not necessarily occur at a protection point. Except over long or severe exposures, two protection points are usually sufficient.

It is necessary to determine the current flowing in the protectors in order to select devices with appropriate current rating. Details of the design methods employed may be found in Reference 2.

During the past year a number of trunk cables has been planned for routes where high voltage parallels exist. Longitudinal voltages of the order of 7,000 V could appear on unshielded cable conductors under earth fault conditions on the power line. In these cases the shielding of the cable sheath is so designed as to limit the induced voltage to a value below the breakdown voltage of the cable. Protective apparatus will then be fitted to the cable conductors to further limit the induced voltage to the C.C.I.T.T. recommendations.

Aluminium is the favoured sheathing material on the basis of cost, particularly when compared with a lead sheathed, tape armoured cable which is provided with a plastic jacket to prevent corrosion of the armouring tapes. Since the aluminium cable is plastic jacketed to reduce corrosion, it must be earthed for alternating currents at each end of the exposure and preferably also at points along the exposure. At the same time it is desirable to keep the cable at a negative potential with respect to earth to reduce corrosion.

Noise in a Telecommunication System due to Induction from a Three Phase Power Line.

Three phase high voltage distribution systems are normally earthed only at the neutral point of the supply transformer, and the only currents circulating between line and earth are those due to the capacitive coupling of the lines to earth. The currents are small in magnitude if the capacitive balance of the three phases to earth is good, and they will have very little effect on a parallel telecommunication line.

On a few occasions a condition has occurred, approaching resonance at the frequency of a triple harmonic, between zero sequence capacitance and inductance in a distribution system. This has caused an increase of the harmonic content in the neutral current, and corresponding telephone interference. Neutral currents caused by the connection of unbalanced single phase lines to three phase systems have also caused interference. In these cases, it has been possible to overcome the interference by modification of the power circuit.

Although high voltage transmission

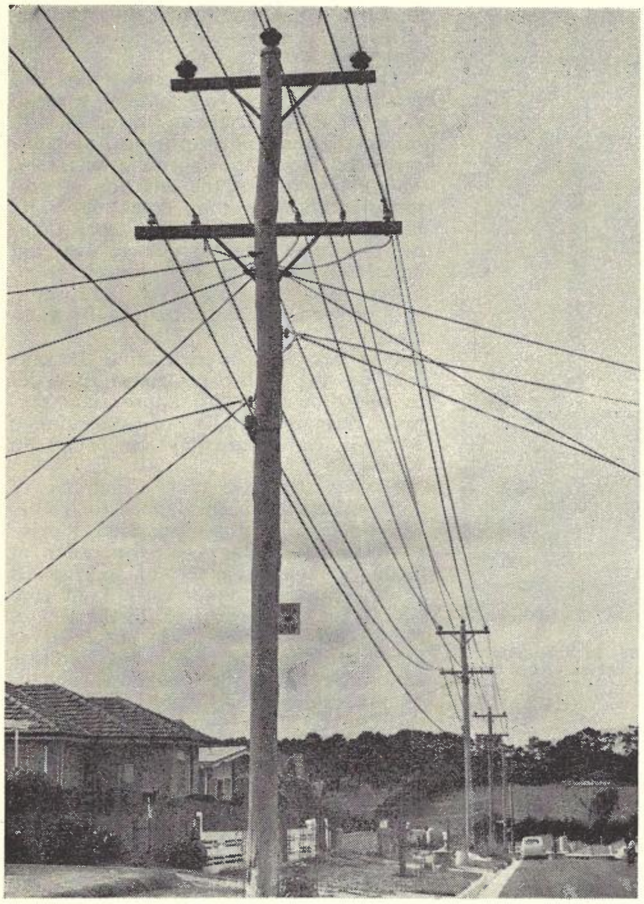

Fig. 3.—Joint Use Construction on a High Voltage Route in a Melbourne Suburb.

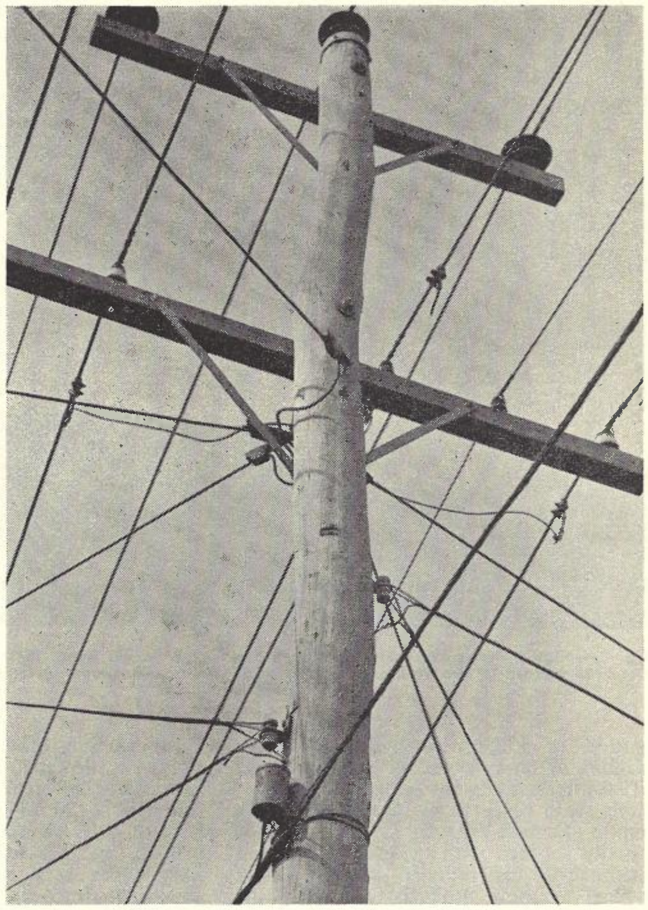

Fig. 4.—Close-up View of Joint Use Construction of Lashed Aerial Cable. Both the Power and Telephone Service leads are insulated.

networks are normally earthed at a number of points, noise induced by circulating earth currents in such networks has not so far been experienced due to the limited exposures which exist at present. The possibility of noise is reduced by the maintenance of a low telephonic form factor for the system voltage and, correspondingly, for the neutral currents.

High induced electrostatic voltages can appear on telecommunication lines adjacent to high voltage power lines and noise can result. The methods for reducing the level of the induced noise consist of:

(i) Balancing the power line with respect to the telecommunication line and to earth.

(ii) Reducing the harmonic content of the power line to a minimum.

(iii) Balancing each wire of the telecommunication line with respect to the power line, earth, and to each other wire.

(iv) Ensuring that the telecommunication terminating equipment connected to ground is balanced with respect to ground.

Voltages induced into telecommunication circuits by capacitive coupling with power lines are reduced by suitable transpositions of the conductors of the power lines. Complete cancellation is not achieved because of lack of symmetry of the conductor system to earth, and because of variations in the separation.

A length of power line in which each conductor is transposed twice to occupy each of the three positions, is called a "barrel". The normal "halting" barrels are used with the transpositions at the end points omitted. Where separation is non-uniform, the transposition points in a barrel are located so as to make the induced electrostatic charges in each of the three sections equal.

A barrel is terminated and a new one commenced in those cases:

(i) Where, with horizontal or triangular configuration of the power line, there is a crossing of the power and telecommunication lines, as the crossing has the same effect as if the outside wires only were transposed at that point.

(ii) Where a "T" junction occurs in the telecommunication route, in order to balance induced voltage both in through pairs and pairs which turn off.

(iii) Where a section of the exposure is at very close separation and close co-ordination becomes necessary.

The term "close co-ordination" is applied to cases where the separation is so small that direct induction into the telecommunication loop becomes significant, and the transpositions of the telecommunication wires must be co-ordinated with the transpositions in the power line to overcome it. The limiting separations, as defined in the C.C.I.T.T. Directives, are applied (3).

The telecommunication wires themselves are normally transposed, point type transpositions being used and the scheme arranged to ensure freedom from crosstalk (4). The ends of telecommunication transposition sections (within which each pair is completely transposed with respect to each other pair for the elimination of crosstalk) are located as near to the end points of the power line barrels as possible.

Power line transpositions may be made by "rolling" the conductors, generally over three spans, or by point transpositions in which the conductors are attached with tension terminations to both sides of the pole or structure, and the phase positions changed by bridge conductors. Generally, the rolling type is preferred as interfering less with the design of the line, but in severe cases where close co-ordination is required it may be necessary to have point transpositions so that the transpositions may be matched with corresponding telecommunication transpositions.

Each wire of a telephone circuit must

be balanced to earth and to other circuits on the route. Transpositions not common to other circuits are of assistance in this regard. In addition, the resistance and leakage balance of the pairs must be maintained. The selection of cable pairs in entrance cables is of assistance in achieving well balanced lines. In circuits terminating in common battery equipment, both legs of the pair are earthed through separate resistances, the balance of which, together with the coupling capacitors, is important.

As mentioned previously, the weighted noise level is kept below — 60 dbm where possible. This corresponds to a psophometric current of 1.28×10^{-6} A through a 600 ohm termination. The maximum permissible longitudinal voltage that can be induced into each leg of the telecommunication line depends on the balance of that line, which is expressed in terms of its coefficient of sensitivity. A coefficient of sensitivity of 0.025 is obtainable in practice on well-constructed lines and this value is used for the design of co-ordination measures.

In central battery systems electrostatic induction from a power line causes a current to flow to earth in the wires of the telecommunication line, the circuit being completed by the capacitive coupling of the telecommunication line to earth. Assuming a telephone form factor of .006, the 50 c/s current flowing in the telephone line wires would be $.53 \times 10^{-3}$ A. Since the capacitive coupling of a telephone line to earth is approximately 250,000 ohms for a mile of line, the maximum permissible open circuit voltage that can be induced in a telecommunication line for any length of parallel can be determined.

Following reports of noise on trunk circuits where a 25 mile exposure with a separation of about 100 ft. exists between a three phase 22 kV aerial power line and a well transposed trunk route, noise measurements were made and it was found that, due to changes in the alignment of the trunk route, the transpositions in the power line no longer balanced that line with respect to the trunk line. A new transposition scheme for the power line was designed, and new noise measurements made after it was implemented.

An improvement in the noise level of the order of 20 db was produced on most of the trunk lines. Even in the case of lines on which the noise was very nearly down to the acceptable limit, some improvement was made, for example, — 58 dbm before transposition improvement to — 68 dbm after improvement.

CO-ORDINATION MEASURES

Single Phase Lines and Aerial Telecommunication Lines

In Australia considerable use has been made of single phase high voltage supply in rural areas, the single phase being obtained by tapping two conductors of a three phase system of which the neutral is earthed. Resolving the conductor voltages to earth into balanced and unbalanced components, there is a residual component equal to 0.289 of the phase to phase voltage on each conductor. The effect of these residual voltages cannot be eliminated by power line transpositions. For a single phase power line at 22 kV, with a separation of 66 ft. from a telecommunication line which is isolated from earth and does not extend beyond the exposure, the voltage induced by this residual component is 240 V.

The voltages to earth which appear on the two wires of a telephone pair are in phase with one another and approximately equal in magnitude and cannot be eliminated by transposition of the telephone wires. Transpositions are necessary, however, to ensure that over a transposed section the induced potentials will be exactly equal.

If an exposed telephone line is short circuited to earth at one end, the current which will flow is determined by the induced open circuit voltage and the capacitance of the exposed section of the line to earth. This current is of the order of one milliampere per mile of exposure at a 50 ft. separation. For multiwire telephone routes, the currents should be reduced by a factor of $3/(z + 2)$ where "z" is the number of wires. On long exposures, the current could affect a telephone linesman working on an exposed line, and in some cases telephone exchange operators have suffered mild shocks.

It is found that the noise produced in circuits connected to magneto exchanges is less than in those connected to automatic exchanges because the equipment itself is not connected to ground, thereby reducing the current flow. If required, the line can be isolated from the equipment by means of transformers, and the longitudinal currents drained to earth. For automatic working, transformers cannot be used because direct current signalling is involved, while balancing is more difficult as both sides of a pair are connected to earth through line relays, and lines are connected together with coupling capacitors.

Calculations for a 22 kV single phase line, based on a noise level of — 60 dbm, a telephone form factor of .006 and a coefficient of sensitivity of .025, show that harmful noise in a telephone will be produced, if the exposure exceeds 1 mile at 50 ft. separation, three miles at 100 ft. separation, or 12 miles at 200 ft. separation. The minimum permissible separation varies inversely with the voltage.

Avoidance of interference is therefore largely dependent on separation. A draft Code of Practice (5) requires the power authority to keep the telephone form factor of the power line voltage below .006, and telecommunication circuits in the neighbourhood of single phase lines are to have a coefficient of sensitivity no greater than .025. Other measures to reduce noise are transposition of power and telecommunication lines in accordance with the above, better balancing of telecommunication lines and equipment, the insertion of isolating networks where possible between line and equipment with drainage to earth, and the conversion of open wire lines to buried telecommunication cable or metallic screened aerial cable.

Tests carried out on an exposure of aerial telephone junction wires paralleling a 22 kV single phase line for a distance of 3.74 miles at a separation of 54 ft. showed that the noise level increased by an average of 20 db when the equipment was connected to the line. The telephone form factor of the power line voltage was measured as .003.

In further tests on a similar telephone line where an exposure of 3.8 miles at 50 ft. separation exists, it was found that the telephone form factor of the power line voltage was .0015 and that the coefficient of sensitivity of the transmission bridges in the terminating equipment was .013. As a result, the weighted noise level was only — 62 dbm despite the severity of the exposure.

Single Wire Earth Return High Voltage Lines.

Single Wire Earth Return High Voltage lines ("S.W.E.R." lines), have been extensively used for electricity supply in relatively sparsely settled rural areas where electrical loading is light and not likely to increase substantially. Because of the earth return feature the load current induces longitudinal voltage directly into parallel telecommunication lines.

The Postmaster-General will permit the use of S.W.E.R. lines under conditions set out fully in (6). In general, the voltage induced into a telecommunication line, under steady state conditions on the S.W.E.R. line does not exceed 60 V as provided in the Directives, when the technical conditions, as summarised below, are fulfilled:

(i) Each S.W.E.R. line shall be electrically isolated by means of a transformer from the three phase or single phase two wire line supplying it.

(ii) The earth return current of each line or group of lines so isolated shall be not greater than 8 A.

(iii) Except for crossings, the separation between any S.W.E.R. line and any aerial telecommunication line shall be as large as reasonably practicable and generally not less than 250 ft. at any point. It may, however, be reduced to a minimum of 60 ft. to avoid obstacles or reach power consumers provided that the total length of sections of reduced separation does not exceed one mile for any S.W.E.R. line.

(iv) Each S.W.E.R. line shall be provided with suitable protection which shall operate in not more than two seconds for a fault current of seven times the maximum load current.

(v) The electromagnetically induced voltage in any telecommunication line carrying morse telegraph circuits shall be not greater than 2.5 V except in certain cases where up to 6.5 V can be tolerated.

(vi) The minimum horizontal separation between any S.W.E.R. line and any overhead or underground telecommunication cable shall be not less than 50 ft. or not less than the separation, if greater, necessary to limit the induced voltage under fault conditions to 430 V.

(vii) High voltage earth connections of transformers in S.W.E.R. systems shall be separated by not less than 50 ft. from telecommunication earths, or by not less than 200 ft. if the latter earth is part of a speech or signalling path.

The maximum current of eight amperes and minimum separation of 250 ft. correspond to an induced voltage of 60 V for a length of parallel of 20 miles and earth resistivity of approximately 1,000 ohm-metres as may be found in rocky ground. Eight amperes also corresponds very nearly to 100 kVA at 12.7 kV ($=22$ kV $\times$ $1/\sqrt{3}$) which has been adopted as a standard voltage. Individual S.W.E.R. lines are normally designed to have maximum loads of not more than 100 kVA, and not to exceed 20 miles in length.

The protection requirement means that a fault current which will induce 430 V (approximately seven times the limiting steady state voltage of 60 V) will be disconnected within two seconds.

With the foregoing technical conditions applied, including the separations for cables and earths, interference from S.W.E.R. lines into telecommunication circuits has been completely avoided, apart from rural earth return telephone lines. These have to be converted to metallic circuit lines if excessive interference occurs. This is usually the case if the separation is less than 450 ft. and is usually avoided if the separation exceeds 1,300 ft.

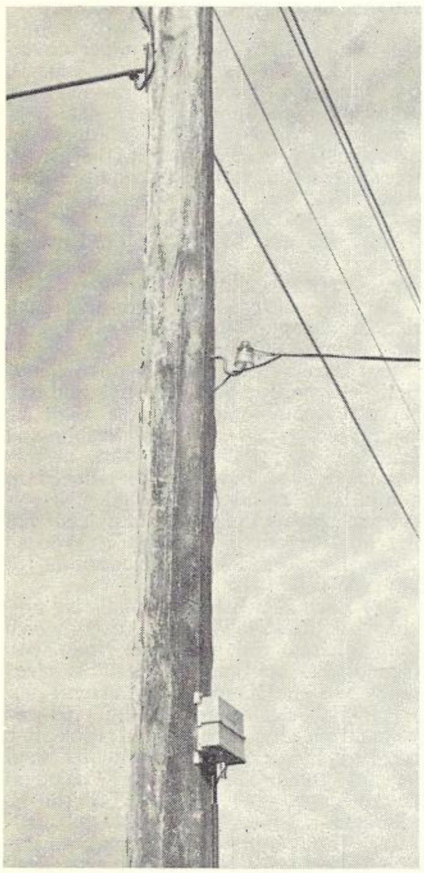

Fig. 5.—Joint Use Construction Consisting of a Cable Box Fed from an Underground Cable and Distribution by Means of Drop Wire.

An experimental installation of S.W.E.R. lines without isolating transformers has been put into service in a rural area of New South Wales. In this case a three phase 22 kV "back-bone" approximately 75 miles in length has S.W.E.R. spur lines, the majority of which are relatively short, and which are distributed among the three phases so as to ensure the best phase current balance and hence minimum residual earth current along the three phase line.

The installation is considered to have been successful on an economic basis. although it was found that the third harmonic in the earth return current was at times greater than the fundamental, while the residual components of fifth and seventh harmonics in the earth current also contributed to the noise which occurred in a few exposures. Because of the separation specified, noise is not a problem for S.W.E.R. lines with isolating transformers. However, conditions to limit noise may have to be considered for systems such as the experimental one without isolating transformers because of the greater noise weighting, and coupling factors, for the harmonic components of the earth current. The harmonics in the earth return current come from the magnetising currents of the distribution transformers, and consideration is being given to the reduction of magnetising current harmonics in the design of transformers for such systems.

CO-ORDINATION MEASURES APPLIED TO THE CONSTRUCTION OF TELECOMMUNICATION LINES

Crossings

A "Code of Practice for Crossings of Electric Power Lines and Telecommunication Lines" has been produced and adopted by the Postmaster-General's Department and the Electricity Supply Association of Australia (7).

The principal conditions for crossings of low voltage power lines and telecommunication lines are:—

(i) Normally the power line crosses over the telecommunication line. Low voltage power lines are permitted to cross under telecommunication lines in multiple-earthed-neutral areas provided insulated, neutral screened power cable is used.

(ii) Clearances between power and telecommunication lines in span are stipulated, together with the minimum distance between a power line and a telecommunication support.

(iii) Conditions under which power lines may be attached to the head of the telecommunication poles are included together with approved methods for the attachment of telecommunication lines to power poles.

In the case of crossings of high voltage lines, additional conditions are included to avoid contacts between wires and electrostatic induction from the power line. Power poles are located close to the crossing to avoid large variations in clearance at the crossing. While the angle of the crossing controls the magnitude of the voltage induced into the telecommunication line, consideration must also be given to the constructional weakness associated with additional angles in the power line.

To determine minimum angles of crossings, a test line was erected under a 220 kV double circuit line and the open circuit voltage to earth measured with various angles of crossing and with various vertical spacings of the two lines. The telephone line was terminated in a 600 ohm termination at one end and the voltage to earth measured at the other.

The results were as shown in Table I.

The measured values of induced voltage for the various angles at the two heights show a fairly constant relationship to the cosecant of the angle of the crossing.

The variation in the induced voltage with varying heights of power lines at crossings was calculated and described in (8). A model of a right-angled crossing of a power and telecommunication line was constructed and the voltage between the telephone line and earth was measured for varying heights of the lines.

Calculations indicate that the induced voltage due to a crossing of a power line at 500 ft. above the ground is reduced to only half that of a crossing where the power line is 32 ft. above the ground. Measured voltages on the

TABLE I.

Power line height 32 ft.			Power line height 47 ft.		
45°	30°	20°	45°	30°	20°
Telephone line height 3 ft.					
Measured voltages					
102	154	—	93	136	204
Cosecant of angle					
1.414	2.00	2.92	1.41	2.00	2.92
Telephone line height 13 ft.					
Measured voltages					
530	670	1.070	354	516	828
Cosecant of angle					
1.41	2.00	2.92	1.41	2.00	2.92

model line confirmed the accuracy of the calculations.

Conditions are also laid down in the Code of Practice for the strength of power poles at crossings, location of joints in wires and method of fastening conductors on power lines. No high voltage conductors are attached to telecommunication poles and only crossings of power lines over telecommunication lines are permitted.

The Code also outlines conditions for the location of parallel power and telecommunication lines in streets and the minimum separation between lines.

Co-ordination of Stays

Power and telecommunication lines commonly form parallels at roadway separations and the associated stays cross or are attached to the line of the other party. In the relevant Code of Practice (9) stays are classified into "sectionalised" and "unsectionalised". The sectionalised stays contain insulators in their length designed to prevent a flow of current in them if they should become energised. The end of the stay so insulated from the power line is treated as safe and permissible clearances from the telecommunication line are reduced to a minimum. The unsectionalised stays are treated as potential conductors with a voltage equal to the highest on the power line and clearances are specified accordingly.

Joint Use and Common Use of Poles

Statutory limits for clearance often make it necessary to attach wires which cross roadways to supports on both sides of the road. As a result conditions for common use (10) of poles have been developed. Extra height is provided in the telecommunication support and the power wires are attached four ft. above the telecommunication wires. This type of construction is known as common use and involves the crossing of wires of one authority with those of another.

Where the wires of one authority are erected for a number of spans on the line of another authority the situation is referred to as "joint use". (The development of joint use has been slow in Australia mainly because the telecommunication system is controlled by the Commonwealth Government while the power systems are in the main operated by the various State Governments). Since codes of joint use construction together with simple systems of payment have been developed (10), joint use has gained in popularity, particularly on the part of the power authorities.

The constructional requirements vary slightly with different power authorities but all codes insist on the use of insulated telecommunication lines and a vertical separation of 4 ft. between the low voltage wires and the telecommunication wires. As yet joint use on high voltage poles not possessing low voltage crossarms is permitted only in special circumstances.

To further the application of joint use the Postmaster-General's Department has developed a light-weight plastic insulated and sheathed cable with a built in bearer wire. An aluminium foil is included to give electrostatic shielding. Because of the high electrostatic voltages that can be induced on open circuited telecommunication conductors from high voltages lines, care must be taken during the erection and repair of such lines to maintain an earth on the conductors and bearer wire. Calculated open circuit voltages between line and ground that would appear on a plastic sheathed cable erected on various types of power lines are 42.8 V for a 230 V single phase power line, 314 V for a 22 kV three phase power line, 2,225 V for a 22 kV unbalanced single phase power line, and 2,996 V for a 12.7 kV S.W.E.R. line. The magnitudes of the induced voltages clearly indicate the need for safety precautions.

CONCLUSIONS

1. The organisation set up to deal with the co-ordination of power and telecommunication systems in Australia, consisting of a Joint Conference of Power and Telecommunication Authorities, with a Federal Joint Working Committee and a similar Committee in each State, has achieved a unified technical approach to problems involving co-ordination and has proved to be satisfactory for a furtherance of co-ordination work.

2. Protection of plant and personnel from danger due to induction at power frequency has been largely achieved in the case of aerial telecommunication lines by the use of distributed protective devices. In the case of trunk cables emphasis has been placed on separation and shielding to avoid danger to the cable and connected equipment. The problem associated with the protection of large subscriber cables is not finally resolved and investigations into suitable methods, and into overseas practices, are continuing.

3. Experience with overhead systems at roadway separation shows that a well-designed scheme of power transpositions will ensure a satisfactory noise level in a well-balanced telecommunication line. For single phase high voltage power lines unbalanced to earth, it is necessary to limit the load current where one conductor and earth return are used, and to specify a minimum separation for two-conductor lines.

4. The possibility of physical interference and danger, associated with close parallels and crossings, is minimised by codes of practice which specify constructional standards and separations between lines.

ACKNOWLEDGMENT

The authors wish to acknowledge assistance from engineers of the Postmaster-General's Department and the Electricity Supply Authorities whose work has made possible the compilation of this paper.

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AN INTRODUCTION TO THE ANALYSIS OF SUBSCRIBERS' COMPLAINTS

*D. J. OMOND, B.E.**

INTRODUCTION

The analysis of subscribers' complaints or CARGO (Complaints Analysing, Recording and Graphing Organisation) as it is now referred to, plays an important part in the improvement and maintenance of an adequate standard of service to telephone subscribers in the metropolitan exchange networks throughout Australia. It had its beginning in a small experiment conducted in Adelaide in 1960 at the request of Headquarters, and this article describes the early stages of its development. A subsequent article will describe its continued progress.

COMPLAINTS CATEGORIES

Complaints received from telephone subscribers at exchange service desks (sometimes referred to as complaints desks) fall into three categories, namely, Non-Technical Assistance, Technical Assistance, and Repair. The types of complaint in each of these categories are as follows:

(i) **Non-Technical Assistance:** Non-Technical Assistance includes all complaints where no fault condition is obvious or suspected in any equipment:

Don't Answer (D.A.)—
Called party not answering but service tests O.K.

Wanted Subscriber Busy (Speaking)—
Wanted subscriber busy and found on test to be in conversation.

Subscriber's Error—
Either in dialling or procedure.

Disconnections—
Attempts to dial disconnected numbers.

Miscellaneous—
Complaints peculiar to public telephones, for example:
Directory torn or missing.
No light.
Broken panes of glass, etc.

(ii) **Technical Assistance:** Technical Assistance includes complaints where a fault condition is evident or suspect in common exchange equipment or in the network linking exchanges:

Wrong Number—
Includes wrong number obtained by a caller as well as reports of calls received when not intended.

No Progress—
Cases where after the initial receipt of dial tone, dialling fails to result in busy tone, number unobtainable tone or ring tone, or where a call reverts to dial tone after dialling.

Busy Tone During Dialling—
After initial receipt of dial tone, busy tone is received before dialling is completed.

Cut-Off While Speaking—
Cut-offs which occur during conversation.

Stop-on-Busy Line (Triple Connection)
A calling subscriber becomes connected to an established conversation.

(iii) **Repair:** Repair includes complaints where a fault condition is evident or suspect on a particular subscriber's service or individually associated equipment:

Cannot Call Out—
Includes no dial tone, cannot break dial tone, busy tone on lifting receiver and clicking noise (open circuit trunk).

Subscriber's or Public Telephone Equipment—
Instances where substation equipment clearly requires repair attention by technical staff, for example, broken handset or cord, missing receiver, or sticking dial.

No Service After Payment (Public Telephones)—
Inability to converse after coins have been inserted or Button "A" pressed.

Coins—
Coins stuck, coin tin full, unable to insert coins.

Others, Technical—
Includes miscellaneous technical faults such as Not Receiving Rings, Ring Trip, Don't Answer complaints found to be "out of order" when tested, and Wanted Subscriber Busy where the called number is found to be engaged, but not speaking when tested.

TABLE 1 — Typical Record of Faults Detected as a Result of Complaints Analysis.

Date and Time	Occurring Trouble	Fault Found	Time Found
5.12.1960			
8.15 a.m.	Unley: no progress to 71 3rd selectors.	Open circuit wiper cord on 3rd selector.	8.30 a.m.
10.20 a.m.	Summertown: wrong numbers outgoing and incoming.	Junction cable being repaired—transposed and reversed junctions.	5.00 p.m.
10.50 a.m.	Unley: wrong numbers to Glenelg.	Faulty repeater at Unley.	11.30 a.m.
11.00 a.m.	Franklin: drop outs dialling 76 or 79 numbers.	No fault found.	—
12 noon	Norton Summit: no progress incoming.	Norwood repeater A relay faulty contacts.	12.25 p.m.
2.30 p.m.	Norwood: wrong numbers outgoing to Glenelg.	Junction hunters incorrectly busied.	—
2.30 p.m.	Wakefield: no progress to Gepps Cross.	1. Faulty junction North Adelaide to Prospect. 2. No rotary on incoming selector at Prospect.	—
3.30 p.m.	Franklin: drop outs dialling 51-6.	Groups selector not latching.	—
4.25 p.m.	Edwardstown: wrong numbers 53-16 final selectors.	Faulty vertical on final.	4.50 p.m.
4.30 p.m.	Brighton: No progress incoming.	No ring tone.	—
6.12.1960			
9.00 a.m.	Unley: significant increase in no progress calls to Wakefield.	Regrade in progress by installation staff.	—
9.10 a.m.	St. Marys incoming 3rd selector stuck on 4th level.	Two 4th selectors stopping on busy trunks causing no release on 3rd selector.	—
9.45 a.m.	Woodville: faulty final 45-24.	Floating vertical on final selector.	11.00 a.m.
10.20 a.m.	West Adelaide: 57-8 4th selectors faulty vertical.	Two group selectors with faulty verticals.	—
1.45 p.m.	Croydon: no progress to Glenunga.	Incoming 2nd selector dropping out at Unley.	—
3.30 p.m.	Norwood: no progress to Paradise.	Switch with no release.	—
4.05 p.m.	Wakefield: no progress dialling 8-45 numbers.	No ring tone on final selector.	—
4.50 p.m.	Wakefield: wrong numbers from the 8-4 unit.	1. Faulty vertical on group selector. 2. Group selector with slow release.	
5.30 p.m.	Wakefield: no progress to Woodville from 8-6 and 8-7.	Group selector at Woodville with release link missing.	6.10 p.m.

* See page 502.

The first category, Non-Technical Assistance, is a non-engineering responsibility and outside the scope of this article. Repair has always been dealt with by referring details of such complaints to engineering staff for follow-up attention but, in the past, this was not done for Technical Assistance. These complaints were generally handled by obtaining the required number for the calling subscriber or re-establishing the interrupted conversation, but there corrective action stopped. It was argued that such service interruptions could be due to any number of reasons, and as they could occur at points scattered throughout the network, it would be quite impossible to locate them. Further, it was contended, the reliability of information supplied by subscribers was open to question and could not be used as a basis for remedial action.

CARGO has convincingly demonstrated that subscribers' complaints can pinpoint trouble spots in the network, in many cases, faster than by conventional fault-finding methods. It does not rely on individual subscriber's complaints but on the cumulative effect of several complaints which in conjunction with a graphical method of plotting the probable path of the call, indicates the location of the equipment failure by a "fault pattern". Thus, on the basis of information previously discarded as of little or no value, service staffs now have a rapid fault-finding system which not only watches the operation of individual exchanges but of the network as a whole. Let us now look at how CARGO was developed.

THE ADELAIDE EXPERIMENT

In September, 1960, the complaints traffic of five Adelaide exchanges was diverted so that it could all be handled at the one point. This was the Service (Complaints) Desk located in Franklin Exchange which then handled subscribers' complaints from the two city main exchanges Franklin and Wakefield and from three suburban branch exchanges, Edwardstown, Henley Beach and West Adelaide, a total of about 30,000 subscribers or roughly a third of the Adelaide network. It was considered that this should be a big enough sample for the purpose and on this basis, an experiment was initiated to determine whether suitable analysis procedures could be devised to obtain useful information from subscribers' complaints which could be used for fault tracing purposes or as an indicator in connection with the qualitative maintenance of exchange equipment.

With only limited previous analysis experience to form a guide, it was decided to split the complaints up into 14 categories and, in each of these classifications, to see how many complaints originated from each 1000-line group of subscribers in each of the five exchanges. This form of analysis was readily achieved using I.B.M. punched cards which on processing, enabled a plot in bar-graph form to be made of the daily total of each type of complaint against the 1000-line originating subscriber groups. After continuing this process for three weeks, it became apparent that no pattern of any sort was developing, meaning in effect that complaints or their associated equipment troubles are not directly related to the points from which the calls originated. A review of the manner in which calls were likely to fail and give rise to complaints therefore became necessary.

The reasoning leading up to the graphical analysis method took the following form. Imagine the process of establishing a call in which successive trains of impulses originating from the calling subscriber's dial set up succes-

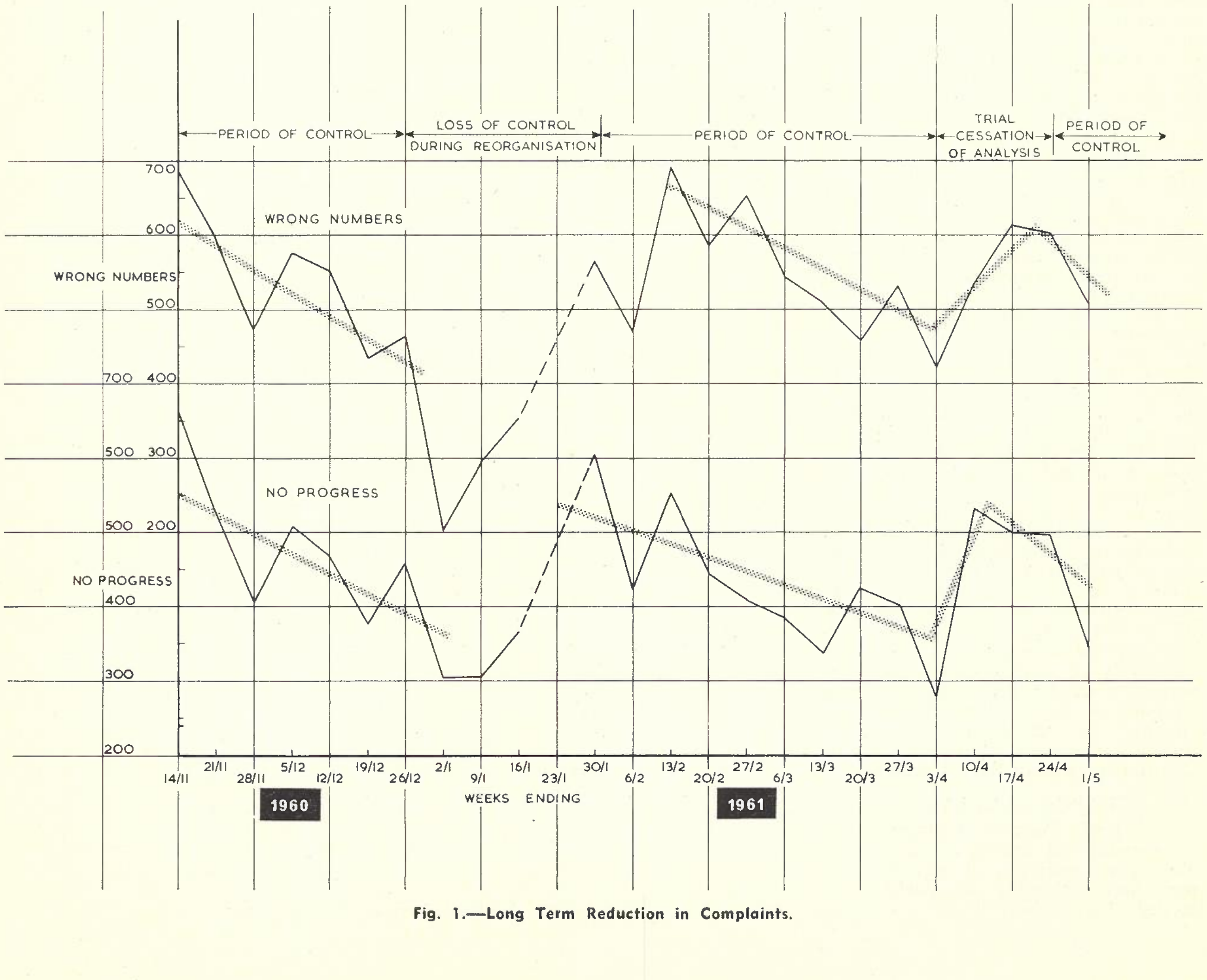

Fig. 1.—Long Term Reduction in Complaints.

sive switching stages which then repeat subsequent impulse trains. A failure can be visualized as occurring when one of these stages fails to correctly pass on the next impulse train, or the next point in the network fails to receive it correctly. Whichever is the case, it can be seen clearly that the reason for a call failure is more likely to be related to a switching stage along the path of the call than to the point from which it had originated. In other words, what the analysis procedure had to do was to trace the whole path of the call to pick up the point of failure, and not just to look at the point of origin as had been done up till then.

Having got the ideas clear on the objective, it was not so hard to devise a graph which would show the complete path of calls which had given rise to complaints. Four complaints categories were plotted, No Progress, Wrong Number, Busy Tone While Dialling and Cut-off While Speaking, and in doing so, the first patterns or grouping of complaints associated with a common fault condition were obtained.

However, at this stage, complaints were being analysed from only one-third of the network so that the picture was by no means complete. To get the full picture, it was decided to extend the analysis to include all complaints being lodged in the network in the four categories shown above. The full-scale analysis commenced on 7th November, 1960, and immediately began to indicate the localities of fault conditions in the network which were giving rise to complaints from subscribers. The analysis results were passed directly to the exchange concerned which subsequently advised the analyser of the results of its investigation. Table I shows a typical record of fault patterns recognised by the analyser together with the faults actually found. The wide variety of faults detected should be noted.

Fig. 1 shows the long-term reduction in No Progress and Wrong Number complaints brought about by analysis. The downward trend in complaints during the periods in which the analyser was active can be clearly seen. The sudden drop and subsequent upswing during the period 26/12/1960 to 30/1/1961 resulted from the Christmas-New Year holiday fall-off in business activity followed by a loss of control while complaints categories were being re-organised and the system stabilised again. The increase during the period 3/4/1961 to 24/4/1961 resulted from a deliberate cessation of complaints analysis to test the extent to which the analysis procedures were lowering the level of complaints, and the ability of normal fault-finding techniques to cope with faults previously pin-pointed by analysis. The rapid upswing in complaints during this period was a clear justification for the retention of the analysis procedures.

GRAPHICAL ANALYSIS

Basic Form of Plotting

As mentioned previously, a graph or plotting diagram was devised on which the whole path of a call could be recorded. Fig. 2 shows the original form which consisted of three main areas designated:

(a) Originating Exchanges (used for recording the point of origin of a call).

(b) Terminating Exchanges (used for recording the point of termination of the call).

(c) Traffic Route Squares (representing the path traversed by the call between the points of origin and termination.

The three areas were divided up into squares, which in the case of (a) and (b) represented particular exchanges, identified by their prefixes and arranged with the main exchanges alongside the area (c) boundary and their associated branch exchanges adjacent to them. For example, the Unley main exchange is represented by the square designated with its prefix 71 and its branch exchanges 76, 78, 79 and 7829 are located adjacent to it. The unusual grouping and the branches associated with 4 and 46 in the Terminating Exchange area are correct and represent the trunking arrangements peculiar to this group of exchanges for incoming calls. Area (c) was divided similarly into squares, each representing the path between the two main exchanges opposite two of its sides, for example the square shown enlarged indicates conditions existing on junctions between 51 and 46. It will be seen that horizontal rows running through the Originating Exchange and Traffic Route areas give a complete picture of outgoing conditions from the particular main exchange and its associated branch exchanges. Similarly, the vertical columns running down through the Traffic Route into the Terminating Exchange area give a complete picture of incoming conditions to the associated main and branch exchanges.

Each individual square was divided into ten columns to represent a fortnightly period (Saturday and Sunday combined with Friday). Complaints were each plotted in three areas to show the point of origin, the point of termination and the Traffic Route path, by inserting strokes in the particular day's column to form a simple bar graph as shown in the enlargement in Fig. 2. By watching for an excessive build up of complaints in any particular square, the analyser was able to recognise the existence of a fault condition and initiate corrective action in the exchange concerned. The methods of interpreting the complaints information will be dealt with presently.

Plotting Diagram: First Modification

As more use was made of the complaints analysis technique, the need for refinements quickly became apparent. For instance, it was discovered that trends could be recognised and faults diagnosed more readily if the analyser could keep abreast of complaints as they were being lodged. This led to details of complaints in the categories analysed, being telephoned in from the suburban Service Centres several times each day instead of being delivered once a day as was arranged initially. Apart from reducing the time between regis-

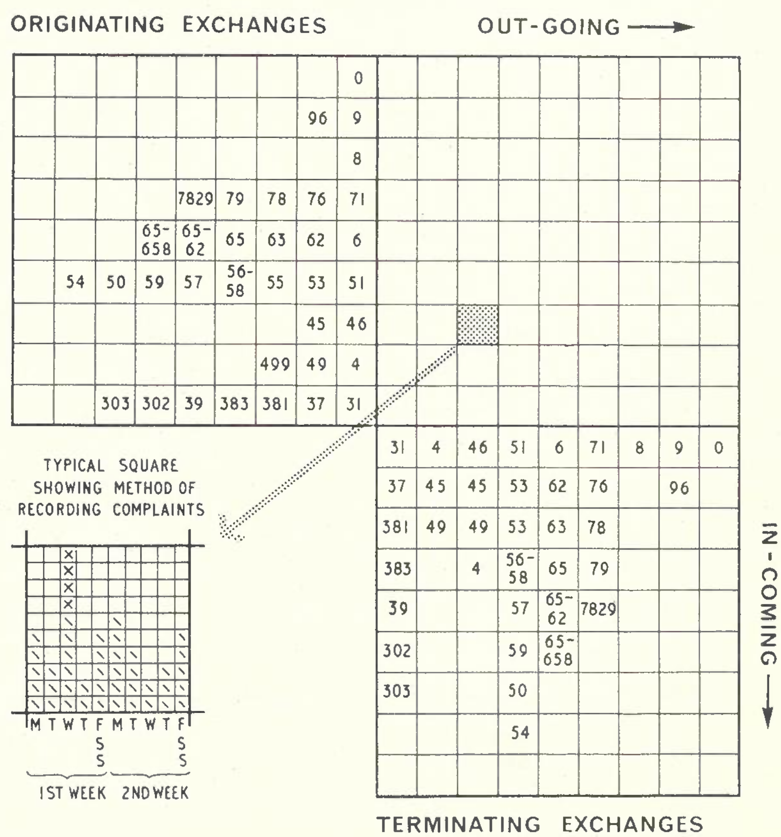

Fig. 2.—Basic Form of Plotting Diagram.

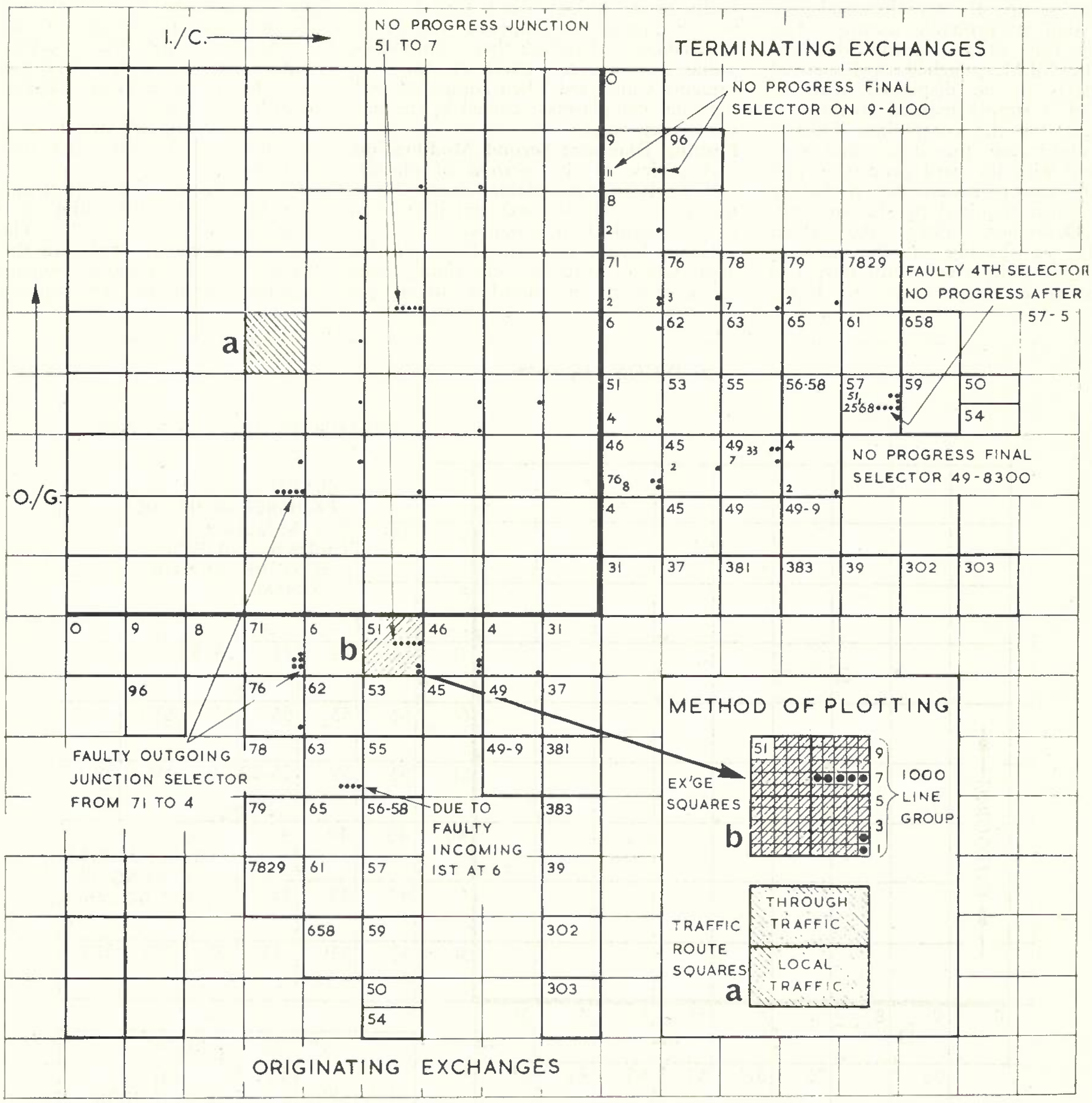

Fig. 3.—Typical Plotting Diagram—No Progress.

tering complaints and the initiation of corrective action, the more rapid plotting procedure also provided a positive check on the effectiveness of remedial measures. In some cases, it was found that a fault attended to and thought to be giving rise to complaints was not the cause at all and further investigation was necessary before the real cause was finally tracked down and eliminated.

In conjunction with the more frequent plotting of complaints details, it was also found convenient to introduce a further refinement. By changing from a fortnightly to a daily plot, it became possible to utilize the ten columns in each of the Originating and Terminating Exchange squares to represent 1000-line groups of subscribers' lines. This meant that complaints could not only be associated with a particular exchange but also with a particular part of that exchange, for example, large group finals. Figs. 3 and 4 show typical plotting diagrams at this stage of development. It will be noted that the whole graph has been rotated through 90 degrees for added convenience in plotting, and Local and Through Traffic have been separated in the Traffic Route Squares.

The graph in this form was becoming, in effect, an extended "memory" for the analyser by providing an up-to-date fault picture of the network and by indicating those particular complaints dockets which would justify a closer scrutiny. Such a check back, supplemented by his own knowledge of conditions at each exchange, for example, type of equipment, grading, etc., enabled him to diagnose the likely cause of a

TABLE 2 — Reduction in Analysed Complaints Categories.

Week Ending	Total Complaints Received	Complaints Received in Analysed Categories	% of Total
14.11.1960	13,276	2,365	18
21.11.1960	12,799	1,950	15
28.11.1960	11,648	1,517	13
5.12.1960	13,489	1,852	14
12.12.1960	13,480	1,642	12
19.12.1960	13,799	1,430	10
26.12.1960	13,759	1,478	11

particular group of complaints and give Service staff its probable location. The changing role of the graph also enabled the I.B.M. punched card method of analysis to be dispensed with in favour of a simple manual sorting arrangement for the complaints dockets, which eliminated the delay and cost associated with the card processing and provided easier access to particular dockets when required by the analyser.

By December, 1960, the effect CARGO was having on the network had become quite clear. Not only was it assisting exchange staffs to locate faults more quickly, but this in turn was beginning to improve service to subscribers and reduce their complaints. Table 2 shows the effect on the four categories analysed when compared with the total complaints received in the network each week.

Plotting Diagram: Second Modification. A review of the method of plotting and analysing complaints currently in use at this time showed that it suffered from several disadvantages:

(a) Its layout, requiring three plotting areas whose positions were rigidly fixed in relation to one another, introduced problems in the larger networks due to the physical dimensions of the graph.

(b) The centimetre squared graph paper then in use prevented analysis of data from the Service Dockets below 1000-line groups.

(c) To obtain full details of a call, it was necessary to refer back to the relevant docket.

To overcome these disadvantages, a new form of plotting diagram was devised as shown in Fig. 5. The layout was improved by replacing the Traffic Route area by a more compact Traffic Summary area and by rearringing the

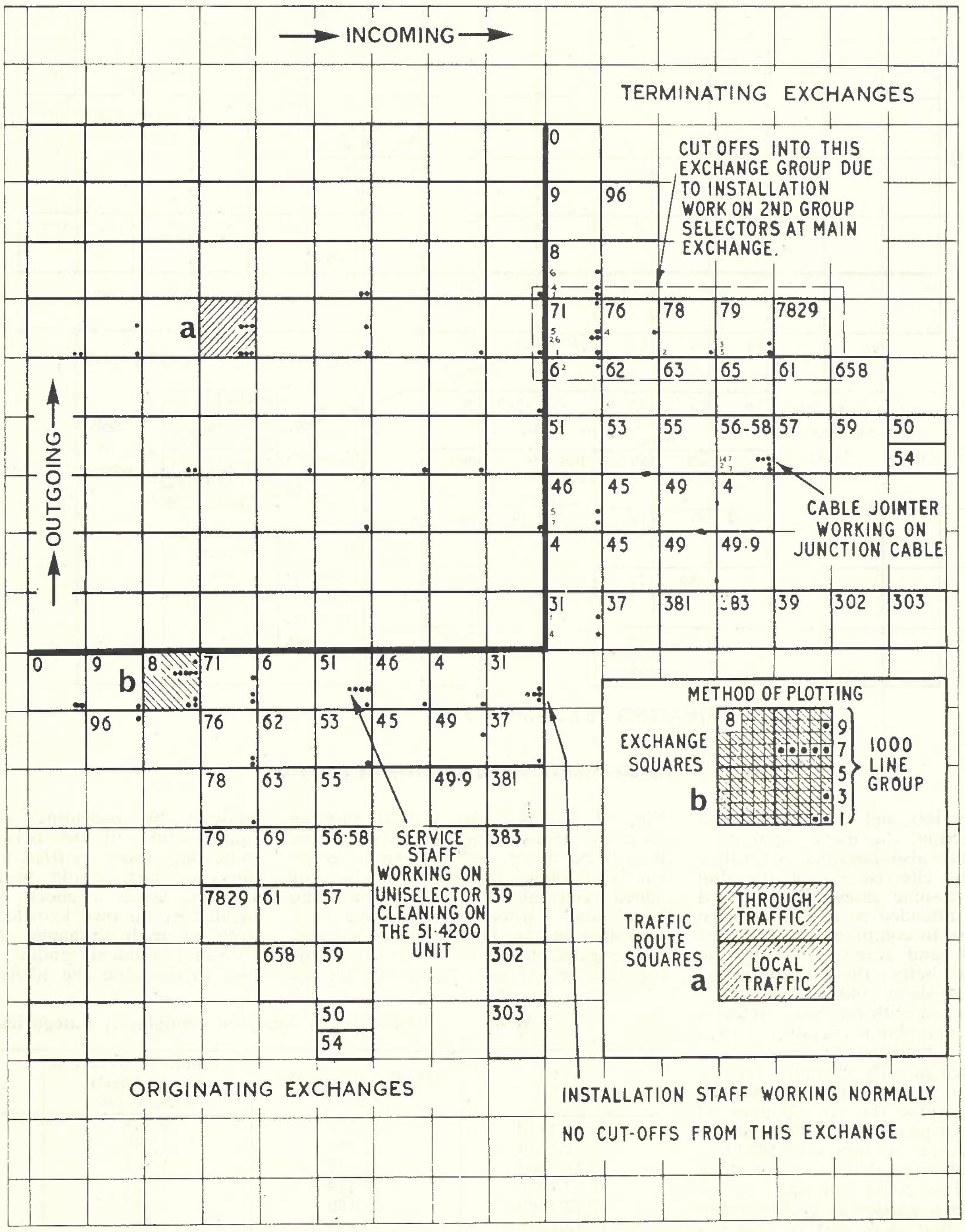

Fig. 4.—Typical Plotting Diagram—Cut-off While Speaking.

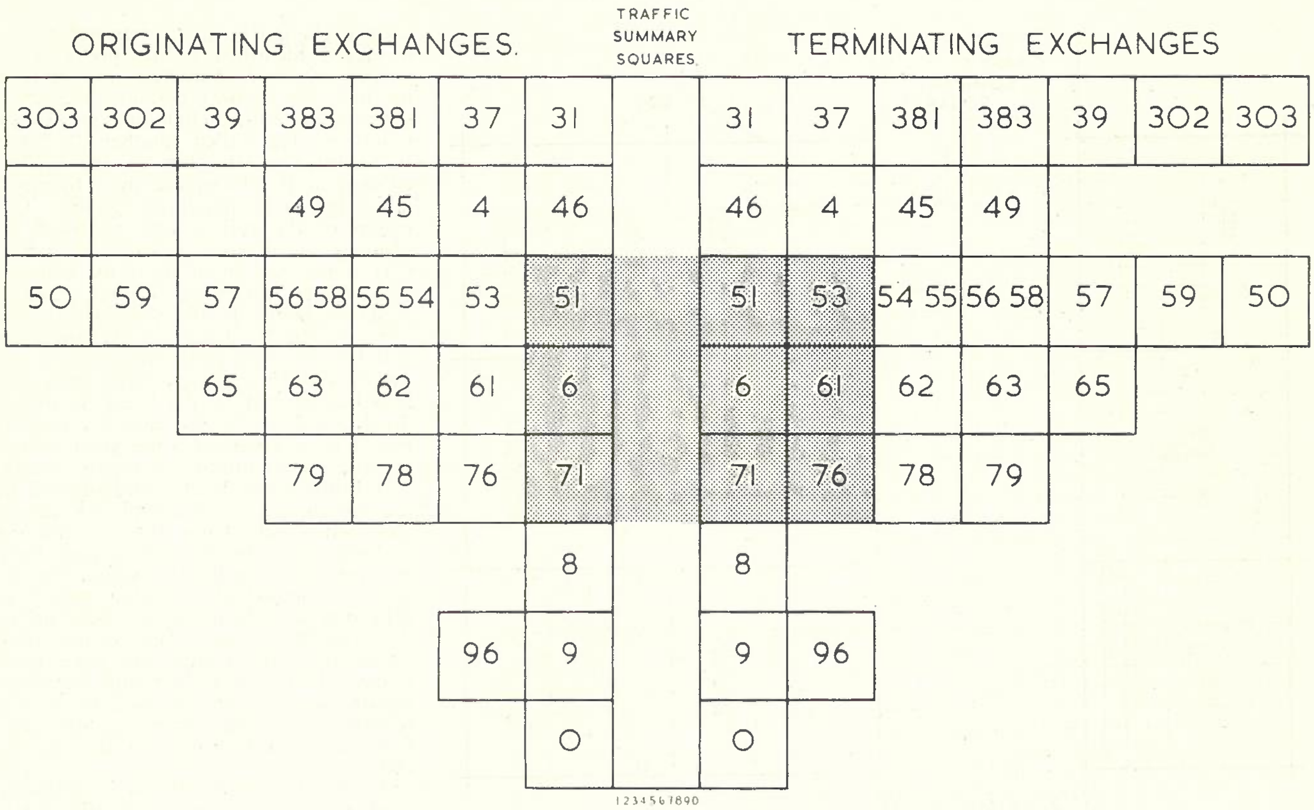

Fig. 5.—Revised Form of Plotting Diagram.

location of the Originating and Terminating Exchange areas. The basic principles associated with the earlier graphs were still retained but by using inch squared paper, it now became possible, within reasonable physical dimensions, to plot complaints data down to 100-line groups. In conjunction with suitably chosen code symbols all essential data associated with a complaint could be recorded on the graph and was immediately available for appraisal during the analysis of a particular fault pattern. This saved the time previously expended in referring back to the original complaints dockets.

At first sight, the recording of more and more information in ever-increasing detail on the plotting diagram, would appear likely to confuse the picture presented. In practice, this was not the case due to the use of "restricted plotting" by which is meant that instead of plotting every complaint in the three areas of the graph as was practised in the early stages of complaints analysis, undue cluttering up the graph was avoided by plotting them only where the information was likely to be significant. For example, if an inspection of the complaints docket definitely indicates that a wrong number is due to a final selector failure, there is nothing to be gained by inserting plots for the originating exchange or in the Traffic Summary area, and so plotting can be restricted to the Terminating Exchange area only. Other instances where restricted plotting can be applied, such as a drop-out during dialling, are also found.

INTERPRETATION OF COMPLAINTS

Before moving on to describe the plotting procedure in detail, it is well to look again at the analysis process to see clearly the respective functions of the graph and the analyser. The prime purpose of the graph or plotting diagram is to show the build-up of complaints in the form of a "pattern" indicating the probable existence of a fault condition. In the earlier graphs, the analyser had to refer back to the original complaints dockets; in the later graphs, all the required information was available from the diagram; but at all times, it was not the graph which pin-pointed the trouble area but the analyser's ability to interpret the available information.

This interpretive ability is the keystone of complaints analysis and largely determines the success the system is likely to achieve in a given network. Actually the interpretation and analysis of limited information as a means of deducing probable fault locations is nothing new and has been practised by exchange staffs for many years. The difference with CARGO is that this is the first time that all available information has been concentrated at one location and an attempt made to process and analyse it in a systematic manner. Further, by permitting the analyser to devote the whole of his time to these duties, he has been able to build up by constant daily practice, a fund of specialised knowledge and experience which other service staff could not hope to acquire in conjunction with their normal duties. The net effect is an operational efficiency expressed in terms of the number of faults found compared with the number of patterns recognized of the order of 80-85% based on handling an average of 17 patterns per day (network approximately 90,000 subscribers).

Turning now to the actual process of interpreting complaints, let us look at a few examples to illustrate the manner in which the analyser recognizes the existence of a probable fault condition:

(a) 71-8654 calls 54-2345 and gets 53-2345. In isolation, this could be attributed to a subscriber's dialling error. On the other hand, it might also be due to a faulty incoming second selector losing one impulse in the train. Confirmation of the existence of this fault condition would be obtained by a subsequent Wrong Number or several No Progress complaints associated with calls following the same path.

(b) 60-5624 calling 60-1813 and getting a trunk operator (018). This is a clear instance of a first selector drop-out in which the first train of impulses was lost and the switch responded correctly to the remainder. Not so easy to recognize is the above call reaching an ELSA operator (7181) in which the first selector in dropping out has mutilated the second train of impulses. Another instance of a drop-out is a call to 92-4001 reaching a service desk (9200) and indicating a faulty incoming third selector.

(c) Faulty final selectors can be readily recognized from Wrong Number complaints of the type, a call to

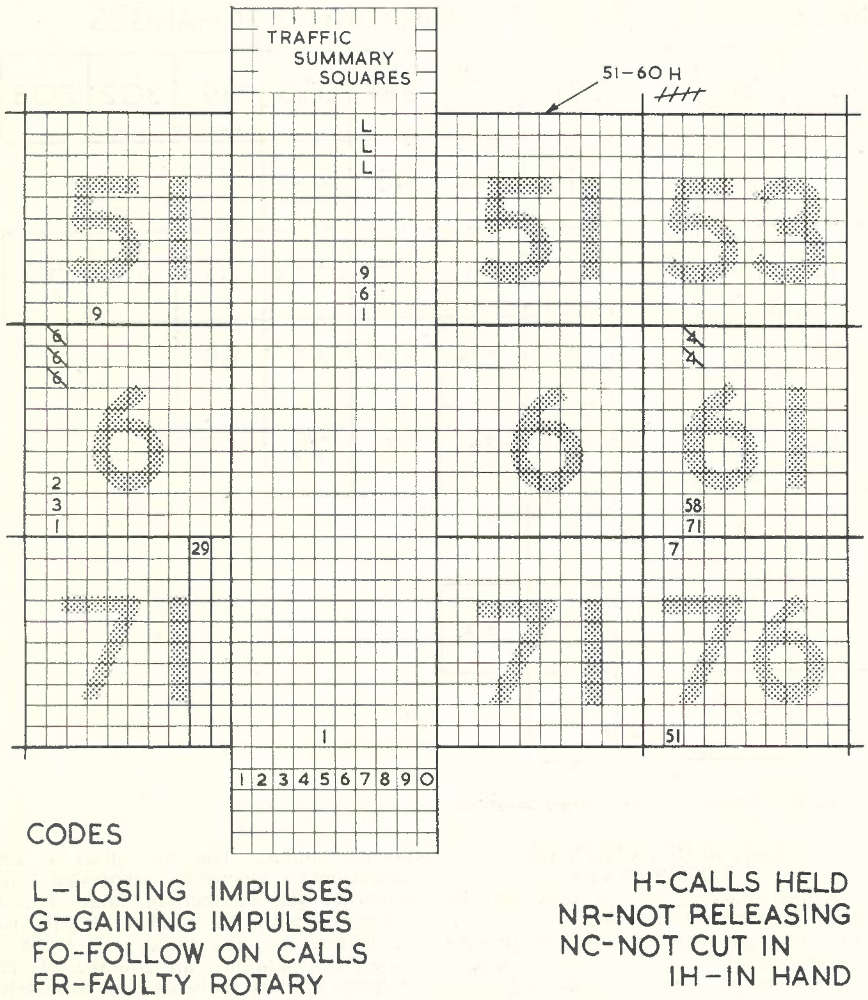

Fig. 6.—Plotting Procedure in Detail.

54-2345 gets 54-2335 followed by a call to 54-2368 gets 54-2358. A not so obvious indication of this condition would be two no-progress complaints concerning calls to 61-3472 and 61-3468 respectively.

The foregoing examples give some insight into the skills needed by the analyser, involving detailed knowledge not only of equipment characteristics, adjustments and fault conditions, but also the types of equipment installed at particular exchanges as well as trunking and grading arrangements. It can also be seen how the association together of calls following the same path, or having the same fault characteristics can change information having the appearance of random subscriber's errors into valuable fault location data. The function of associating together complaints having common paths or fault characteristics belongs to the plotting diagram, and typical fault conditions are illustrated in Fig. 6.

DETAILED PLOTTING PROCEDURE

The method of recording the complete path of a particular call on the new graph (ignoring restricted plotting for the moment) is illustrated in Fig. 6, which shows an enlargement of a small area of the full plotting diagram (Fig. 5).

Consider a call originating from subscriber 51-4932 and terminating on 76-2784. In the Originating Exchange area, each exchange is represented by a square identified by its prefix overwritten in large characters and divided up into ten vertical columns each representing a 1000-line group of numbers. 51-4932 is recorded in the 51 square by a 9 inserted in the fourth column.

In the Traffic Summary area, each square is associated with the adjacent Terminating Exchange area and is used to show the number and origin of calls incoming to that particular group of exchanges. Each square is divided up into ten vertical columns each associated with the originating group of exchanges whose prefix commences with the number of the column. In the example, the origin of the call (exchange 51) is recorded in the square opposite the row in which the terminating exchange (76) is located by the insertion of a figure 1 in the fifth column.

In the Terminating Exchange area, each exchange is again represented by a square identified by its prefix overwritten in large characters and divided up into ten vertical columns to represent the individual 1000-line groups of numbers. The called number (76-2784) is recorded at the top of the second column of the 76 square by a figure 7, indicating the hundreds group. The origin of the call is also recorded by showing the originating exchange prefix (51) at the bottom of the same column.

A faulty incoming second selector is shown in the Traffic Summary square opposite the '5' group of exchanges. It will be seen that calls originating from 71, 76 and 79 exchanges have each lost impulses (shown by the letter 'L' above the 1, 6 and 9). In this case, the recording of three complaints has given ample justification to initiate corrective action.

A faulty final selector is indicated in the '61' square where complaints associated with calls from the 71 and 58 exchanges to the 61-3400 group have been recorded. In the '51' square can be seen the method of recording ineffective calls due to a final selector held up in the 51-6000 group. The stroke tally shows that five complaints have been lodged. In the '6' Originating Exchange square can be seen recorded three first selector drop-outs occurring on calls from the 6-2000 group to the '6' exchange.

At the bottom of Fig. 6 is a list of other code letters used to identify other recognized fault conditions.

CONCLUSION.

The present article has been confined to the complaints analysis and fault finding aspects of CARGO. While the results of investigations in these areas have yielded valuable returns, they comprise only a small part of the benefits which have arisen directly as a result of the Adelaide experiment. Such developments as the stroke-classification method of recording complaints, transmission of complaints information by teleprinter, the remote preparation of fault dockets and the statistical analysis of complaints to provide exchange performance indicators, to mention a few, also had their origins at Adelaide and in view of their importance in present-day maintenance practices, their development will be dealt with in a later article.

ACKNOWLEDGEMENT

The development of CARGO since its inception in September, 1960, has been an outstanding example of co-operation between exchange staffs, Service engineers of both State and Central Administrations, and officers of the Telecommunications Division, and it is therefore impossible to mention by name all who assisted in its development. There is one exception, however, this being Mr. John Kell, who undertook the onerous plotting and analysis duties at the beginning of the experiment and who has continued in this position up to the present time. Without his patience and skill in analysing complaints and improving plotting methods, CARGO might not yet have reached its present stage of refinement.

NUMBERING FOR THE WORLD-WIDE AUTOMATIC TELEPHONE SYSTEM

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INTRODUCTION

Spectacular advances in new fields of technology capture the public imagination and tend to divert attention from the great growth and development in established fields. In telephony not only has there been tremendous growth with, for example, the number of telephones in the world increasing from 70,000,000 in 1950 to 133,000,000 in 1960, but also rapid mechanisation has occurred, bringing new concepts in speed and range of connections. Local automatic service, first envisaged in 1892, is now the normal form of service, nationwide automatic systems are being planned and implemented, and preparations are being made for world-wide automatic operation.

In the last issue of this Journal, an article (1) by Mr. Sawkins outlined the current activities of the International Telecommunication Union in the planning of world-wide Telecommunications. It summarised the progress made so far in planning for world-wide automatic telephony since a Special Committee was established in 1960 to co-ordinate the Study Group activities in this work. This article deals in more detail with numbering in the world system. It includes the proposals which have resulted from the work of Study Group XIII and which have been referred to Administrations for consideration. The proposals will receive final joint review by Study Group XIII and the Plan Committee in 1963 before recommendation to the next Plenary meeting of the C.C.I.T.T. at Moscow in 1964.

* See Vol. 12, No. 4, page 297.

GENERAL CONSIDERATIONS

The numbering plan for any automatic telephone system must be designed to serve two main purposes. Firstly, it must provide the basis for the directory information to enable any caller to establish connections to other stations in the system. Secondly, it must provide information in the digital form required by the automatic switching equipment to carry out its functions of setting up the connection to the wanted station and of applying the appropriate charge.

The directory information must be as simple as possible to understand and to use so that the automatic system is attractive to subscribers and also to avoid unproductive usage of expensive plant due to inaccurate dialling. Experience in national system planning has shown that this requirement is best met by:

(i) The use of closed (linked) numbering. In this form of numbering each station has a unique number which is dialled in calling that station from any other location in the system.

(ii) Keeping telephone numbers as short as possible consistent with providing adequate capacity to enable the system to remain effectively unchanged for a long period.

(iii) The use of all numeral presentation of telephone numbers.

(iv) Keeping the number of separate dialling procedures to a minimum.

So far as equipment design is concerned there is the additional requirement that:

(v) The number of digits which need to be examined for the desired complexity of switching and charging should be minimised.

These principles also stand for world system numbering. They must be applied, however, so that existing national systems and international dialling schemes can be incorporated into the world system with a minimum of modification. This raises a number of problems.

Fig. 1 shows how the designations on the dials used for national telephone service vary for different countries. It will be seen that whilst there are wide variations in the alphabetical characters appearing as dial designations, there is considerable agreement in the numeral designations. World-wide numbering based on all numeral presentation is thus the way to incorporate existing systems with minimum change. Moreover all numeral presentation is being used to an increasing extent in national systems because of the increase in usable number capacity and improved accuracy of dialling which results.

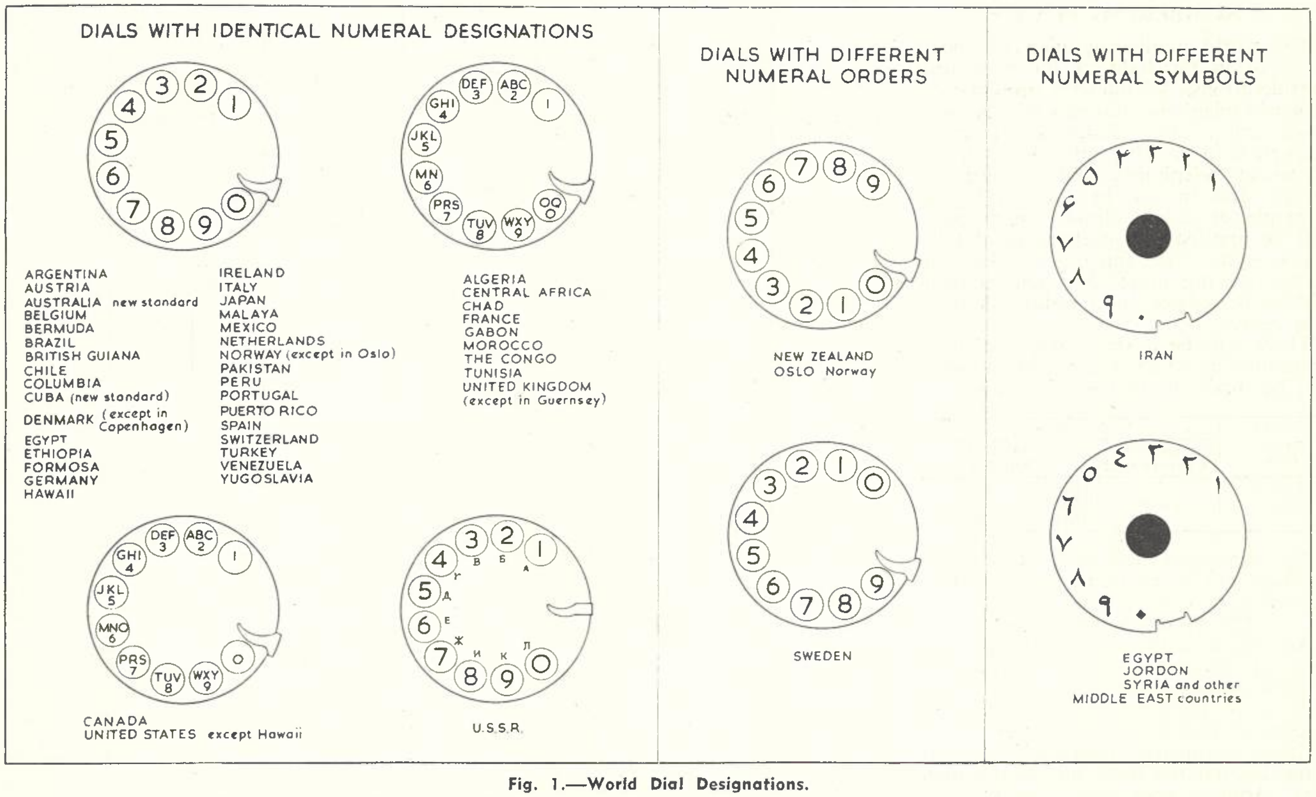

Fig. 1.—World Dial Designations.

Existing national systems also present conflicting requirements in regard to the length of world telephone numbers. Arising from the different basic methods used in the evolution of national automatic systems there is a requirement on the one hand presented for example by the vast North American system, for the number length in the world system to be kept as short as possible because of limitation of digit storage equipment associated with registers. On the other hand, there is a desire for larger numbers from countries such as Germany and Austria where in-dialling to private exchanges is prevalent and is accomplished by adding the extension numbering onto the normal length national numbers. A compromise is therefore necessary in the world-wide system numbering.

An international dialling scheme centred on Europe is already being implemented. This was devised at a time when the availability of large numbers of intercontinental circuits seemed no more than a long-term possibility and techniques for mechanisation of systems were less advanced. In this scheme, each of the separate nations in Europe and the Mediterranean Basin was designated by a two digit code (see Volume VI of the C.C.I.T.T. Red Book, Page 29). The world numbering plan can retain the codes for many of the larger countries but such liberal use of the numbering spectrum cannot be allowed for the smaller telephone systems, such as those of Luxemburg and Gibraltar, and these will be re-designated with three digit codes.

THE PROPOSED WORLD NUMBERING PLAN.

The world numbering plan has been prepared in the light of the preceding considerations. All numeral presentation of world telephone numbers will be used based on a dial designated from 1 through 9 to 0. This suits the majority of world telephones and corresponds to the dial in use in Australia. The principle of closed (linked) numbering will be applied and each national telephone system or integrated telephone system serving more than one country will be designated by a unique destination code.

There will be a single world dialling procedure in which the world numbers will be made up in the following way:

World Access Code	World Number	
	Continental or Country Code	National Number
2 or 3 digits	1 digit	Max. of 10 digits
	2 digits	Max. of 9 digits
	3 digits	Max. of 8 digits

The maximum length of the world numbers will be 11 digits, but 12 will be permitted in certain cases.

The World Access Code

An access code is required for each level of automatic network operation. Within national systems a trunk access code, 0 in the case of the Australian system, is dialled to gain access to the national automatic network for calls going beyond the local numbering plan area. Another code must now be allocated to allow access to the world system. It is not proposed to standardise this code. Uniformity would be the ideal but would be very difficult to achieve because of the different and heavy commitment of suitable codes in the various countries. There is not a great disadvantage, however, in the use of codes with different digits or of different length.

In Australia a three digit code, possibly 016, will be used as the access code.

The World Number

A subscriber's world number consisting of the continental or country code plus the subscriber's national number would be unique and would be dialled to call that subscriber from any other country in the world.

A boundary condition proposed is that the world number would not exceed 12 digits in length with the additional recommendation that, wherever practicable, Administrations should endeavour to plan their national systems so that, for 25 years or more, their world numbers will not exceed 11 digits in length. This limit is prescribed to simplify the immediate problems of world-wide operation for countries such as America where a large investment exists in switching equipment with limited storage capacity, and also to keep down as far as practicable the maximum number of digits which a subscriber will encounter in world dialling.

The two components of the world number, the continental or country code and the national number, will therefore be variable in length. For example, a country catered for adequately by an eight digit national numbering scheme could have a 3 digit country code, whilst the U.S.A. and U.S.S.R. with 10 digit national schemes would each be identified by a single digit code.

National Numbers.

The national trunk access codes will not be included in the world telephone numbers. For example, in the case of Australia the trunk access code 0, which precedes all national numbers, would be omitted.

In the proposed framework, the maximum length of normal national numbers (excluding the access code) which are to be accessible directly from all

TABLE 1.—NATIONAL NUMBERING IN THE WORLD'S LARGEST SYSTEMS.

Country	Number of Digits in National Numbers			Telephone Development		Country or Continental Code Allotted
	National Number (excl. access code)	Area Code	Local Number	Existing at 1960	Estimated at 2000 AD	
U.S.A. and Canada	10	3	7	76,240,000	250,000,000	1
Japan	9 max.	1	8 max.	4,865,000	40,000,000	81
	,,	2	7 ,,			
	,,	3	6 ,,			
	,,	4	5 ,,			
France	8	1	7	4,085,000	12-15,000,000	33
	8	2	6			
Australia	8 max.	1	7 max.	2,164,000	15,000,000	61
	8 ,,	2	6 ,,			
	8 ,,	3	5 ,,			
		and in exceptional cases				
	8 max.	4	4 max.			
	8 ,,	5	3 ,,			
West Germany	Up to 14 digits	3 or 4 or in exceptional cases 6	2 to 10 including digits for P.B.X. extensions	5,516,000	18-20,000,000	49
Britain	8	1	7	7,848,000	17,000,000	44
	9	2	7			
	9	3	6			
	8	3	5			
	9	4	5			
	7	3	4			
	9	5	4			
	7	4	3			
	8	5	3			
U.S.S.R.	10	3	7	4,023,000	200,000,000	7
Italy	8 max.	1	7 max.	3,518,000	12,000,000	39
	8 ,,	2	6 ,,			
	8 ,,	3	5 ,,			
Sweden	8	1	7	2,637,000	4,000,000	46
	7	1	6			
	6	1	5			
	8	2	6			
	7	2	5			
	8	3	5			

countries will be governed by the number of digits in the code allotted to the particular country and the condition that the world number is not to exceed 12 digits in length. It should be noted, however, that this condition does not preclude the use of larger numbers for purely national use. For example, some countries may prefer to number general extensions on P.A.B.X.'s accessible by in-dialling, with numbers longer than normal network numbers whilst meeting the number length requirement for the manual board and for selected extensions which are to be directly accessible from the world system.

Table 1 shows the maximum number lengths in use and planned in a number of the larger national telephone systems. It includes examples of three philosophies on national number length — the American approach which aims at gaining a constant length of national number, another of which Australia is typical which envisages varying number lengths but with a maximum length stipulated, and a third group of which Germany is an example which has not specified a number length limitation. This latter group contains the cases which will not meet the world system number length criterion for all telephones. However, when the subscribers development potential indicated in Table 1 for these countries is weighed against the fact that a uniform 10 digit scheme gives a theoretical capacity for 10^{10} numbers and a practical capacity in the range 100-1000 million numbers, it will be realised that the majority of numbers in these countries will be of suitable length and that adequate capacity would be available for gradual inclusion of the remainder, if this were desired.

Whilst endeavours should always be made to keep the maximum number length as low as possible from the viewpoint of subscriber usage, all new national equipment and certainly all world network switching equipment should be designed with storage capacity in excess of the limit so that the limitation from an equipment viewpoint will be a temporary one.

The Continental or Country Codes

Study Group XIII has tentatively allocated, for all countries, codes based on their system number potential at the year 2000 A.D. The codes have been arranged so that the first digits define continents or broad regions of the world, with one first digit being kept spare to cater for unforeseen developments in any particular region. The areas defined are:

Digit		Area
1	—	North America
2	—	Africa
3 & 4	—	Europe
5	—	South America
6	—	South East Asia
7	—	U.S.S.R.
8	—	Asia
9	—	India, Pakistan and Asia Minor
0	—	Spare.

By alloting the first digits in this way some simplification will be gained in the design of the automatic switching and charging equipment. A geographical association in the codes will also act as a memory aid for subscribers in their use of world numbers.

The allocation of digits 3 and 4 to Europe enables 17 of the European countries to retain two digit codes with 7 of the codes being the same as in the existing European dialling scheme. One or two digit codes have been allotted to countries with special conditions of size or development potential. Those for the larger system are shown in the last column of Table 1. Sufficient numbering capacity has been available to provide all other countries with three digit codes.

The country code allotted to Australia is 61. Typical world numbers for Australian subscribers would therefore be:

for Melbourne subscriber 630 7555
61 3 630 7555
for Perth subscriber 25 4444
61 92 25 4444

IMPLEMENTATION OF THE SCHEME

As indicated in Reference 1, the technical means of providing the world-wide automatic system are already available. National systems are being mechanised rapidly, generally in forms suitable for inclusion, with little change, in the world system. Suitable switching and signalling systems and large capacity submarine cable systems are available, and the feasibility of satellite communications systems has now been proved as a means of providing the numbers of circuits required in an automatic network. The world numbering scheme will be implemented progressively. A number of the codes are already in use in the existing European scheme and the rearrangement of this scheme to conform exactly to the world numbering does not appear to be a very formidable task. The Commonwealth cable system which is scheduled for completion in 1963 will make use of the relevant codes from the world numbering as will all new international communication projects.

Within the next few years, therefore, Australian telephonists will be using direct dialling with world telephone numbers to reach subscribers in New Zealand, Canada, U.S.A., Britain and, through Britain, Europe. The world numbers of Australian subscribers will also be operative and will be dialled directly from these countries. During the next decade development should be rapid and semi-automatic operation using the world numbering scheme should become widespread in the world system. It is possible that within this time subscribers will dial world numbers directly on some routes.

REFERENCE

(1) E. Sawkins, "World Automatic Telephone Network"; Telecommunication Journal of Australia, Vol. 13, No. 5, page 363.

TECHNICAL NEWS ITEM

LARE INCREASE IN CHRISTMAS TELEPHONE CALLS THROUGH COMPAC

Figures released from the Overseas Telecommunications Commission show a marked increase in telephone and telegram traffic, over the Christmas period, between Australia, New Zealand and Fiji, through the first two stages of the new Commonwealth Pacific Cable (COMPAC). Over three days at Christmas, December 24, 25 and 26, 1977 telephone calls were made between Australia and New Zealand, against 792 calls for the same period in 1961, an increase of 1185 calls or a 150 per cent rise.

Public telegraph traffic between December 18th and 25th, also showed an increase; a total of 110,089 messages were sent and received via the new cable, against 98,647 messages for the same period in 1961, an increase of 11,647 messages or a 12 per cent rise.

THE AUSTRALIAN OUTPOST RADIO COMMUNICATION SYSTEM

*L. F. PEARSON**

INTRODUCTION

This article gives an outline of the communications system provided by low powered high frequency radiotelephone between control stations at inland centres served by the landline telegraph and telephone networks, and outpost stations in remote undeveloped areas of the Commonwealth of Australia which are not so served.

The system was introduced primarily to enable the provision of medical aid and advice to residents in isolated localities where doctors and hospitals are not readily available. It also permits exchange of messages with all other centres in Australia and elsewhere in the form of telegrams passed over the public landline telegraph network, enables conversations between neighbouring isolated settlers, provides supplementary educational facilities to children in small remote communities where schools cannot be established economically, facilitates collection of meteorological data, is helpful in reporting movements of aircraft on off-route flights, and plays an important role in search and rescue operations over the vast uninhabitated regions involved.

Information is given concerning the types of equipment employed at both base and outpost stations, methods of working, and traffic statistics. Fig. 1 shows the areas served, together with location of control and associated outpost stations.

ORIGIN AND HISTORY

Following experiments using high frequency low-powered radio equipment, the system was inaugurated by the Australian Inland Mission in 1929, using a 200 watt transmitter based at Cloncurry, an isolated inland centre approximately 900 miles north-west of Brisbane, Queensland, which is connected into the Commonwealth's landline telegraph network. The primary purpose of the system was to provide medical aid and advice to those residing in distant outback locations where doctors were not available, where no defined roads exist and which are not provided with communication facilities of any type. Initially eight very low powered transceiver equipped "outpost" stations were set up at widely separated homesteads at distant strategic points. The base station used telephony for transmission to the outposts which employed telegraphy in reply. Because of difficulties encountered by laymen at the outstations in learning the morse code a lettered keyboard unit was developed for code transmission. Improvement in transceiver design enabled speech to be substituted for the code transmission. One of the main difficulties met with at the outpost stations was with power supply since, at that stage, household electric lighting and power was generally not obtainable in the areas concerned. To overcome this disability a foot-pedal generator was developed and was employed extensively in the early years of the service, being later replaced with battery-vibrator power supplies which are now being superseded by transistor oscillator-inverter units. Much of the radio equipment now being supplied to outstations is fully transistorised except for the final transmitter stage.

FACILITIES PROVIDED

General Communications: Control stations and outpost stations are required to transmit and receive telegrams on behalf of the general public and consequently are listed in the Post Office Guide as telegraph offices. Messages to and from telegraph offices connected to the Commonwealth landline telegraph system, overseas points, etc., are passed by radiotelephone between the base and outpost stations. No provision is made for connection of outpost stations into the landline telephone system, but these stations are permitted to freely converse among themselves on the lowest frequency channel assigned for use of the particular outpost network.

Medical Aid: Arrangements exist for discussion over the system by doctors directly with patients or those caring for them. Each outpost station is supplied with a medical kit containing bandages, commonly used drugs, etc., for which the doctor can give instructions as to use during the consultation. Where hospitalisation of the patient is essential the organisation provides for the despatch of a light aircraft to convey him to the nearest hospital. A doctor or nursing sister accompanies the pilot in such cases.

Supplementary Education—"School of the Air" Facilities: In general, properly qualified primary teachers make use of the base station facilities to communicate directly with students at outpost locations enrolled in correspondence educational courses. Lectures supplementing the correspondence material are transmitted and students have the opportunity of addressing questions to the teacher on points on which they may not be clear. Regular sessions are conducted daily.

Meteorological Information: Certain selected outpost stations provide meteorological data relating to wind direction and velocity, barometric pressures, temperatures and rainfall, etc., to the Commonwealth Meteorological Service, again in the form of telegrams.

Aircraft Movements: The service provides for reporting of aircraft movements on off-route flights in the wide area which it covers, advice as to serviceability of landing strips, etc., and has given valuable assistance in search and rescue operations in the sparsely populated regions which it serves.

TECHNICAL CONSIDERATIONS

Equipment—Base Stations

Generally available communication type transmitting equipment is used by all stations. The unmodulated radio frequency output power varies with the type of installation between 50 and 300 watts. Crystal control is used on all channels.

Receivers are crystal locked communications type superheterodynes. Some stations are equipped with alarm devices to enable them to be alerted by outpost stations in the event of contact becoming necessary in emergencies occurring outside scheduled hours.

Base stations are all served with 3 phase A.C. town power supply.

Equipment—Outpost and Portable Stations

The transmitter, modulator, receiver and power supplies are all housed on the same chassis. Transmitter output power varies with the type of unit between 3 watts and 25 watts (unmodulated radio frequency). Except for the final transmitting stage, all equipment now being supplied is fully transistorised. All transmitting channels are crystal controlled. Receivers, which are of the superheterodyne type, employ a crystal locked oscillator with pretuned aerial and radio frequency circuits. In most instances tunable reception covering medium and high frequency broadcasting bands is provided.

All outpost stations employ secondary batteries as the primary power supply, the older installations using vibrator packs and the most modern being equipped with transistor-oscillator inverters. Battery charging is from petrol driven homestead lighting generators. Some use wind driven generators.

Since both transmitting and receiving equipment is necessarily operated by unskilled personnel, special care has been taken to achieve simplicity of controls.

Special attention is given to the aerials of the outpost installations, precut half-wave systems being provided by the manufacturer with comprehensive diagrams and instructions for erection. Generally a separate aerial is used for each frequency of the network complement.

Costs for the complete outpost station installation (less aerial masts) vary between £A135 and £A250 depending on transmitter output power, number of receiving and transmitting channels, etc. These must be borne by the outpost station licensee who must also arrange for maintenance of his own equipment, units having to be returned to the base station for servicing as occasion demands.

Frequencies Employed

Three channels ranging between 1620 kc/s and 8165 kc/s are assigned to each network, a typical complement being

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* See page 501.

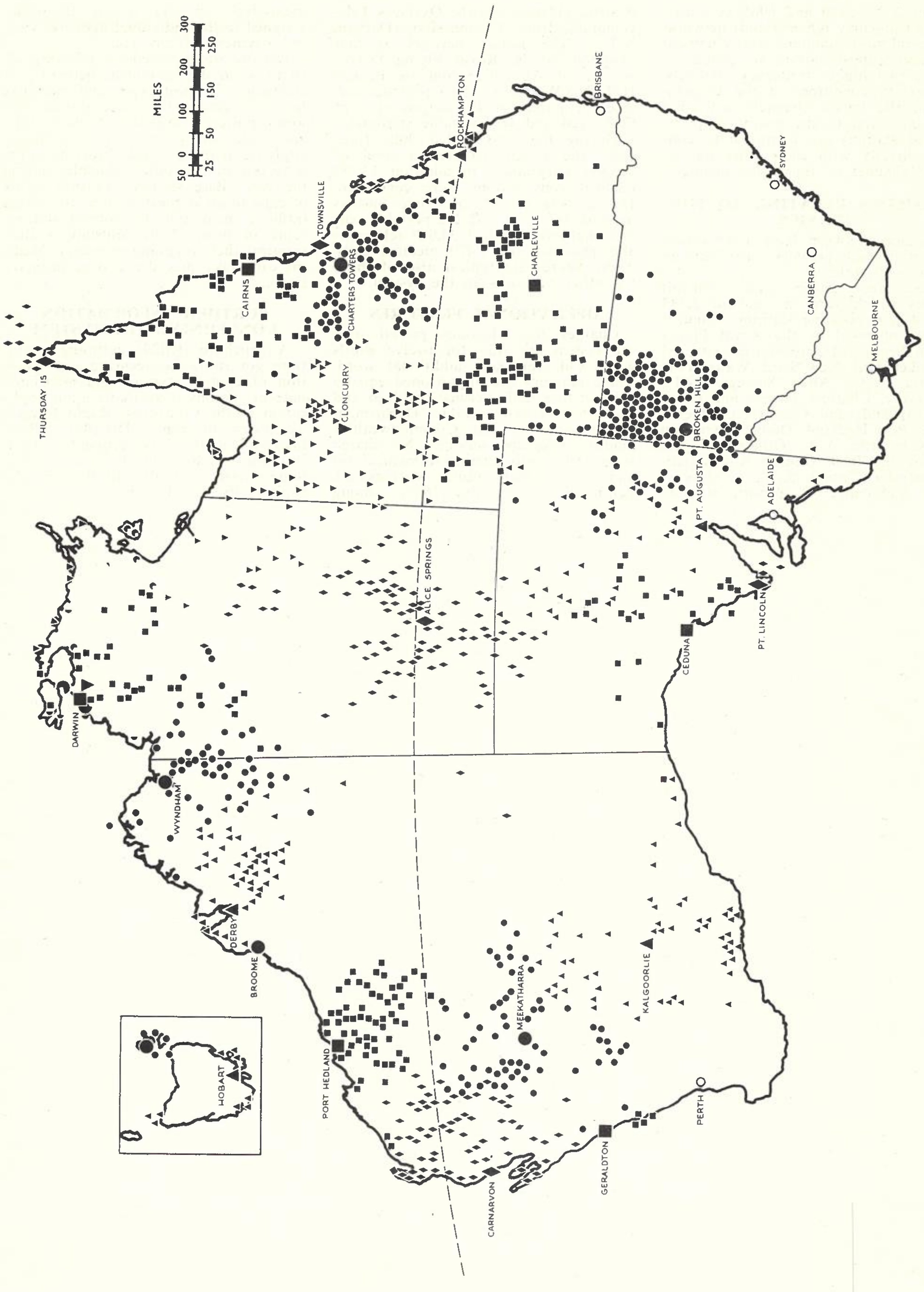

Fig. 1.—Locations of Outpost Service Stations. Control Stations and Associated Outpost Stations are denoted by identical markings.

that of 2020, 5110 and 6965 kc/s used by the Cloncurry (Queensland) network. In general most communications between base and outpost stations are conducted on the two higher frequency channels, propagation conditions at the frequencies of the lowest channels restricting communication to the nearer outposts. Outpost stations are permitted to converse directly with each other on the lowest channel of the complement.

STATISTICS RELATING TO THE SERVICE

Distances between base and outpost stations in each network vary between 10 and 600 miles.

There are sixteen base (control) stations which serve a total of 2,383 outpost and portable stations. Control stations operated by the Royal Flying Doctor Service of Australia are situated at Broken Hill, New South Wales; Port Augusta, S.A.; Alice Springs, N.T.; Charleville, Charters Towers and Cloncurry, Q'land; and Carnarvon, Meekatharra, Port Hedland, Derby, Wyndham and Kalgoorlie, W.A. Others are operated by the Bush Church Aid Society of Australia (Ceduna, S.A.), the Queensland Ambulance Transport Brigade (Cairns, Q'land), and the Overseas Telecommunications Commission (Darwin, N.T.). The largest network is that operated by the Royal Flying Doctor Service of Australia from its Broken Hill (N.S.W.) base. This provides service for a total of 447 outpost stations (262 fixed and 185 portable stations).

During the year ended 30th June, 1961, the system handled a total of 305,891 telegrams. In addition 13,753 medical consultations were conducted. During this period the Alice Springs network (97 fixed and 252 portable outpost stations) handled 34,009 telegrams and provided for 1,470 medical calls. These figures are typical also of those for other networks in the system.

OPERATIONAL FEATURES

Charges for telegrams passed over the system are A3/- for twelve words with A3d. for each additional word. These amounts are apportioned equally between the radio service involved and the Postmaster-General's Department which conducts the Commonwealth's landline telegraph service. No charge is made for calls relating to medical aid and advice, and outpost stations are permitted to converse freely among themselves on the lowest frequency assigned to the individual network without payment of any fee.

Usually traffic schedules covering all channels in the individual network are conducted in post-dawn and pre-dusk hours to enable the more distant and lower powered outpost stations to take advantage of propagation conditions applying at those times. Most networks have one or two other schedules during the day. Base stations transmit a list of calls to all outpost stations for which traffic is held and the outpost stations reply in turn. Other outstations then transmit their outgoing messages. Medical calls take precedence over ordinary traffic.

FURTHER INFORMATION CONCERNING THE SYSTEM

A brochure (RB29) outlining conditions governing the licensing and operation of control stations and associated outpost stations is available upon application to the Controller, Radio Branch, Telecommunications Division, Postmaster-General's Department, I.C.I. Building, Melbourne, C.2, or to the Superintendent, Radio Branch, in the capital city of any State.

SOME ASPECTS OF THE DESIGN AND USE OF CABLE PLOUGHS — PART I

*D. MacQUEEN, A.M.I.Mech.E., A.M.I.E.Aust**

INTRODUCTION.

Ploughing telephone cable directly into the ground is not a new development (1); in fact the first recorded instance in America dates back to the end of the last century. However, it is only in comparatively recent years that it has been used widely and on a large scale. Ploughing techniques were introduced into Australia in the 1930's (2, 3) and modern usage stems from the introduction of heavy crawler tractors for the purpose after the second world war (4).

Although the first equipment used in the post-war era was of American design, considerable progress has been made in recent years in Australia in both equipment designs and methods of working. There appears to be little published literature on this subject, except for general discussions of the various equipment used by different overseas utilities, and local developments have been made initially on a trial and error basis with field data collected from the first developments providing the basis for subsequent developments.

This article deals with cable ploughing in two parts. The first part discusses the ploughing equipment and practices in general terms; the second part discusses investigation and developmental work carried out by the Postmaster-General's Department into various problems associated with cable ploughing. The article is not a comprehensive report on cable ploughing, but shows the way in which some of the problems associated with the work have been approached and the results so far obtained. It is written primarily from the point of view of mechanical engineering and cable problems, and other telecommunication aspects of ploughing are discussed only in passing.

* See page 501.

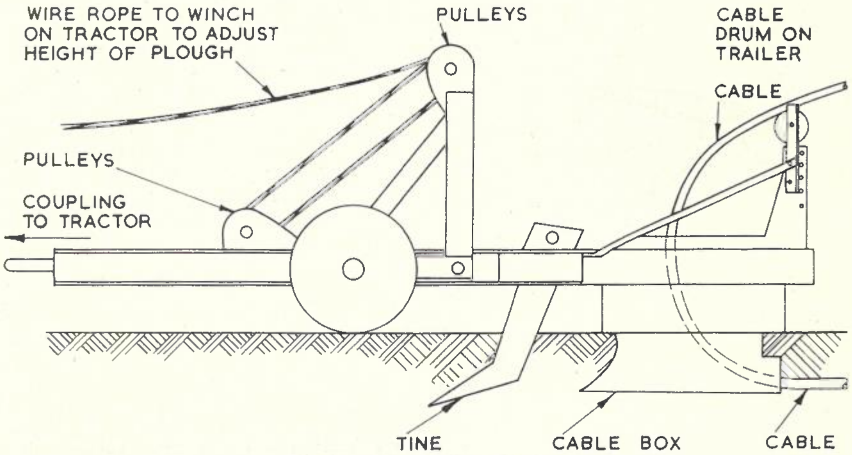

Fig. 2.—Towed Cable Plough.

TYPES OF CABLE PLOUGHING EQUIPMENT.

The first cable ploughing equipment was probably improvised from agricultural equipment; the technique was to cut a shallow trench with a plough drawn behind a tractor or winched along the route, and to separately feed the cable into the trench, then backfilling the disturbed soil into the trench to cover the cable. The next development was to attach the cable to the rear of the plough blade to drag it directly into the trench, the cable being fed off a stationary drum. Fig. 1 illustrates such an arrangement using a type of agricultural implement known as a mole plough.

The next major development was a plough designed specifically for cable laying; in its modern form it cuts a narrow slot in the ground and feeds the cable into this slot as soon as it is cut. The slot recloses as the plough passes on. Fig. 2 illustrates such a plough.

This plough consists of two parts, the tine which penetrates the ground and cuts the slot, and the cable box which feeds the cable into the ground; the box is attached immediately behind the tine. The cable plough can be mounted either on a separate trailer drawn by a tractor, or mounted directly on the tractor (Fig. 3). The cable drum can also be mounted on a trailer or on the tractor.

Earlier cable ploughs such as those described in references 2, 3 and 4 were trailer mounted, and the assembly of one or more tractors hauling a plough and one or more cable drum trailers is called a "cable train" (Fig. 4). Thousands of miles of lead covered cable have been laid in Australia with these ploughs, the progressive development of which is shown in the references quoted. The self-contained laying unit, consisting of a plough permanently mounted on a tractor with the cable drum carried on the same tractor, is a recent development which will supersede the "cable train" in some applications.

GENERAL REQUIREMENTS OF CABLE PLOUGHING EQUIPMENT

Cable laying operations may need to be carried out in several separate stages, depending on the route conditions encountered. Thus it could be necessary to clear a section of the route of heavy timber as a first stage, remove obstructions such as large rocks as a second stage, for example by the use of a "ripper" plough, and carry out the cable laying as a third stage. On suitable sections of a route, the first two stages could be combined with each other or with the cable laying stage.

Ideally the cable ploughing unit should be able to carry out all operations and in as few stages as possible. It should be able to pick up the cable where it has been dropped by the stores vehicle, transport it to the job and lay it along a given route at a given depth,

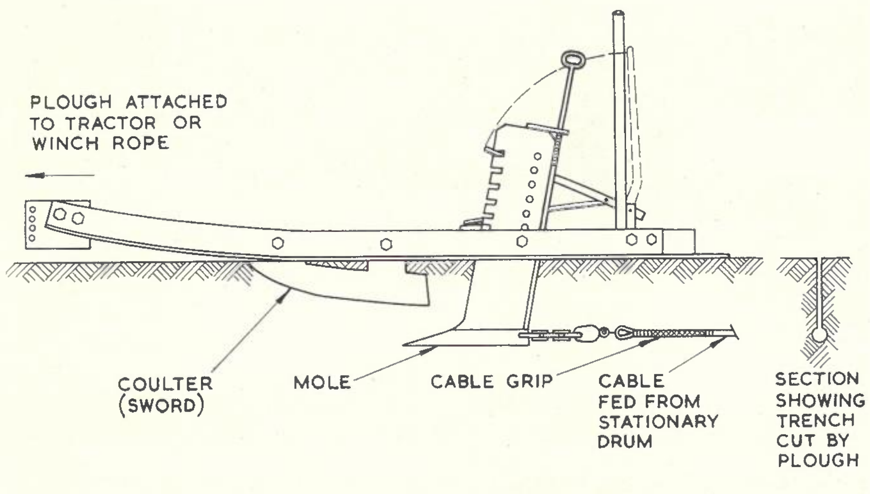

Fig. 1.—Agricultural Plough Adapted to Lay Cable.

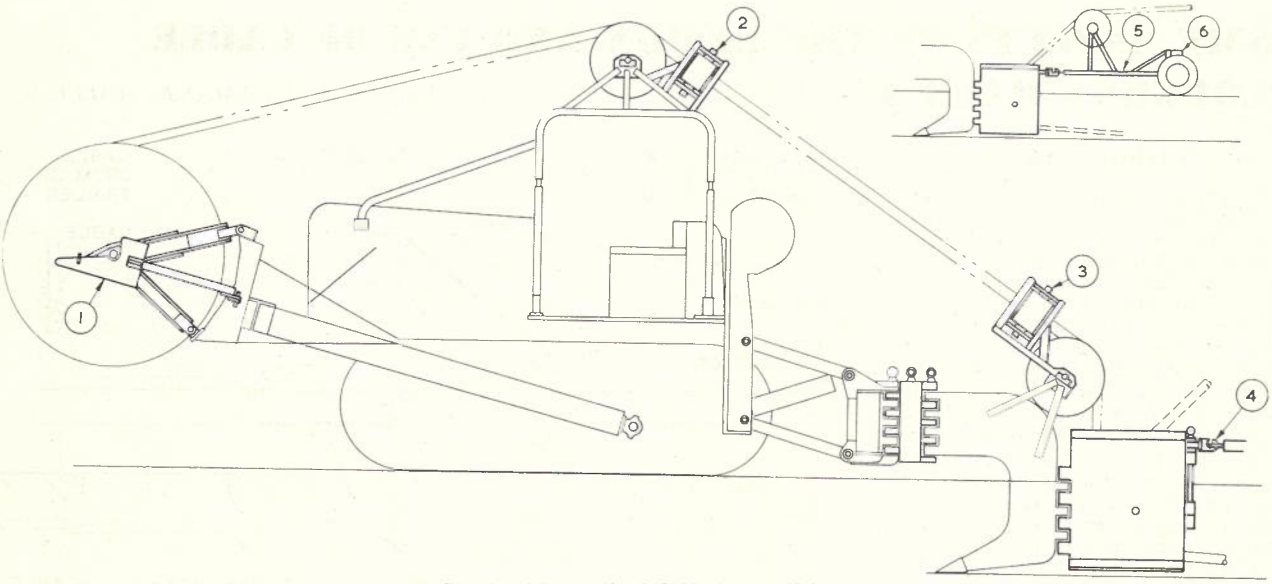

Fig. 3.—Self-contained Cable Laying Unit.

(1) Front Cable drum carrier mounted to the blade with quick release couplings. The blade can be used separately. **(2)** Top cable fairleads. **(3)** Rear cable fairleads. **(4)** Military pattern towing hook; with swiveleye on trailer, allows full articulation of the trailer. **(5)** Towing trailer, to offset effect of rise and fall of cable plough box on cable trailer itself. Used in preference to an adjustable towing hook on the plough box. **(6)** Towing hook for attaching cable drum trailer.

consolidating the trench as it goes so that the only work remaining to be done after the unit has passed is to joint the cable.

It is essential that the cable laying operations should be carried out in such a way that neither the cable sheathing nor the cable conductor insulation is subject to strain during ploughing (5), due either to ground conditions or to plough design. The bending radius of the cable in the plough must always be greater than the limit for the type of cable concerned, and for this reason it is sometimes preferable to use two or more smaller cables in place of one large one.

For economic reasons, the basic equipment unit should be a commercially available tractor, modified and with additional equipment added where necessary; the finished machine must be within legal road transport weight limits. This unit must be adequately powered and have adequate traction under all conditions. It must be capable of clearing the proposed cable route of brush, trees, stumps, boulders, and build access ramps into and out of rivers, creeks and water courses. It should be equipped with cable drum carrying equipment, fitted at the front end to offset the forces set up when the tine and plough box are in the ground. This carrying equipment should be so designed that it can be easily and quickly attached and detached.

The carrying equipment should be clearly visible from the driver's seat. It should be so designed that the unit can pick up a cable drum with minimum manoeuvring. Towing attachments should be fitted for towing cable drum trailers so that either more than one cable may be laid at a time or to save a return journey to a pick up point when the route is far from a vehicle road. It should also be possible to readily attach the ploughing and ripping equipment when clearing operations are complete.

GROUND CONDITIONS.

General.

Ground conditions are the largest single factor to be considered when burying cable because they not only affect the design of the cable sheathing and the equipment to be used for laying, but to a large extent dictate the route that must be followed. A study of ground conditions must include in it the properties of the soil, the underground services, the type of cover and the size of trees, hills and grades, water courses, rivers, and generally any naturally occurring or man-made hazards likely to affect the performances of either the laying equipment or the working cable. Any study of the properties of soil is complicated by the vast range encountered, from swamp to parent rock and including dry sand and wet clay, each having widely varying physical properties and, with the exception of rock, each being subject to

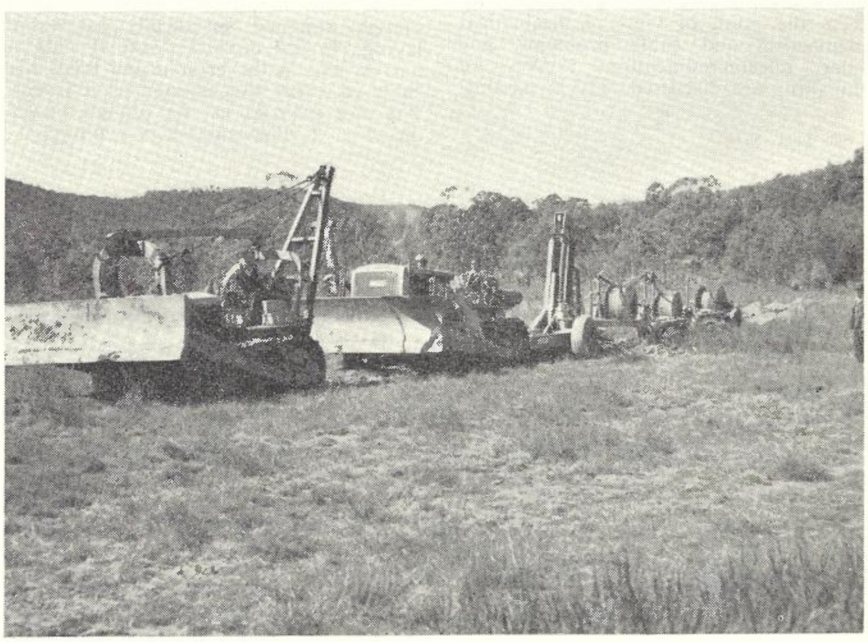

Fig. 4.—Cable Train consisting of D6 and D8 Tractors Pulling a Cable Plough and Three Drum Trailers. Photo taken in 1949 of laying of the Sydney-Bathurst trunk cable.

variation according to climatic conditions. Clay and rock predominate in New South Wales in the coastal belt, changing to loam and black soil on the inland plains and finally to sandy loam in the west.

It is not proposed to discuss in this article the effects of ground conditions on the cable itself, but rather to concentrate on the aspects affecting the cable laying and the design of the laying equipment. Thus such effects as corrosion, depth of laying and erosion will not be discussed. It could be appropriate to make brief reference, however, to mechanical damage through settling rock. This is a particular hazard when cables are ploughed into the ground. Although steel wire armoured cable and steel tape armoured cable have usually been found satisfactory in most types of country, coaxial cable and plastic sheathed cable are particularly prone to damage by crushing. As a matter of interest some tests were carried out in Sydney, extruding cement-lime mix around plastic tubing while it was being ploughed into the ground. This gave a stabilised cylinder around the half-inch diameter tube which varied from 1 inch to 2½ inches in diameter with a crushing resistance varying from 300 to 780 lbs. per sq. in.

Ground Conditions Affecting Cable Laying Equipment.

Ploughs and Rippers: The main soil properties that affect the ripper and cable plough are hardness, friction, adhesion, cohesion and abrasion. When ploughing, hardness is the resistance to penetration and it is at a minimum for sand and at a maximum for dry clay (solid rock is not included). Boulders and floaters or rock outcrops increase the power required for penetration, and are troublesome when they are oversize for the machine or packed so firmly in place that they cannot be pulled to the side or ripped through. As the digging end penetrates, friction absorbs an increasing proportion of the drawbar pull. Friction is affected by the amount of moisture and natural lubricants in the soil, such as humus and soft clay. Adhesion is the sticking of soil to the equipment being used and considerably increases the drawbar pull required in wet weather. Cohesion is the resistance to tearing apart and it is most marked in clay which has more or less uniform cohesion to great depths. Abrasion is the property of wearing away of the digging equipment by the soil particles.

Tractors: Ground conditions have an important influence on the selection and use of tractors. These factors will be dealt with later in a general discussion on tractors.

Road Vehicles: The ground conditions affecting road vehicles used for carrying cable and stores to the job are generally the same as those affecting the tractors. Except on flat dry plains, road vehicles are not suitable for off-road working and it is cheaper for road vehicles to drop stores at some convenient point close to the job and for tractors with special attachments to take over from there. Such equipment as must be carried to the job by vehicles should be carried by 4 x 4 or 6 x 4 cross-country vehicles.

Weather: The weather and the season of the year must be taken into consideration when ploughing. Many soils, ideal for ploughing most of the year, become impassable to machines during even a brief spell of wet weather. All equipment is subject to this restriction and rubber-tyred equipment even more so. For example, the black soil country in the west of New South Wales cannot support the unladen rubber-tyred tractors after rain. This type of soil must have a grass covering to give traction before it can be ploughed.

Trees and Undergrowth: In the high timber country, large tractors are often required for clearing the route although smaller machines are adequate for actual ploughing in the cable. However, the narrower route required for cable ploughing is bringing into being a general purpose cable layer able to clear its own route as a first stage, and plough the cable in afterwards without the unit being over- or underpowered for any particular phase of the work.

Grades: A gradient of 1 per cent., which is one foot rise in 100 feet, adds some 22 lb. per ton to the tractive effort required on the flat. When tractors are working at full power, gradients of more than 10 per cent. (which decrease the available drawbar pull by some 4,500 lb. on a 20-ton machine) cannot be ploughed except from the top down.

TRACTORS.

General.

The history of the tractor, fitted first with steam engines, starts in the last century when iron-wheeled machines began to be used for road traction and agricultural work. However, there was no widespread use until the invention of the internal combustion engine. About the time of the first world war, the crawler tractor came into being although it was well into the 1930's before it made a serious impact on the earth moving industry. Since then the rate of development has increased enormously due to improvements in steel and alloys, with the resulting increase in speeds and horsepowers available from compact power units. Nowadays, 600 h.p. machines are readily available. Until after the second world war the crawler tractor was in an unchallenged position in the earth moving industry because of its versatility. However, the field of the crawler tractor is being invaded with a great deal of success by the all wheel drive rubber-tyred machines. Both types of machines find use for ploughing telephone cable.

Ground Conditions Affecting Tractor.

Essentially, a tractor is a means of applying a force (drawbar pull) at a certain speed, and today engines and transmissions of almost any desired power and transmission characteristics are available for tractors. The extent to which they can be used to do useful work at the drawbar depends on the mechanical losses between the engine and the final drive and on the losses in the soil by wheels or the tracks. The transmission losses are more or less constant whatever the duty the machine is performing. The losses between the wheels or tracks and the soil are the main source of power loss. Thus in the design of any tractor, whether crawler or wheeled, the basic factor involved is a knowledge of the soil properties and how they react to the forces involved in traction.

A survey of the problems of traction can be brought within reasonable proportions by considering the generally prevailing soil properties which fall between the extremes of a purely cohesive soil, such as wet clay, and a purely frictional soil, such as dry sand, bearing in mind that the presence of any moisture at all in sand substantially affects its cohesive properties. Although it is possible to find a purely frictional material such as the sand in some areas of Australia, clay soils with predominantly cohesive properties, where friction is entirely absent, are rare.

On perfectly dry soil, the drawbar pull is determined by the friction between the surface of the soil and the tracks or wheels of the tractor, thus:

$$\text{Drawbar pull} = W. \tan \phi$$

where W = weight on traction wheels; and ϕ = angle of friction of soil.

As ϕ in the case of dry soil is approximately 35° and $\tan \phi = 0.7$, the drawbar pull of a machine under these conditions cannot theoretically exceed 70% of the machine weight. This is confirmed in practice and is best illustrated in cross-country vehicles when four-wheel drive is engaged. There is then a sudden increase in drawbar pull, because the full vehicle weight instead of half-weight is used on the traction wheels. Generally, however, traction is dependent upon a mixture of soil friction and shear.

In the crawler tractor the factors influencing traction are:

(i) Width and length of track. Increasing the dimensions provides improved flotation.

(ii) Design of grousers. These are metal ribs which penetrate the soil to give a better grip of the track on the soil. They are attached to the tracks at right angles to the tracks and to the direction of motion. Suitable depth of grousers is required to ensure that traction is obtained by shearing the soil and not by the friction of metal on soil.

The pitch of the grouser or the separation between successive grousers on the tracks must also be considered as the longer the pitch, the greater the angular movement of the grouser on entering the soil, with a corresponding increase in tractive resistance.

On the rubber-tyred machine the factors influencing traction are weight and weight distribution; tyre size, inflation pressure and tread pattern; and track and wheel base.

From the wide range of tractors available today it is comparatively easy to evaluate the relative merits of each type of machine on a cost or time basis on any class of work or soil. For traction in various soils, a choice of various widths and lengths and depths of tracks is provided on crawler tractors and a choice of tyres and inflation pressures on rubber-tyred machines. Once the whole range has been viewed it can be shown that certain units are best fitted to do a particular job. The machines used by the Department work in conditions varying from the extremes of broken stone to swamps (though the greater part of the work is carried out under conditions varying from sand to grass covered clay) and weather conditions from drought to floods and snow. It is impossible to avoid these variations in soil conditions, or to incorporate in any one machine design such features as will make it equally suitable in any soil conditions, and still be able to sell it. It is difficult not to come to the conclusion that the machine that is really required is a crawler tractor that can be converted to a rubber-tyred machine by pressing a button.

Selection of Tractor Type.

To an even greater extent the problems outlined in the previous paragraph are faced by the tractor manufacturers and a great deal of credit is owed to the industry for producing complex equipment that gives many years of reliable service under the most arduous conditions, and which can, at the same time, be handled by people with little training. Reliable machines are on the market which can do a job under a great variety of conditions, with extra equipment available, particularly in the way of tracks, for varying soil conditions — narrow and wider tracks — deeper shoes — road pads — swamp pads and the like. But in spite of this the machine is still a compromise tractor able to do many jobs reasonably well, but not necessarily best suited for any particular job.

In considering the present-day tractor, certain traditions and conventions have grown up in the industry alongside sound engineering principles. For instance, tractor buyers have become accustomed to a certain layout and appearance and certain standards have come into being such as fuel consumption, a power to weight ratio of around 10 horsepower per ton, a more or less rigid tractor frame, speed range, drawbar height, towing hook position and a number of points both great and small which add up to the complete machine. Most of them are dictated by sound engineering principles, some by the manufacturer who is, after all, concerned with making a profit, and some points are dictated by the customers who have an idea of what a tractor should be like and who go to the manufacturer who will cater for them. Unfortunately, it is not only in the fashion world or in the styling of motor cars that whims play a part. A few manufacturers have in recent years, in all good faith, tried to bring out a machine designed from start to finish on sound engineering principles and not on modifications to traditional equipment. The difficulties they have encountered and the financial losses they have made are well-known.

The question posed when cable ploughing equipment was first being considered was — what is the most suitable equipment to cope with the range of work? This was soon modified to— what is the best type of standard equipment which can be most easily modified to handle the variety of work? In answering this question, major aspects of design which will now be considered are the type of traction — crawler or rubber-tyred — and the type of transmission. The third important aspect is the power requirement. This will be discussed in the second part of the article.

Crawler and Rubber-tyred Machines.

The rubber-tyred tractor is intended to offer all the crawler's advantages as well as higher speeds, particularly on return runs, and it is a completely self-contained unit, able to move under its own power along highways from job to job. There is no job on which it would not be an advantage to have machines able to travel under their own power everywhere, especially at vehicle speeds on highways when moving from job to job. However, this convenience must be paid for and in general in Australia rubber-tyred tractor conversions suitable for cable ploughing are substantially more expensive than crawler machines of equivalent power. The relative merits of rubber-tyred and crawler tractors for ploughing are summarised in the following paragraphs:—

Traction: Table 1 illustrates the comparative tractive efforts of crawler and rubber-tyred tractors under different ground conditions. It will be noted that neither is superior under all conditions but each is superior under certain conditions.

TABLE 1 — COMPARATIVE TRACTIVE EFFORTS OF CRAWLER AND RUBBER-TYRED TRACTORS.

Surface	Tractive effort as percentage of weight	
	Crawler	Rubber-tyred
	%	%
Dry sand	30	30
Wet sand	40	40
Loam	70-80	40-50
Clay	90-120	70-80
Concrete	40-50	90

(Figures taken at various speeds down to stall on torque converter machines, using hydraulic gauges to measure the pull.)

Steering: A desirable feature of cable ploughing is keeping a straight course between markers. Rubber-tyred machines are more difficult to keep on a straight course than are crawlers, particularly on the sides of hills, and both the type of transmission and the means of steering the rubber-tyred machines influence this. The transmissions available for rubber-tyred machines are clutch-brake, differential and limited slip differentials with the clutch-brake machines being steered by skidding the wheels and the differential drive machines having steerable wheels at the front or the rear or all round.

For ploughing work generally, the all wheel drive rubber-tyred machine with all wheel steer fitted with limited slip differentials is by far the best because the oblique steering properties tend to offset any tendency to slip downhill sideways. Next in order are the clutch brake machines with skidded wheel steering and then the front wheel steer, while the rear wheel steer machine is all but impossible to keep on a straight course when the tine and cable plough are in the ground.

Ground Damage: It is the practice in Australia to plough cable along the most suitable track, whether it is along the side of the public highway or across private property, and much cable is ploughed into farming or grazing land. In many areas where soil improvement is being carried out, farmers and graziers are understandably reluctant to grant permission for cable laying. Even when the cable track has been seeded it is at least two years before the land begins to look fully recovered. Over hundreds of miles of cable track it has been found that crawlers do far less surface damage than rubber-tyred machines, and it is often difficult to obtain permission to operate rubber-tyred machines over private land. On the other hand, when machines have to be moved across surfaced roads, footpaths and the like, the rubber-tyred machine does no damage while the crawler does.

Mobility: The main advantage of the rubber-tyred machines over the crawlers is in their mobility. They are able to travel from job to job under their own power and more often than not do so at vehicle speeds and are ready to start work immediately they arrive on the site. It is solely for this reason that the purchase can be justified although a mention must be made of the clutch brake skid steer machine. Even with the offside tyres at reduced pressure to allow for road camber, tyre damage on bitumen and concrete roads is heavy. Their use for travelling under their own power for any distance is confined to areas with dirt or gravel roads. For a selection of machines on this account the cable ploughing work falls into two distinct categories:

(i) Rural exchange work with subscribers and junction cables. Multi-pair cables are run along the sides of roads where possible, with spurs to properties and houses on either side. There is a considerable amount of idle running on this type of job with frequent road crossings. The minimum depth at which the cable is required to be buried is between 18 inches and 2 feet, and for this type of work the rubber-tyred machines are the obvious choice.

(ii) Straight cable laying over long distances requiring 3 ft. of cover, with a variety of soil conditions. Here, the crawler tractor is the best type of machine.

Costs: Completely fitted rubber-tyred machines with drawbar pulls in average soils from 10,000 lb. to 20,000 lb. cost around £12,000. These are suitable for laying cable to a maximum depth of about 2 ft. Completely fitted torque convertor crawler tractors with drawbar pulls of between 10,000 lb. to 14,000 lb. in average soil, suitable for laying cable to a depth of 2 ft., cost about £6,500.

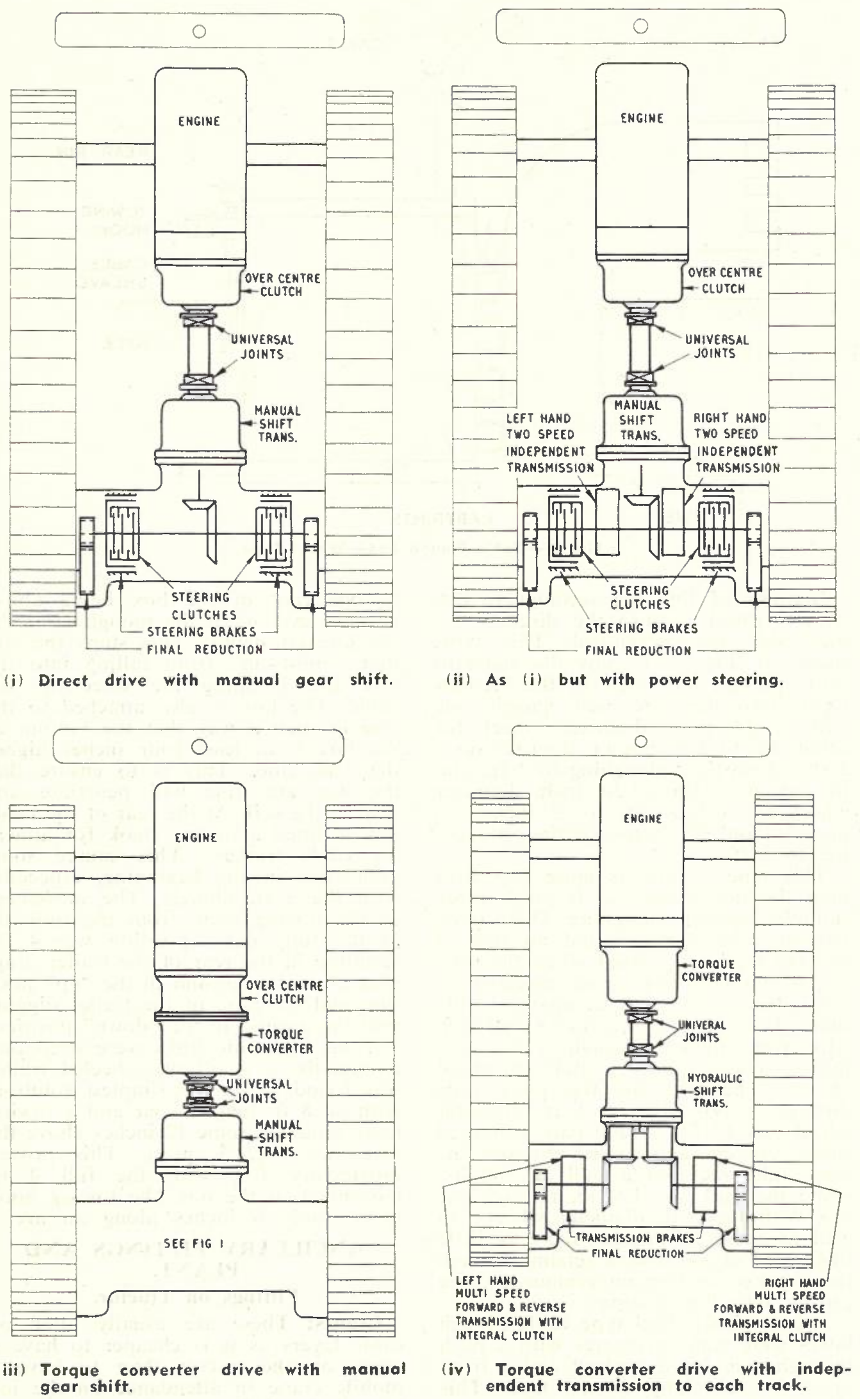

Fig. 5.—Schematics of Transmission Trains of Crawler Tractors.

Completely fitted torque convertor crawler tractors with drawbar pulls of from 25,000 to 35,000 lb. in average soil cost about £15,000. These are suitable for laying cable 3 ft. deep.

These costs, however, are no indication of the economics of operation of these machines. With the rubber-tyred cable layer, for instance, machine costs taken over a two-year period have been around £15 to £20 per mile of cable laid. The costs with the large crawler tractor are around £40 to £50 per mile of cable laid. These figures cannot, of course, be used for comparative purposes between the two classes of machines as the type of cable laying operations involved are not comparable.

Types of Transmission.

There are a number of transmission combinations available to transmit power from the engine flywheel to the tracks or wheels. For coupling the engine to the gearbox there is a choice of friction clutch, fluid coupling and torque convertor; gearboxes range from completely manual to fully automatic over a wide range of intermediate stages; control may be fully manual or power assisted; final drive is through crown wheel and pinion with either clutch brake or differential drive to the axles and the choice of power turn on the tracks when steering. Electric and hydrostatic transmissions have also been developed but their commercial application has been restricted.

Fig. 5 illustrates schematically some transmission systems widely used on crawler tractors. For cable ploughing, torque convertor transmission with or without clutch and free wheel has been found most suitable combined with three speed range transmission, the final drive for crawler machines being through clutch brake and, for rubber-tyred machines, through limited slip differentials and hub reduction.

The reasons for preferring torque convertor drive to mechanical drive using gearboxes will be considered at length in Part II of this article. In brief the torque convertor machine, although more expensive to purchase at present and having a slightly greater fuel consumption than a gear type machine, is preferred because the maximum drawbar pull is developed at stall, that is when the machine is just about to move, and as a result there is least possibility of damaging the cable.

DIRECT MOUNTED OR TOWED UNITS.

Comparing the direct mounted and towed units (Figs. 2 and 3), the advantages of the towed unit are that the tractor can be a general purpose machine available for other purposes. In operation, the towed plough can be unhitched for crossing soft patches, swamps, streams and the like and winched through with the tractor standing on hard ground. Over undulating country it does a better job of maintaining the cable at depth than some of the mounted ploughs. Generally, however, the mounted unit is superior. It is more easily manoeuvred, there is adequate down pressure for penetrating hard strata, and it can rip through rock and hard ground which the towed unit cannot do because it does not have enough weight on it. It is more easily transported, the one low loading tractor carrying tractor, blade and plough. With automatic depth control, the depth of laying with the mounted unit can be accurately controlled. Generally, areas where the ground is too soft to give traction can be avoided or, if this is not possible, a second tractor can be used as an anchor.

The self-contained unit is also inherently more stable. It can be shown that the reaction at the towbar of the tractor pulling a separately mounted plough can be sufficient to lift the front of the tractor off the ground and even overturn it, and that the stability of the tractor increases as its own weight is increased and decreases as the drawbar pull increases. On the other hand, it can be shown that the stability of the tractor with a directly mounted plough increases as the drawbar pull increases and the resistance offered by the earth to the tine increases.

The stability of the separately mounted plough unit can be increased by suitable design of the tine but not to such an extent as to make it as stable as the direct mounted unit.

TINE AND CABLE PLOUGH BOX.

Design of the Tine.

Ripping tines akin to those used for cable ploughing have been in use for centuries for cultivating the ground, and such specifications as exist for modern tines are mainly confined to agricultural ones. The correct design of the tine is critically important in cable ploughing and the second part of this article will describe among other things the extensive developmental work done by the Department on this aspect of the work.

Cable Plough Box.

Cable plough boxes used in the past, as distinct from the tine itself, have consisted generally of tubular chutes, of suitable radius at the bottom end and attached to the back of the tine. Originally, they consisted merely of a mild steel tube of suitable diameter bent into a suitable curve and welded to the back of the tine as a means of feeding the cable into the ground. Developments have taken place, perhaps the most important one being that the tube was split along its length so that the cable could be laid into the tube instead of being threaded in from the top. There are a number of modern variations of boxes with rear and side opening chutes for removing and inserting the cable. Some are fitted with rollers to cut down the friction at the bend as shown in Fig. 6.

They are reasonably satisfactory for the smaller cables (up to 25 pair armoured, and up to 50 pair plastic) and at shallow depths (12 to 18 inches). Their weakness is their high co-efficient of friction and the need to grease the cable to lessen this. The rear of the tube is not rigid and is subject to damage, especially if the machine has to reverse with the cable box attached.

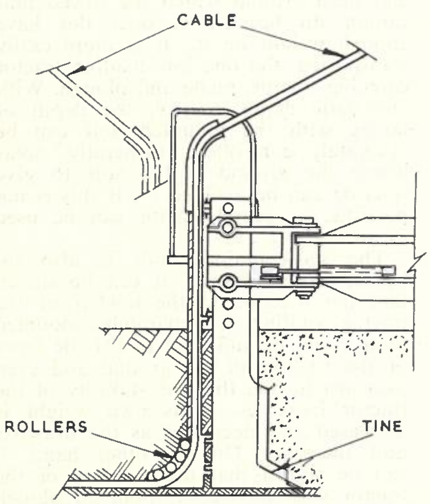

Fig. 6.—Cable Plough Box—Tube Type.

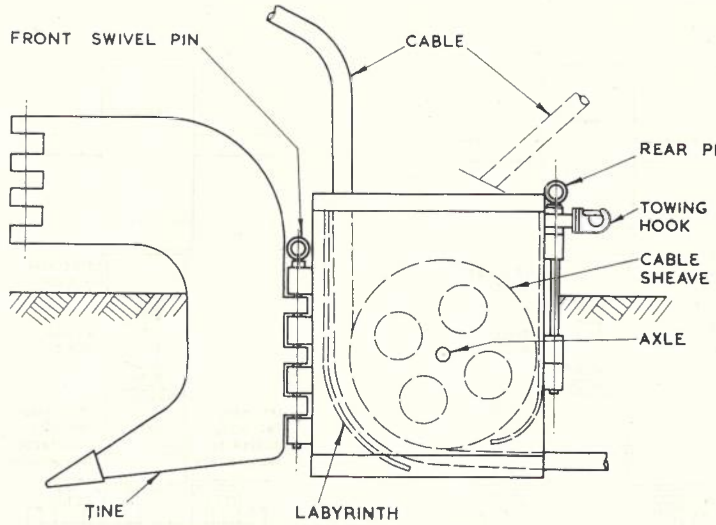

Fig. 7.—Cable Plough Box—Wheel Type.

Because of this the rectangular box with a wheel to turn the direction of the cable was developed. This type, shown in Fig. 7, is now the standard cable plough box used in the Department. Two sizes are used, namely one with a 24 inch. diameter wheel for cables up to 2 inches in diameter on a 2 ft. 6 inch tine, ploughing to 2 ft., and the second with a 30 inch diameter wheel for cables up to 3 inches in diameter on a 3 ft. 6 inch tine, ploughing to 3 ft.

This type of box is more expensive than the tube type, but is much more suitable for deep ploughing. There is no risk of cable damage, and no risk of damage to the box itself when the tractor is manoeuvring. The lessening in friction is considerable compared to the tube. Tests have shown that a half-inch wire rope pulled through a 12 inch radius tube requires a pull of about 78 lb. The pull for the same rope through a box with a 2 ft. diameter wheel was 17 lb. A 200 pair armoured cable, greased and pulled through the same tube required a pull of 560 lb., while the pull was 190 lb. through the box with the 2 ft. diameter wheel. As well as these advantages there is little likelihood of the wheels seizing through the bitumen coating on armoured cable getting into the bearings.

The original wheel type cable plough boxes were rigid structures with a push through axle for the wheel and a front pivot for attaching to the tine. This was not satisfactory because there are many occasions when the tractor cannot pull through the whole drum length of cable on account of roots, rocks, soft patches or, more particularly, creeks and river crossings. The cable has then to be cut and rejointed at these points. With a side opening box with the front pivot used as a hinge and the front bosses split, the cable can be lifted off the machine without the need for cutting and jointing. With this modification, a labyrinth has to be fitted in front of the wheel to keep out mud and clay.

The general box used today includes these features and allows for six inches to one foot of the box being above ground level when the plough is at the the greatest depth. This stops the soil that "builds-up" from falling into the box and jamming the wheel or the cable. The box is also attached to the tine in such a way that the bottom of the box is at least four inches higher than the tine. This is to ensure that the box and tine will penetrate and stay in the soil. At the rear of the cable box is fitted a towing hook for attaching cable trailers. This caused some difficulties in the beginning, especially with the 3 ft. plough. The movement of the towing hook from the fully up to the fully down position was 4 ft., resulting in the rear of the trailer dragging along the ground in the "up" position and the nose of the trailer digging into the ground in the "down" position. Various hydraulic links were tried out. Eventually, a small two-wheeled trailer was found to be the simplest solution, with an 8 ft. long towbar and a towing hook mounted some 12 inches above the axle (see Fig. 3 inset). This proved satisfactory for, with the full 4 ft. movement of the box, the towing hook moves only 6 inches along an arc.

ANCILLARY FITTINGS AND PLANT.

Fittings on Tractor.

Cranes: These are usually fitted on cable layers as it is cheaper to have a crane on the tractor than to have a mobile crane in attendance on the job for all the lifting operations that arise from time to time. Further, cable drums placed along the route ready for picking up by the cable layer and/or the cable trailers, may sink in soft ground after rain. When this happens, hours can be spent in the absence of a crane, manoeuvring the tractor to use the front pick up, or trying to place the drums in such a position that the self-loading cable drum trailers will operate.

Backfill Equipment: Most of the backfilling that is required with cable ploughing is done by using the angled dozer blade on the layer after the cable has been ploughed into the ground and then consolidating the rip by running the tracks or wheels over the ridge. A V-blade, towed behind the tractor, which backfills immediately behind the cable is being developed for use in conjunction with a tamping roller so that the ploughing, back-filling and consolidation can be done in one operation.

Cable Drum Transport.

To handle and transport cable drums from the job store to the laying unit calls for mobile handling equipment over and above that on the cable layer, and it is this phase of the job that accounts for most of the delays that occur in ploughing operations. The magnitude of the drum handling problem can best be appreciated considering a ploughing rate of 2,000 yards an hour which is the average figure. This means that four 500-yard length drums have to be transported from the job store to the exact locations where the cable layer will pick them up, every hour. The distance involved may be up to 20 miles for the round trip, a large part of it involving cross-country movement together with the attendant hazards.

Because of the dangers of theft and vandalism it is the practice to lay out only one day's supply of cable drums along the route of the ploughing operations. Hence special purpose equipment for laying out drums must be held for the duration of the job instead of laying out all the drums required in one continuous operation and then going on to the next job.

A satisfactory but costly item for the purpose is the high lift straddle carrier, but it has so far proved uneconomical because it cannot be used near its full capacity.

The units that are being developed for this purpose are 3 ton 4 x 4 off-the-road trucks, with tray bodies fitted with a 2-ton hydraulic crane behind the driver's cabin. This type of vehicle has all the advantages of a mobile crane and a cable carrying or equipment carrying truck as well. It is proving particularly useful for handling and transporting drums of plastic cable. For the heavier drums, used with the crawler cable layer, 20 ton low loading trailers have been fitted with similar types of hydraulic cranes mounted on the semi-trailer gooseneck and having a capacity of 5 tons (see Fig. 8).

Whatever method is used to handle and transport the cable to the cable layer, the occasions always rise when there is no alternative to the use of cable drum trailers. In some rough and swampy country the only vehicle which can obtain traction is the cable layer itself, and it has to be used to transport the drums from the nearest point that vehicles can reach, either by carrying them or by towing one or more cable trailers.

Cable Drum Trailers.

Most of the cable drum trailers are self-loading, making use of either hydraulic or screw lift jacks or a hand winch and inclined ramp at the rear. Cable handling gangs prefer the inclined ramp type of trailer as, when used with a winch truck as a towing vehicle, a bridle can be made up and the power winch used to load the trailer.

For ordinary cartage, however, it is not economical to use a winch truck as a towing vehicle. The most easily operated mechanism for hand loading is a hydraulic jack, which is reliable and economical in normal service, but on cable handling it has a very short life. To try and meet the conflicting demands of economy, ease of operation, and safety, current testing is along the lines of hydraulic jacks powered by electrically driven hydraulic pumps, the electricity supply being taken from the vehicle battery and generator.

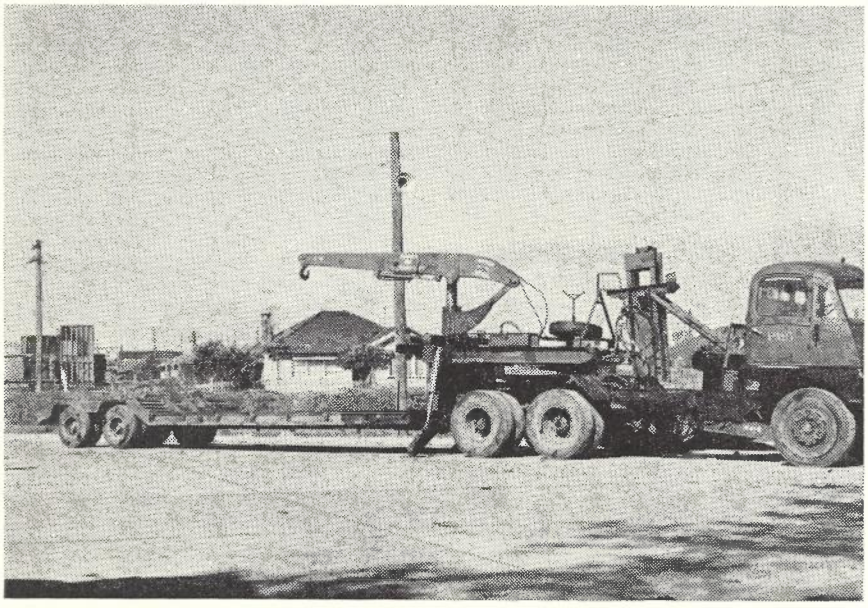

Fig. 8.—Low Loading Trailer with Crane.

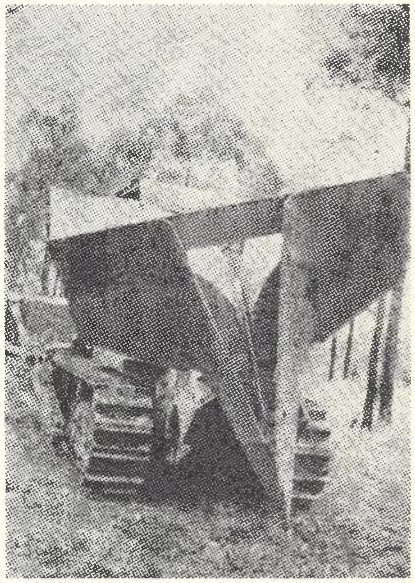

Fig. 9.—Trenching Plough Attached to Back of Tractor.

Another type of trailer which has been developed for use with cable ploughing equipment is the six spindle flat top cable trailer. This is a long, flat top trailer, carrying six vertical spindle turntables on which the drums lie on their side. It has been found particularly useful with plastic cable when it is towed behind the rubber-tyred cable layer on rural exchange cable laying; main cables and spur cables can be laid as required without the need for frequent drum changing as the cable size changes.

Transport of Cable Layers.

The only cable layers at present in use which are suitable for travelling under their own power on any road are rubber-tyred machines fitted with power assisted steering. Rubber tyred machines with clutch brake steering are suitable for road travel on gravel or dirt roads but for any distances over about 50 miles road transports must be used to carry them. The Departmental tractor floats consist of 20 and 25 ton low loading semi-trailers, the largest that can be used on all roads without the expense of changing over to double gooseneck trailers. If cable has to be ploughed any deeper than the present maximum of 3 ft., large tractors will be required of the order of 200-400 h.p. as well as double gooseneck floats to carry the increased weights.

TRENCH PLOUGHING.

Although ploughing cable directly into the ground is the quickest and cheapest method of burying cable, it is not suitable for lead covered coaxial cable, because of the danger of crushing of the coaxial tubes during ploughing operations or, where the soil contains rocks, of damage caused by rocks settling afterwards. For this reason all of the coaxial cable being laid in the extensive programs now in hand is being laid either in conduit or in trenches cut by ditching machine (6).

Because of the higher cost of ditching compared to ploughing, consideration was given at the planning stage of the coaxial cable programme to the use of deep trenching ploughs to cut a trench into which the coaxial cable would be laid in sand. However, a 4 ft. ploughed trench proved impracticable and ditchers had to be employed.

The tests carried out on these ploughs are of some interest, however. With the equipment available initially (Fig. 9), the best trench that could be cut was 2 ft. to 2 ft. 6 inches in depth, the batter of the sides varying from 60° to 45°, and the trench and the spoil on either side leaving a swathe some 12 feet wide. Tandem machines were then tried (two 175 h.p. tractors), the plough being fitted to the rear of the rear machine. With this arrangement, a trench some 3 ft. deep was ploughed. The trench walls remained unstable in both cases, largely because of the spoil heap, and a stable trench could not be achieved with a slope of less than 45°. At a depth of 3 ft. the width of the top of the trench was 6 ft. and the spoil extended up to some 5 ft. on either side.

The difficulty of digging a 4 ft. deep trench in one pass led to tests of a front mounted plough trenching to 2 ft. 6 inches with the intention of following this with a rear mounted plough from 2 ft. 6 inches to 4 feet. The trench cut by the front mounted plough could not be stabilised and gave way under the weight of the machine and no further tests were carried out.

From the data collected and from overseas information, a trench 4 ft. deep with a top width of at least 8 ft. was a proposition with a tractive effort of some 100,000-300,000 lb. The size of the tractors required for this type of work more or less precluded their use because of the terrain and the transport difficulties over country roads and bridges. Economically, special purpose units of this size were not justified for this one job. Taking all factors into account and including the amount of backfill required for this type of trench, the most economical means of carrying out the work was found to be by ditching machines which could be used generally throughout the country at the completion of this job.

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TECHNICAL NEWS ITEM

SYDNEY-MELBOURN TELEVISION CIRCUIT

A two-way television circuit on the Canberra-Melbourne section of the Sydney-Melbourne coaxial cable was placed in service on the 11th February. It has been connected at Canberra to channels of an existing microwave radio system to provide through transmissions between Sydney, Canberra and Melbourne for the Royal Tour as well as for the concluding match of the England-Australia Test Cricket series and other programmes.

The general plans for the circuit have been described in previous articles in this Journal and a full description of the equipment and performance will be given in the next issue. Briefly, the circuit gives facilities for two independent simultaneous transmissions, one in each direction, and is provided by vestigial sideband equipment using a carrier frequency of 1.056 Mc/s. The circuit extends for 420 miles and is one of the longest distance single circuits of this type existing in the world.

The original programme for the Sydney-Melbourne project, as described previously in this Journal, required the Sydney-Canberra section of the television circuit to be completed ahead of the Canberra-Melbourne section. However, when plans for the Royal Tour were announced last June, the contractor, Telecommunication Company of Australia Pty. Ltd., agreed to rearrange the programme so that through facilities between Sydney and Melbourne could be made available for this important event. The contractor was involved in difficulties with equipment supplies and the installation staff was required to work a considerable amount of overtime as a result of the rearrangement at such comparatively short notice. It is gratifying that the facilities have been completed satisfactorily and on time, and our congratulations must be extended to the staff of Telecommunication Company of Australia Pty. Ltd. for their efforts.

The most difficult aspect of the work of providing the new facilities has been the phase equalisation of the overall bearer circuit which involved over 80 cable repeater sections. The attenuation of the cable had also to be equalised to within 0.5 db over a frequency band extending up to 6 Mc/s. The equalisers required were designed in Holland and Germany by the contractor's associate companies, N. V. Philips Telecommunicatie Industrie and Felten Guilleaume Fernmeldeanlagen G.M.B.H. Further variable equalisers, which are not required initially, are provided to adjust for system variations of a long-term nature, such as possible diversions of sections of the cable.

The long distance circuit has been extended from the main terminal stations of Redfern Radio Terminal in Sydney and City West Exchange in Melbourne to the Australian Broadcasting Commission studios in Sydney and Melbourne, by means of short distance video on coaxial cable systems of the type described in the October, 1961, issue of this Journal. Systems of this type have now also been installed as part of the links to National regional television stations and are giving very satisfactory performance.

THE EVOLUTION OF JUNCTION NETWORKS

*A. H. FREEMAN, A.M.I.E.Aust.**

INTRODUCTION

The earliest automatic exchanges have always had a manual assistance switchboard in the same building and all junction or trunk calls, whether incoming or outgoing, had to be completed by an operator. This scheme was completely satisfactory only for a town which could be served by a single exchange, but in spite of its limitations many applications were found, and by proving its worth in such cases, automatic telephony rapidly established itself. The first automatic exchange in Australia, installed at Geelong in 1912, was of this pattern. As a matter of interest, Canberra, Wagga and Tamworth automatic exchanges, as installed initially, had no requirements for junction circuits, and Broken Hill is still trunked as an isolated exchange.

Another early development was the R.A.X., although it was not known by that name for some years. The advantages claimed for it were the provision of continuous service and the elimination of inefficient manual working at small exchanges. It also had only one link to the outside world via a manual operator, who was however located some distance away at a large manual exchange.

MANUAL NETWORKS

When attempts were made to extend the automatic system to large towns and cities a number of obstacles were encountered. Even at this early date the junction networks of large towns had evolved into an efficient system in which the intelligence of a human operator was a vital component. The disadvantages of manual tandem switching, that is completing a call between two exchanges via a third exchange, were discovered very early in the development of junction networks and every effort was made to connect exchanges with direct junctions if there was a significant traffic between them. For example, the policy in Sydney in 1907 was to provide a direct route if there was an average of ten calls in the busy hour. The provision of direct routes for such a small traffic was only possible because of the operator's ability to maintain a high efficiency by queueing calls when necessary, as is still the practice on trunk lines. With manual control, a group of two junctions can carry one erlang of traffic with about one-third of the calls delayed; in the manual networks, very few of the delayed calls were required to wait more than two or three minutes, and subscribers were still prepared to accept this kind of service on junctions between suburban exchanges, although in time they grew to expect something better.

These factors resulted in networks in which every exchange had direct junction groups to a number of other exchanges where justified mainly by the traffic, and provision to reach the remaining exchanges via some nominated switching centre, or centres. In Sydney this latter facility took the form of using City Exchange as the tandem centre, since all exchanges had sufficient traffic to justify a direct route to City. Direct routes could be, and were, added as justified and if provision of a particular route presented some problems it did not have to be provided.

STEP BY STEP AUTOMATIC NETWORKS

Compared with the flexible manual scheme, the facilities offered by step-by-step automatic systems were extremely restricted. Firstly, the automatic equipment could not provide queueing to increase the traffic capacity of a small route. For example, a route with one erlang which could be operated manually at some inconvenience with as few as two circuits, would require six junctions for standard grade of service in an automatic network, and eight junctions if the route were divided into incoming and outgoing groups. Secondly, the switching scheme was linked to the numbering scheme so that its direct routes were determined by the equipment regardless of traffic considerations.

On the other hand, automatic tandem switching could be arranged with ease and this was the factor which allowed the automatic system eventually to provide a completely different network, capable of competing with the most elaborate manual schemes.

The development of step-by-step junction schemes was quite rapid and between 1907 and 1911 the Strowger system evolved from single exchanges to networks containing the essential features of the 6-digit step-by-step schemes now in use in Australian Capital Cities. Although most of the direct evidence is no longer available it is fairly clear how this took place, and the following reconstruction is probably correct in all important details. Before 1907 each subscriber had an individual first selector and exchanges were built up of composite racks containing 100 first selectors, ten second selectors and ten final selectors. The inter-rack cabling was quite extensive, and the whole design now looks impossibly inflexible for a multi-exchange network. With the invention of the Keith line switch in 1907 came a completely new physical layout with primary boards containing line switches and final selectors for 100 subscribers and separate suites of 1st and 2nd selectors. The relatively light cabling between the primary boards and the rest of the switching plant must have been immediately appreciated by the installation and design engineers.

Also, there must have been then, as now, many large towns with an exchange of several thousand subscribers in the business area, and one or more much smaller exchanges in isolated suburbs, and it is reasonably certain that when a network of this kind was converted to automatic it was regarded as a 10,000 line exchange with some of the primary boards located in a separate building (or buildings). It was realised that a local call between two subscribers within the one satellite used two junctions to the parent, but this disadvantage was more than offset by dispensing with the services of operators (the salesman for the automatic equipment could easily gloss it over by saying that it wasn't much traffic anyhow, and it was cheaper than paying operators). Indeed, it was claimed that because automatic satellites could be used more freely than small manual exchanges, an overall economy of line plant could be obtained by judicious use of them. Although the claim was somewhat premature, mainly because all the problems of network design were not yet understood, it marks the first realisation that exchange area design, junction network design, and equipment design are inter-related. Traffic between adjacent satellites in such a network would not be enough to justify direct junctions.

In areas requiring more than 10,000 lines capacity which was the practical limit of a manual multiple exchange, the network would be divided into several exchanges. An automatic system for such an area requires an extra rank of switches, and it is easy to see how the 1st selectors would then be regarded as "Office Selectors". Each 10,000 line exchange would have its own 1st selectors and a full mesh of junctions to the other exchanges. Almost certainly, there would also be some smaller exchanges which could be better treated as satellites, and these would be connected to the nearest of the large exchanges to produce a scheme.

In this way the main and branch exchange trunking scheme was evolved. This may seem, in retrospect, to be no great achievement, in fact, it seems that the system almost invented itself, but we must not forget that we have the advantage of 50 years of experience. For these pioneers, every step brought new problems. The mere introduction of junctions required the development of repeaters, which was no easy task, and in fact, this was the weakest element in the early exchanges. The need for economy in junction usage led to the creation of more effective trunking arrangements, and even the use of 5-digit numbers was approached very cautiously for fear the subscriber's memory would be unequal to the task.

There is no evidence of any but the most primitive ideas on traffic theory at that time and the evolution of main and branch trunking was largely empirical. However, looking back half a century later, the solution is seen to be quite efficient. The star network linking branches to mains assembles the small quantities of traffic from the branches, to give a sufficient traffic to

* See page 501.

justify the mesh between main exchanges. Every link in the network carries enough traffic to operate at reasonable efficiency, and at the same time by using a number of tandems, the actual junction routes followed by most calls are nearly the same as if direct junctions were provided.

ORIGINATING REGISTER CONTROLLED SYSTEMS

In larger cities, such as London, New York, Chicago or Paris, some more versatile system was needed. A step-by-step design was prepared for London in 1919, but rejected because of its inflexible and uneconomic junction arrangements. The first successful system for a large city was the Western Electric Panel system, designed from the start with New York in mind, and must be accepted as the first instance of a complete system design. The essential features were the use of a device called a "Sender" in which the exchange code was translated into routing instructions which could be different at each exchange. Therefore each exchange could have direct routes wherever it wished, and pass the remaining traffic via tandems. The exchanges served by any tandem were determined purely by junction economics, and the dialling code had no influence on tandem routing. The resulting network was at least as efficient as the manual network it replaced, and could be changed to meet almost any need as development proceeded.

Soon after this, the "Director System", which gives essentially the same facilities with bi-motional selectors, was developed. At the same time a number of machine driven systems similar to the "Panel" system came into use in Europe, the main ones being the Rotary system, and the Ericsson 500 outlet selector system. In all of those, the junction switching provided for one or more tandems, and each exchange had its own routing scheme in which traffic to a particular destination was carried either by direct junctions, or via one or more of the tandems. The routing of a call was completely determined at the originating point where all routing "intelligence" was located.

The translation of the dialled digits into a completely different routing code required elaborate and expensive circuits and the development of these systems was possible only when it was realised that, since the equipment which controlled the routing of a call was only used for about 15 seconds per call, it need not be a permanent part of each 1st selector. Instead, a common pool of control equipment was provided with facilities for the 1st selectors to gain access to an idle one when required. The development of this technique, which is generally referred to as "common control" therefore marks a definite stage in the development of junction networks. The facilities it provides were adequate for the most complex telephone junction networks and from 1920 to 1930, virtually every large city in the world adopted plans for conversion to automatic operation. The common control and step-by-step systems both found applications, as it was only in the larger networks that the junction savings possible by common control were sufficient to offset its higher cost.

Once a large telephone network is committed to the use of a particular system, it is very expensive to change it, so that after about 1923 there came a period in which no completely new systems were developed. On the other hand, there was a considerable amount of adaptation of the basic design to meet local requirements of the various networks, and continual improvements in details.

ALTERNATIVE ROUTING

The next major change in junction switching facilities came when attempts were made to convert trunk networks to automatic working in the 1930's. The trunk networks had all the features of the large manual metropolitan areas, except that traffic densities were lower, more emphasis was placed on obtaining the greatest traffic capacity from every trunk so that delays were considered as a normal state, and a considerable amount of tandem working was unavoidable. The early ideas were simply to rearrange the manual network with its mesh of numerous small routes so that it became more or less a star network, and to provide automatic switches instead of operators at the tandem points. This was really only the same as was done in the early metropolitan areas when they were converted to automatic but it was less successful because of the smaller volumes of traffic, and the higher costs of individual circuits. It was found to be essential to retain alternative routing and since the network was under the control of trained operators, this could be done simply by giving the operator a list of the dialling codes for the various alternatives.

Attempts to provide a fully automatic alternative routing scheme encountered problems which could not be solved by the use of originating registers, and eventually led to the development of a completely new approach to switching. The obvious solution of providing the originating registers with additional facilities would have made them far too complex and expensive. Furthermore, any change in the trunk network would require every register to be re-strapped to record the new routing and in a large network it would be very difficult to avoid errors creeping in. A second problem was "post dialling delay", which of course is present in any register system but is greatly aggravated with alternative routing because of the large number of switch operations which may be needed to establish a call. A third problem is that an originating register cannot easily be made to control the switching between different alternatives at a distant tandem.

The first part of the problem was overcome by distributing the intelligence over several devices, each responsible for control of routing through its own exchange, or often through a single switching stage. A change in the network would then require modification to a very small number of control devices, and each control device had a limited function to perform. This also provided a solution to the third of the problems listed, but greatly increased the amount of information transfer between the register and the intermediate devices, so that high speed signalling became absolutely essential.

CROSSBAR SYSTEMS

In implementing this type of system, crossbar switches have great advantages. Each group selector stage in a crossbar exchange must have a common control device or marker to control the switching of the link trunked sub-stages, so that all that is needed is to add more facilities to the marker. Moreover, because of the inherent high speed switching of crossbar, one marker can control 160 selectors, so that there are relatively few markers involved. The cost of adding these facilities is therefore very small, so that, although it was first developed for trunk networks, alternative routing is now offered as a matter of course in any crossbar system.

It can be seen that the basic difference between the three systems of automatic switching lies in the method of providing routing intelligence. In the step-by-step systems intelligence was permanently associated with the individual switches, and because of this, economic considerations placed a severe limit on the flexibility which could be provided. The use of originating registers provided a system in which the intelligence was separated from the switches, so that one register might suffice for as many as ten selectors and a considerably more sophisticated scheme could be justified. In modern crossbar systems an even greater degree of flexibility is attained by dividing the intelligence into blocks, distributed through the network, and only calling in those blocks required for the call being handled. Thus the registers and markers in Sydney do not know that Busselton is a secondary centre in the Bunbury Primary Area. They merely know that all National codes commencing with 09 are switched via Perth, and when a Perth trunk is seized a register or marker will be called in which will know how to switch the call.

THE ORIGINAL SYDNEY AUTOMATIC NETWORK

All the different types of automatic systems were developed by the manufacturing companies in response to either an explicit need or an anticipated need of the operating organisations, and there has at all times been an inter-action between the traffic patterns of telephone networks, the plant available to provide junctions, and the switching equipment. The history of every telephone network displays this

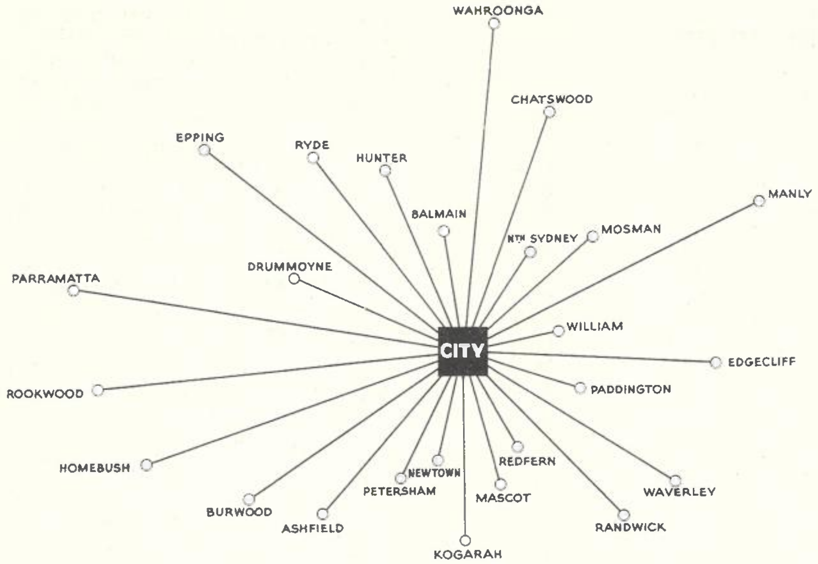


Fig. 1.—Sydney's Manual Network from 1904 to 1914.

kind of inter-action, and Sydney is a typical example.

Commencing in 1882 with a 50-line magneto switchboard, the Sydney Network rapidly evolved until by 1904 it consisted of 28 exchanges, as shown in Fig. 1. Most of these exchanges were established haphazardly in existing Post Offices wherever the demand arose, but those opened after 1898 seem to have been established on the basis of an overall plan. However, planned or not, this network remained substantially unchanged for 30 years.

As early as 1913 the Australian Post Office had decided that the larger telephone networks would be automatic, and in 1914 the conversion of the Sydney network was commenced. At that time, of course, there was no alternative to step-by-step switching, and a main and branch exchange scheme was adopted with nine main exchanges and 5-figure numbering. The earliest record of this switching scheme is a drawing dated January 1913, and Fig. 2 is based on this. Three problems associated with conversion of a large network to step-by-step automatic are the changes in junction configuration, the need to establish a main exchange before its branches, and the handling of automatic to manual traffic during the transition period. These problems were particularly acute in Sydney because, for its size, it had a surprisingly large number of exchanges. Thus, Los Angeles with rather more telephones had ten exchanges, and when it was converted to automatic, six were trunked as mains, and the pre-existing junction network was only altered slightly.

It was obviously out of the question to convert all of Sydney in one step and a fairly long period of mixed automatic and manual facilities was inevitable. Traffic from manual to automatic could be handled by dialling in, and City Exchange was equipped with special key senders for the purpose, while at least some smaller exchanges had dial keys and dials on each position. Traffic from automatic to manual was handled by dialling codes giving access to operators at the called exchange. As the dialling codes were spread over all levels, this required the 2nd selector component of all main exchanges to be set up, and provided a strong inducement to convert the main exchanges to automatic. This, surely, is the reason why eleven exchanges in Sydney were converted in the first two years.

The first purchase order for automatic exchanges provided for Newtown (L), Glebe (M), and Balmain (W) main exchanges together with key senders and 1st selectors for Central (B). These exchanges were close together, and direct junctions between them were readily provided. It is not known whether at this stage any dialling codes were provided for access to manual exchanges other than City. The second purchase order was for Ashfield (U) main with branches at Burwood (U4, 5), Homebush (U6), Lidcombe (U7) and Parramatta (U8), Randwick (A) main, Mosman (Y) main and Vaucluse (F7) branch with F level second selectors in City. By reference to Fig. 2, it can be seen that only the J and X mains were left to be established. The Y level for Mosman was a temporary measure pending establishment of the J Main Exchange, and apparently Wahroonga and Chatswood were to be manually switched at North Sydney and Mascot and Kogarah at Redfern.

Some changes were made, even before the equipment was completely installed. It was decided that the Randwick equipment could be used better at Chatswood and the effect of this is seen in the dialling codes listed in Table 1 for October, 1916. Chatswood was given level J and switched for Wahroonga and North Sydney, while the A group was given temporary codes on level M, the most convenient level available. Another unrelated change was that Kogarah was switched via the L group and thus the two small exchanges at Mascot and Liverpool were the only ones not directly accessible to automatic subscribers. Further changes which were made in the next few years are also shown in Table 1. It was realised that switching North via Chatswood was inefficient

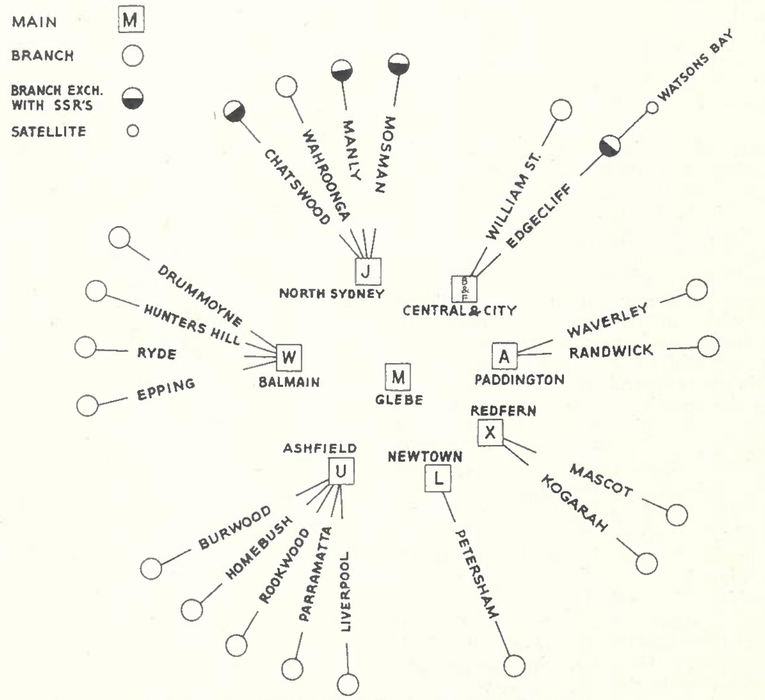


Fig. 2.—Automatic Network as Proposed in 1913.

TABLE I
DIALLING CODES 1913 TO 1923

Exchange		Proposed 1913 (1)	Oct. 1916	Oct. 1918	April 1923
Ashfield	(A)	U (4)	U (4)	U (4)	U (4)
Balmain	(A)	W (4)	W (4)	W (4)	W (4)
Burwood	(A)	U	U 4, 5	U 4, 5	U 4, 5
Central	(M)	B (4)	B (4)	B (4)	B 9
City North	(A)	—	—	—	B (4)
Chatswood	(A)	J	J (4)	J (4)	J (4)
Drummoyne	(M)	W	W 4	W 4	W 4
Edgecliff	(M)	F	F 1	F 1	F 1
Epping	(M)	W	W 8	W 8	W 8
Glebe	(A)	M (4)	M (4)	M (4)	MW (4)
Homebush	(A)	U	U 6	U 6	U 6
Hunter	(M)	W	W 3	W 3	W 3
Kogarah	(M)	X	L 8	L 8	L 8
Lidcombe or Parkwood	(A)	U	U 7	U 7	U 7
Liverpool	(M)	U	B (3)	B (3)	B 9 (3)
Manly	(M)	J	Y 7	Y 7	Y 7
Mascot	(M)	X	X (2)	M 7	M 7
Mosman	(A)	J	Y (4)	Y (4)	Y (4)
Newtown	(A)	L (4)	L (4)	L (4)	L (4)
North Sydney	(M)	J (4)	J 6	X (4)	X (4)
Paddington	(M)	A (4)	M 6	A 1	F 2
Parramatta	(A)	U	U 8	U 8	U 8
Petersham	(M)	L	L 4	L 4	L 4
Randwick	(M)	A	M 9	A 7	F 9
Redfern	(M)	X (4)	M 4	M 4	M 4
Ryde	(M)	W	W 7	W 7	W 7
Wahroonga	(M)	J	J 7	J 7	J 7
Waverley	(M)	A	M 8	A 4	F 8
William	(M)	F	F 5	F 5	F 5
Vaucluse	(A)	F	F 7	F 7	F 7

Notes: (1) First digit only.
(2) Manually switched at Redfern.
(3) Manually switched at Central.
(4) Main exchange.

and no doubt gave poor transmission, so Redfern and Mascot were moved to the M level to free X for access to North. Paddington, Randwick and Waverley were established for a while on their planned codes of A1, A4 and A7 (with, it is believed, selectors at City), but because of false traffic troubles they were transferred to the F level.

After these initial adjustments, the switching and numbering became almost frozen, and as time went on it became progressively harder to modify it. Now that the basic network was established, conversion to automatic took place at a much more leisurely rate only as exchanges became worn out or unable to cope with further growth. During this period the exchange areas which had been established by 1904 were almost invariably followed, the only exceptions being the opening of five new exchanges in areas of rapid growth remote from existing exchanges (Rose Bay, Dee Why, Lakemba, Sutherland and Cronulla) and a redesign of the inner city area into City North, City South and City East. Fig. 3 shows the network as it was in 1931, and should be compared with Fig. 2.

During this period the register controlled systems were developed and applied overseas to many networks similar to Sydney. However, the Department continued with the use of step-by-step, on the basis that the advantages of register working were not sufficient to justify a change. Another factor was that register working was not economical in small exchanges because of the high "first in" cost, so that exchanges of less than about 3,000 lines would have to be trunked as satellites in any case. Manchester, for example, with a network very similar to Sydney had 33 exchanges of which only 11 were equipped with directors.

INTER-WAR REVISIONS

The 1930's saw a renewed interest in studies of the network as a complete entity, due no doubt to a realisation that the "suburban sprawl" was causing problems that were not capable of solution by following established precedents. Transmission conditions, for instance, were becoming intolerable with longer junction routes, and a survey of transmission was made in 1931 which led to the introduction of loading on a number of routes. (Up till then, the only loaded junctions were from Newtown to Sutherland and Cronulla.) The transmission scheme was based on a main-main attenuation of 7 db and a main-branch attenuation of about 3.5 db.

Exchange area design was the next topic to be studied and here spectacular changes were made. The British Post Office had investigated the relationship between economic sizes of exchanges and the telephone density and had reached conclusions which favoured rather small exchange areas. The adaptation of this work to the Sydney network was almost entirely the work of

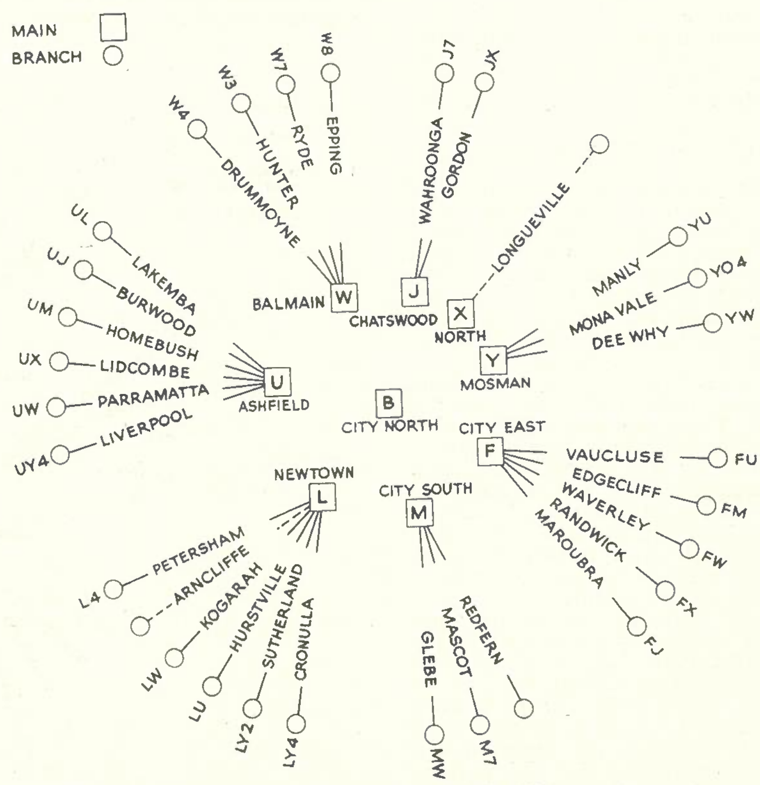


Fig. 3.—The Sydney Network in 1931.

one man, Wilfred Hayes, who was then Telephone Survey Officer. He conducted the first survey of the Sydney network on modern lines and concluded that in 20 years many more exchanges would be required. He recommended a network of 77 exchanges which has been followed with very little change up to the present.

The effects of this redesign were very widespread. Firstly, it meant that for quite a few years development would be met by opening new exchanges, while the existing exchanges remained the same size, in terms of subscribers connected, but had their areas reduced; incidentally, several manual exchanges such as Ryde, Epping, Liverpool and Wahroonga had their life extended by up to 15 years in this way.

Secondly, there were insufficient levels to meet requirements. The numbering plan could cope with eight branch exchanges on each main, and with the B group reserved for City North and the Y group reserved for trunks, this placed a limit of 64 exchanges. Fortunately, a number of the exchanges were under 1,000 lines in 20 years and were given satellite numbering from the nearest branch exchange, and the minimum number of junctions in one call increased from three to five. Up till this time spare levels had been used at the main exchanges for 5-figure numbers, but with the exception of the B and M groups, this was no longer possible. The proposed switching and numbering plan which finally evolved is shown in Fig. 4.

Thirdly, a further review of transmission was necessary, as many of the new exchanges were in the outer part of the network and it was found economical to increase the attenuation allowance for main-branch junctions at the expense of main-main junctions. The reduced main-main attenuation was economically achieved by loading existing junctions and the distribution of attenuation was about 4 db main-main and 5 db main-branch. The use of loading allowed lighter cables in some cases and for the first time junction loop resistance became a major consideration.

Also, for the first time, it was seen that the limit of 6-digit numbering was being approached. It was believed that 7-digit step-by-step was impracticable and that eventual conversion to the Director system was inevitable, but the prospect was in the distant future.

INTER-BRANCH JUNCTIONS

The first branch exchanges in the U group were equipped with switching repeaters, similar in principle to Discriminating Selector Repeaters (D.S.R's) which were used for local switching only. They appear to have been unsatisfactory and were scrapped after a few years, Burwood, Homebush and Lidcombe then becoming repeater branches and Parramatta being equipped with Switching Selector Repeaters (S.S.R's) of an improved type. Later exchanges were equipped either with S.S.R's or repeaters depending on the economics of line plant and equipment costs, but inter-branch switching was not employed, mainly because of the small volumes of traffic offered. It was not until about 1940 that any great application of inter-branch switching was made, initially in the F and U groups. In the last few years it has been found possible to provide alternative routing on inter-branch junctions by suitable D.S.R. modifications.

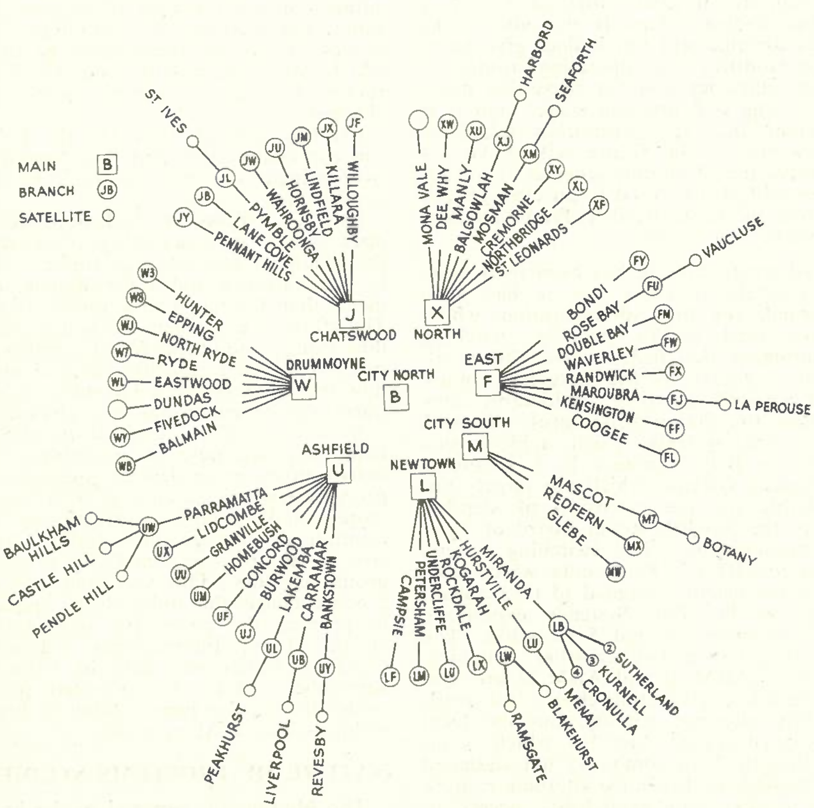


Fig. 4.—Proposed Redesign of Sydney Network in 1941.

POST-WAR DEVELOPMENTS

By 1947 the need for 7-digit numbering became urgent but this was a most inopportune moment to make a change. Automatic equipment was in such short supply that it was impossible even to meet development, let alone embark on a complete conversion of the network. Moreover, it was apparent that new developments which were around the corner could completely change our ideas on automatic equipment. The emphasis therefore was placed on extending the life of the 6-digit system by transferring exchanges from heavily loaded to lightly loaded groups, and using the Y level, which was being reserved for trunk access. This new numbering plan involved much more use of satellite working to make maximum use of each code, the B level co-main system in the city, and changes to the telephone numbers of many subscribers. It is interesting that all these techniques were foreshadowed in a step-by-step proposal for the London network which was published in 1919 and was rejected as being unreasonably complicated and too inflexible. This scheme achieved its object of deferring conversion to register control over the period between 1950 and 1960, which has been a time of intensive development of new switching systems, with the result that the crossbar equipment now being introduced is much superior to any of the systems available in 1950.

CONCLUSION

The Australian Post Office is now again at a turning point in the development of the telephone system, and the next few years will see many dramatic changes comparable to those in the period 1914 to 1920 when automatic operation was first established in the larger cities. In preparing the information for this article it has been interesting to discover many parallels between problems now being faced and those which were encountered with the original conversions to the step-by-step system. Let us hope that our solutions will stand the test of time in the same way as those of our predecessors nearly half a century ago.

MORE ACCURATE CALCULATION OF OVERFLOW TRAFFIC FROM CROSSBAR GROUP SELECTORS

*N. M. H. SMITH, B.E.E.**

INTRODUCTION.

This article has been written as a brief general description of a detailed mathematical paper which is to be published separately as an Australian Telecommunication Monograph (See page 475—Ed.). The Monograph will comprise a theoretical paper on telephone traffic engineering, as applied to crossbar exchanges, which was prepared for presentation at the Third International Teletraffic Congress held in Paris in 1961. The most important result to date has been a set of universal overflow traffic graphs which can be employed with any type of trunking, and is not restricted to crossbar.

PAST TRAFFIC ENGINEERING PRACTICES.

One of the more useful attributes of step-by-step switching equipment is the comparatively easy traffic engineering. This can be best explained with an illustration. With step-by-step, all one has to do to get the number of circuits on a particular route is to measure the traffic, check the availability of the switches, note the required grade of service and look up the answer from the correct page in one of the quite small number of standard traffic tables. One does not have to consider, for example, the number of racks which feed the grading or the way which those racks are cabled away to the T.D.F.s, since one knows that the standard book of grading schedules contains an arrangement which will give satisfactory results. Of course, all this simplicity is not obtained for nothing. Unfortunately, the advent of crossbar means that henceforth things are not going to be quite so easy. Not that this means that crossbar is intrinsically more complex, since it isn't, but rather that the Australian Post Office has adopted crossbar in order to employ certain new trunking possibilities which will save money. One of the more important of these trunking possibilities is alternate routing.

ALTERNATE ROUTING.

Alternate routing is not a new technique, but it has never been used very extensively in Australia because of the limitations of step switching equipments. The method seeks to obtain the best of two worlds: If you wish to have short direct junctions which will bypass a large number of switching stages in your telephone network, you can provide direct routes between the branch exchanges. This, however, has the disadvantage that the routes are small and, if they are provided at the standard grade of service, the circuits are very lightly loaded. An alternative technique which has been extensively used in the step-by-step networks of Australia, is to route the traffic via a succession of main exchanges, thereby achieving large routes and good circuit loadings but, at the same time, the calls must pass through a large number of switching and junction stages and this is also expensive. Alternate routing combines the advantages of the first course with those of the second by letting one provide a limited number of direct circuits between the branch exchanges while the residual traffic overflows via fairly large routes through the main exchanges. Since the direct routes between the branch exchanges now have a poor grade of service, their efficiency remains high and the average cost of disposing of the direct traffic is low. The traffic passed via the main exchanges is still expensive to handle but it is now only a small percentage of the total and a very considerable overall reduction in the average cost has been made.

Theoretically, this technique can be extended by providing direct routes to each group of 1000 lines (SL stage) in each branch exchange to which there is sufficient traffic to justify this step, overflowing the sum of the remainders to the incoming group selector (GIV) in that exchange, which gives access to the whole of it, then overflowing the sum of the remainders for a group of branches to the parent tandem for that group, etc., to give a total of 3 or 4 or more choices. This is not always the best arrangement but it does give many opportunities for operating routes at high efficiency and for bypassing many switching and junction stages, and it is certain that the Australian telephone networks of the future will make extensive use of similar schemes. The process will also be used to an even greater extent in the Subscriber Trunk Dialling system.

Alternate routing has been used quite extensively overseas but it has been normal, for the Administrations which have used it, to provide switching equipment designed to give full availability access to the outgoing routes. As we will see, this considerably simplifies the design procedures. Typical switching systems which achieve this are the Bell Numbers 1, 2, 4 and 5 Crossbar systems, which are largely unsuitable for the extension of step-by-step, the Swedish Royal Board of Telecommunication's Toll switching system, and the I.T.T.'s Pentaconta which was, to some extent, designed to take advantage of the Bell System's experience with Numbers 4 and 5 Crossbar. The L M Ericsson Toll crossbar switching systems ARM.50 and ARM.20 are also designed to give multi-choice full availability alternate routing, but the local exchange system ARF.101 which is installed in Toowoomba is not designed to provide multi-choice alternate routing or to give full availability access to junction routes.

AUSTRALIAN SWITCHING REQUIREMENTS.

During the course of those investigations which led to the adoption of the L M Ericsson switching systems as the standard for use in Australia, it was soon realised that ARF.101 could be modified simply to provide multi-choice alternate routing, since it already catered for two choice alternate routing, but it could not provide full availability access to the junction routes. This was at first thought to be a serious disadvantage, but further investigation showed that if a satisfactory design procedure could be found, the 400 outlet group selector used with ARF.101 would be quite suitable for exchanges with total originating traffics up to about 250 Erlang whilst other arrangements could be made for larger exchanges.

Once it was decided to adopt the L M Ericsson crossbar systems and to modify ARF.101 to give multi-choice alternate routing, it became necessary to provide tools which could be used by the Traffic Engineers in the Department's State offices, who had to design the alternate routing schemes to be used with those exchanges. From this came the following conclusions:

(i) The existing L M Ericsson traffic tables were based on approximate expressions which, whilst reasonably accurate for good grades of service, became considerably less accurate for grades of service comparable to those which would be provided on the direct routes between crossbar branch exchanges.

(ii) The general defect in the Ericsson expressions was that they tended to over-estimate the overflow traffic at high congestions.

(iii) No expressions had been developed which gave anything more than the mean of the overflow traffic. That is, the variance and other higher moments than the mean were not available. Therefore, the manner in which overflow traffics should be added together in order to properly specify the total overflow traffic offered to a second or subsequent choice route was not obvious.

It was, therefore, decided to put in hand a programme of probability research in order to deduce equations or processes which would give a much more complete and more accurate description of the overflow traffics from circuit groups connected to crossbar group selectors. This was done and, as a consequence, the author was requested to prepare the paper for presentation at the Third International Teletraffic Congress which was held in Paris in September, 1961. As indicated previously, this is the paper which is being published as a Monograph.

NATURE OF PROBLEMS STUDIED.

The Monograph paper gives the basic mathematics which have been used to

* See page 502.

produce a large number of graphs, and which will be used in the near future to produce an advanced computer programme which may be used to carry out the entire alternate routing calculations for a crossbar exchange. The mathematical methods of the paper are not new but some of the techniques have not previously been employed by telephone traffic engineers. Several different problems are considered but the basic essence of all can be explained by reference to one of them. For convenience, we take the first which deals with the overflow traffic from a route connected to the ordinary 400 outlet ARF.102 group selector. This route contains a number of circuits designated c of which n are busy at a particular instant in time. We also define $\beta(n)$ as the average probability that, if a call arrives at a time when n out of the c circuits are in use, the call cannot be connected to the route and must overflow. Given these assumptions and the average offered traffic (A), which, for simplicity, we assume to be Erlang (that is, Pure Chance or Poissonian), we obtain a system of difference equations which defines the inter-relationships between the probability states for the numbers of calls on the route itself (n), and the numbers of calls which have previously overflowed from that route (m). These interrelationships are illustrated in Fig. 1.

equations into a finite system of simultaneous differential equations. This technique is known as the employment of Generating Functions. The employment and understanding of Generating Functions is certain to gradually become more important to Australian traffic engineers with the passing years since they can be used for many purposes and can lead to some very practical and elegant simplications.

Systems of simultaneous linear non-constant co-efficient differential equations such as have arisen in all of the problems considered in this paper are rarely if ever really easy to solve. Very fortunately, however, the telephone traffic engineer is not normally interested in the general solution of such systems of equations but only in their solution at or close to the one point in the range where the boundary conditions can be defined. Even more fortunate is the fact that it is usual for the systems of simultaneous differential equations which are obtained by the traffic engineer to have a singular point (that is, a point at which the algebraic coefficients of some of the higher order differential terms in a differential equation become zero) at the point at which the boundary conditions can be specified. This is very good because it quite often permits one to trick the equations into giving one a finite set of simultaneous linear equations, which are

provide a Double Testing system. This is an arrangement in which a group of outgoing circuits is reached from the first group selector of the pair through a small availability, and the traffic which cannot be connected at this point overflows to the second group selector unit which also gives access to the same routes through another and usually much larger availability. This is illustrated in Fig. 2.

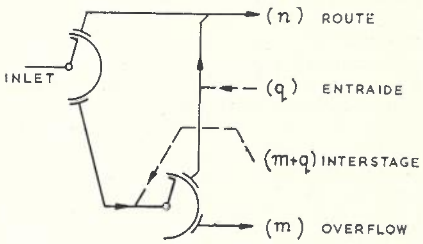


Fig. 2.—Double Testing Access System.

The advantage of this is that the total availability to the route is very nearly equal to the sum of the availabilities given by the first and second group selectors, but the quantity of traffic which must be handled by the second group selector is reduced to perhaps one-tenth. The nett effect of all this is that the total number of subsidiary

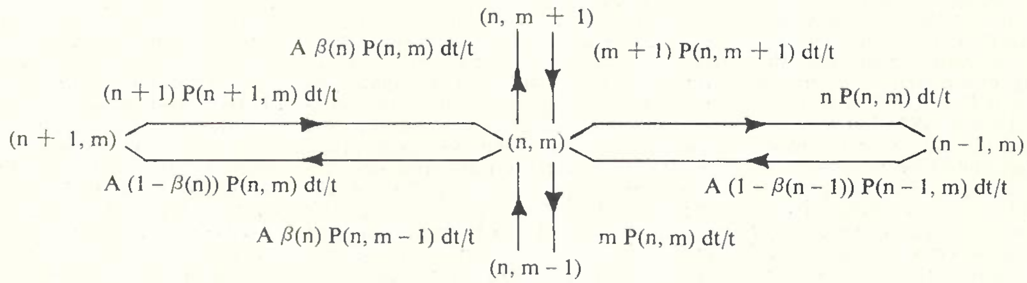


Fig. 1.—Probability Relationships Around State (n, m).

Since for strict accuracy, the overflow route must be assumed to be of infinite size, we have an infinite number of probability states (n, m) and therefore an infinite number of differential equations. A typical equation from this set, which is also the first equation given in the paper, is:

$$\begin{aligned}(A + n + m)\,P(n, m) &= (m + 1)\,P(n, m + 1) \\ &+ (n + 1)\,P(n + 1, m) \\ &+ A\beta(n)\,P(n, m - 1) \\ &+ A[1 - \beta(n - 1)]\,P(n - 1, m) \quad \ldots\ldots (1)\end{aligned}$$

where P(n, m) is the joint probability of n calls on the route and m on the overflow and so on.

Fortunately, one does not have to do an infinite amount of work to solve an infinite number of such equations since, if one can find a general solution for some typical equation from the set plus some sort of boundary condition, it is possible to solve the whole with a finite number of steps. This can be done by using a well known probability technique which converts an infinite (or finite) system of simultaneous difference

easily solved with an electronic computer.

The material of the Monograph paper is largely a description of this process as applied to two situations, plus extensions. This part of the treatment is sufficiently detailed to make the subsequent calculation procedures obvious. Quite a surprisingly large number of previously known results also fall out as by-products. This appears to be because of the quite general formulation of the problems.

OTHER PROBLEMS — DOUBLE TESTING AND "ENTRAIDE".

Several other problems are considered in less detail. These arise if a group selector is not large enough to be efficient. Under these conditions one method which can be employed to improve the performance is to provide a subsidiary unit to which some of the circuits can be connected. However, this arrangement is also not very efficient because subsidiary units are expensive and a much better arrangement is to

group selector units required in a large exchange is cut to perhaps one third whilst the overall trunking efficiency of the outgoing routes is better. A similar testing system is used with Pentaconta except that with this equipment, calls which overflow from the route after the second test do not remain connected to the second group selector but drop back to the first before the next attempt. This is more efficient but it leads to other difficulties, the most notable of which is that excessively large crossbar selectors are required.

The second of the five problems covered in the paper deals with this situation and shows that the statistical moments, that is, mean and variance, etc., of the overflow traffic, the interstage traffic (traffic between the first and second group selectors), and the resubmitted or "entraide" traffic in the Pentaconta terminology, can be calculated by fairly simple methods. The fourth and fifth problems are concerned with similar arrangements but the circuit groups are not offered Pure Chance traffic. In these cases the offered traffic is specified in terms of its first four Factorial Moments. Factorial Moments are a piece of quite convenient mathematical trickery which are fully explained in the first and third problems of the paper.

SOME DISCOURAGING EQUATIONS.

The complexity of the equation systems obtained from the fourth and fifth problems forced the author to adopt some of the standard mathematical techniques employed by, for example, aeronautical engineers analysing the influence of solid friction in air frames. These techniques certainly lead to solutions but the resulting processes are extremely tortuous and the author would be most grateful to receive suggestions from any reader who can offer more economical alternatives. The search for economical and systematic methods for the solution of simultaneous linear, non-constant co-efficient differential equations of higher order than the first is not merely interesting but also of great potential practical value, and the author commends it to the attention of all who are mathematically inclined.

EQUIVALENT RANDOM METHOD

Because of these difficulties, an artifice was found which permits quite accurate solutions to be obtained without solving the equations directly. It is based on a method originally discovered by the American mathematicians, Nyquist and Molina, who investigated the full availability group some time in the late 1930's. (A Bell internal report appeared during 1939 or 1940 but this was never published as far as the author knows; however, it has been referred to in other Bell articles.) They discovered that if one had a specific traffic offered to a group of n circuits which was characterized by a known mean intensity α and a known variance v ($v = \sigma^2$ where σ = standard deviation), it was possible to obtain the mean and variance of the traffic overflowing from the group of circuits by first assuming that the input traffic (α, v) was the overflow from a group of n_1 circuits offered an Equivalent Pure Chance traffic E.P.C. That is, they found that if they had the equations which gave the mean and the variance of the traffics overflowing from groups of circuits which were offered Pure Chance traffics, they could always invert these and find a number of circuits n_1 and a Pure Chance offered traffic E.P.C. which would explain a given mean (α) and variance (v). They then found that, if they assumed that the Equivalent Pure Chance traffic E.P.C was offered to the group of circuits n_1 plus the number of circuits n to which the original traffic (α, v) was offered, then the overflow traffic from the whole system (α'', v'') was correct. That is the E.P.C. offered to the $n_1 + n$ circuits gave the correct result.

GEOMETRIC GROUPS.

After some work, it was found possible to generalize this method to include arrangements which were not full availability by introducing the concept of two state devices, called "toggles", one of which was placed against each circuit in the route. The idea of the toggles is that each is independent of its fellows and if it is in its "off" condition when a call arrives, the corresponding circuit in the route cannot be taken by that call even if it is free. Such a system has the property that the probability of a call arriving and overflowing if it is offered to a route with c circuits when there are n calls in progress will be given by:

$$\beta(n) = p^{c-n}$$

where p is the probability that a particular toggle will be turned off. Of course, this assumes that all of the toggles have identical probabilities of being turned off. When viewed as a function of n, this loss characteristic $\beta(n)$ can be seen to be a geometric series, and for this reason the corresponding purely theoretical circuit group is called a Geometric Group.

UNIVERSAL CONGESTION GRAPHS

The tremendous utility of the Geometric Group comes from the fact that it is a very good approximation to practically all kinds of actual trunking. Thus, no matter what trunking arrangement is used, whether it be bimotional switches with grading, random start sequential hunting motor uniselectors with interconnecting schemes, or Crossbar equipment, of any of the known types, the envelope of the $\beta(n)$ or loss probability characteristic is very nearly a geometric series. It therefore follows that if one can calculate the factor p for a particular piece of trunking one has merely to look up the appropriate mean and variance graph for the Geometric Group and one has in a moment the overflow traffic for any offered traffic. These graphs have now been issued as Departmental drawings and they will have very great significance as far as future Australian traffic engineering practices are concerned. For this reason reduced sample sheets are being included in the Monograph. The reasoning which permits one to know that the process discovered by Nyquist and Molina is valid for the Geometric Group is also given in the Transaction paper. It may here be added that there are very close analogies between the Geometric Group, the full availability group and electrical ladder networks, and that the author suspects that this may be how the original theorem was discovered.

PROBABILITY CO-EFFICIENTS.

The Monograph paper includes, finally, some notes on the methods used for calculating the $\beta(n)$ or arbitrary loss factors for the various routes and the problems which arise with multi-choice alternate routing schemes from the ARF.102 group selector. Under multi-alternate routing conditions, this selector suffers from a rather curious limitation which we have called Correlated Availability.

The Correlated Availability problem arises because the successive routes in an alternate routing sequence from the ARF.102 group selector are tested through the same links and this means that, if a call overflows from one route, it is quite likely that several of these links must be occupied because the first route almost certainly had some unoccupied circuits, one of which could have been reached if those particular links had not been occupied. This means that, when an overflow call is offered to the next route in the testing sequence, it will be much more likely to overflow from that route than would a fresh call. This is a serious problem which must be allowed for when designing the arrangements. Methods have recently been developed which make safe designs practicable.

RELATIVE PERFORMANCE OF SYSTEMS.

The Monograph paper concludes with a few remarks about the comparative performance of different switching systems, which are of interest because they may yet bring about the development of a much improved first switching stage for use in ARF.102 exchanges. Reduced copies of some of the more important graphs presented at the Congress are also included.

PRESENT AND FUTURE WORK.

A good deal of work has already been done to produce practical results from this theoretical work, and a great deal more is being planned. The results to date are presented in several series of graphs which include such information as:

(i) Optimum numbers of circuits on Direct Routes with availabilities of 5, 10 or 20 outlets from ARF.102 group selectors, with inlet loadings of .5, .6 and .7 Erlang. Also, optimum numbers of circuits in Geometric Groups for p = 0.1 to 0.8 by steps of 0.1.

(ii) Required numbers of circuits and total interstage traffic for Double Testing arrangements with availabilities of 20 outlets at both stages and good grades of service (0.001, 0.002, 0.005 and 0.01).

(iii) Influence of Correlated Availability on mean effective availability of second choice routes. Computed for two cases of 10 outlet routes followed by 10 outlet routes, plus 10 outlet routes followed by 20 outlets and 20 followed by 20.

(iv) Mean and Variance of overflow traffics from Geometric Groups for p = 0.1 to 0.8 in steps of 0.1. These are now available in both large and small scale ranges.

(v) Mean and Variance of overflow traffics from 5, 10 and 20 outlet routes from ARF.10 group selectors with inlet loadings of .5, .6 and .7 Erlang.

(vi) Mean of overflow and interstage traffics for Double Tested routes from ARF.102 group selectors. Availabilities are 10 followed by 10, 10 followed by 20, and 20 followed by 20. Inlet occupancies are .6 and .7 individually and in combination.

Generally, it can be said that the theoretical models have stood up well to various tests and, for example, the results which they predict agree very well with the results of simulations. However, a great deal more checking and testing still needs to be done, particularly where the more complex trunking arrangements are involved. In addition to this, it is also becoming obvious that the multitudinous practical situations, which can be covered by suitably changing the co-efficients in one or two of the theoretical models are much too numerous to be covered by "Graphs for All Occasions" and the Department's Headquarters traffic engineering group is now slowly advancing toward a general kind of computer programme which will employ the basic recurrences which have been deduced from the mathematical models to carry out the entire calculation. Unfortunately, the present limit to this proposal is that it requires a computer of the calibre of an IBM 7090 if the calculations are to be completed in a reasonable time. However, one can reasonably expect that, given time, it will be possible to reduce this difficulty to manageable proportions.

NEW PUBLICATION

AUSTRALIAN TELECOMMUNICATION MONOGRAPHS

Arrangements have been made recently between the Australian Post Office and the Telecommunication Society of Australia for a new technical publication to be issued to supplement the Telecommunication Journal of Australia in describing telecommunication developments in this country. The Journal will still appear in its present form three times each year. The new publication will be known as the "Australian Telecommunication Monographs" and will cover specialized subjects which would not be of real interest to the majority of the readers of the Journal. Each Monograph will cover a single subject only and will appear from time to time on a non-periodic basis which will be determined by the supply of papers offered for publication.

The publication arrangements for the Monographs will be made by the Australian Post Office, editorial arrangements by the Board of Editors of the Telecommunication Journal of Australia, and copies will be supplied to subscribers through the Telecommunication Society of Australia. A separate charge will be made for each issue. Before each Monograph is issued a summary of the contents will be published in the Journal, and a subscription slip will be included in the relevant issue of the Journal to facilitate ordering.

The Society is extremely grateful to the Australian Post Office for initiating this new publication. As the Telecommunication Journal of Australia has been the only Australian technical journal specializing in telecommunications developments, it has had an obligation of providing a medium for the publication of all types of papers on telecommunications subjects, including ones of a highly specialized nature. At the same time it has been necessary in the interests of circulation and cost to ensure that each issue would appeal to the majority of readers who are Technicians and Engineers employed by the Australian Post Office. There has also been a further requirement of presenting information on Australian telecommunications developments to overseas readers in an endeavour to repay in some small way the immeasurable benefit that Australia has received from information published in overseas journals.

The general objectives of the Journal have therefore been to give a generally balanced coverage of all important developments in the telecommunication field in Australia, concentrating where practicable on topics of the greatest interest to the majority of readers, for example, exchange equipment developments, but at the same time acting as a publication medium for specialized articles which either contribute something new to the telecommunication art, or give a good survey of their field. In trying to meet these objectives it has been the hope of the Editors that a Journal of fairly high technical standard would also result, and that it would obtain a reputation at home and overseas as making a good contribution to telecommunications literature.

With any multiple objective the requirements must conflict from time to time. This has been the case with the Journal and it has been necessary on a number of occasions to reject very good articles because they have been too long and their field of interest too narrow. At other times articles which for best use as references warrant publication as a complete unit, have been divided into parts and spread over a number of issues. Some potential authors have also been discouraged from preparing articles for the Journal or have been persuaded to have them published in other journals. Nobody associated with the Journal has been happy about this situation, and it is hoped in the future that the new Monographs will overcome these difficulties and give a better service both to readers and to authors.

Two separate Monographs will be issued shortly. The first of these is a mathematical type of paper on telephone traffic by Mr. N. M. H. Smith and a summary of it is given in a short paper in this issue of the Journal. Wide interest in this paper was shown when it was presented to the International Tele-traffic Congress in Paris in 1961, and its standard was such that an offer for its publication was received by a well known overseas journal. The second Monograph will cover a series of papers on the preservation of wooden poles which will be presented at a symposium to be held in Melbourne shortly. Australia has made a number of contributions in the field of timber preservation and there is no doubt that some overseas organisations will obtain value from the information on Australian developments which will be given in the Monograph. The Society is proud that it will be associated with the publication of both these Monographs and feels that they will add to the prestige of Australia in the telecommunication field.

In general, papers appearing as Monographs will be more lengthy than those appearing in the Journal. For example, Mr. Smith's paper will occupy about 40 pages compared with the average length of Journal articles of about six pages. The timber preservation symposium issue will be even bigger. For this reason and because of the limited circulation expected, the charge per issue must be of the order of 10/-. However the exact price will depend on the demand and there is some difficulty in estimating the demand at this stage. It is most desirable that the Society should be able to quote a firm price for each Monograph before orders are taken, and it would be of considerable assistance if readers could indicate their likely requirements by filling in the questionnaire attached to the subscription slip at the front of this Journal. It is emphasized that this information will be used only to estimate total demands and costs and will not commit any reader to purchase any future Monograph. All readers are urged to co-operate in supplying this information which will be invaluable in connection with the launching of the new publication.

HIGH-SPEED RECORDINGS OF POWER AND RAILWAY TRACTION INTERFERENCE WITH COAXIAL POWER FEEDING

*J. LAMMERS, M.Sc.(E.E.)**

INTRODUCTION

During the installation of the Melbourne-Morwell Coaxial Cable System (1), it was found that the power fed over the two centre conductors of a pair of coaxial tubes to dependent repeater stations was switched off intermittently by the overload protection devices provided on the 2 x 600 Volt A.C. (50 c/s) remote power feeding equipment. The disconnection was effected by that part of the supervision equipment which senses the feeding current symmetry on the two tubes. To enable an investigation to be made into the nature of disturbing voltages interfering with the remote power feeding, special recording equipment was required. This article describes the recording equipment used and discusses the types of disturbances recorded.

A suitable commercial instrument for recording disturbances on a 50 c/s power supply is, for instance, the Ferranti Disturbance Recorder Type "S". This instrument records waveforms of 50 c/s signals on a paper chart, a recording being made only when a disturbance to the 50 c/s signal is observed. However, an instrument of this type was not readily available, and suitable recording equipment was then designed and built in the Long Line Equipment Laboratory, Central Office, of the Postmaster-General's Department. This equipment gave a satisfactory recording of various types of pulses (positive, negative and oscillatory) with durations as short as 2-3 milliseconds and with no limit imposed on the maximum duration of a pulse or a series of pulses. An indication of the time at which a disturbance occurred was also provided, and the recording equipment was designed for unattended operation.

Giving due regard to continuity and maximum speed of recording and to the range of instruments available, a set-up was chosen which permitted a permanent record to be obtained simultaneously on a high-speed paper recorder and on a high-speed tape recorder, these high-speed recorders being in operation only when a disturbance was present. A "memory" was required for storing the information on the disturbance until the high-speed recorders were switched on and ready for recording. A block schematic of the recording equipment used for recording disturbances on a standby coaxial tube (not carrying remote power feeding current) is shown in Fig. 1. Great care was taken to obtain a reliable "memory", preference being given to a delay magnetic tape recorder. When a disturbance was detected, the high-speed paper recorder and the high-speed tape recorder were made to record the output from the "delay recorder" by bringing their driving mechanisms into operation and removing the short circuit across their input terminals. This short circuit was introduced to keep the writing pen of the high-speed paper recorder in the rest position between recordings. All the necessary switching to start the recorders and for marking the time at which a disturbance occurred was carried out by contacts of relays operated by a device which detected the presence of pulses exceeding a certain magnitude and duration. These relays were kept operated for the duration of the disturbance and for a sufficient period after the end of the disturbance to obtain all information still stored in the memory.

GENERAL DESCRIPTION OF EQUIPMENT

The following paragraphs give a short description of the design and operation of the disturbance recorder,

* See page 503.

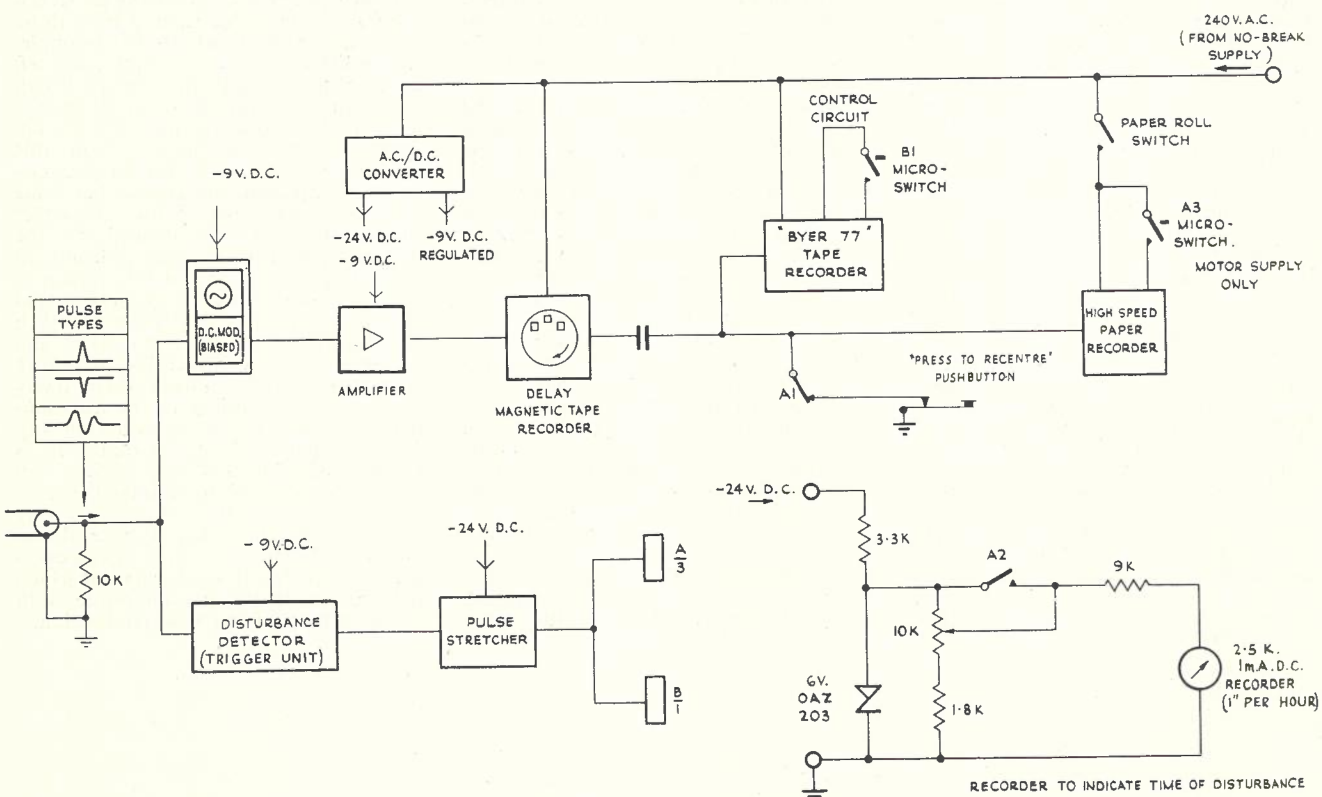


Fig. 1.—Block Schematic of Recording Equipment.

and make reference to the block schematic of Fig. 1.

A delay magnetic tape recorder was made up having three heads (a record, a play-back and an erase head) and with a motor suitable for continuous operation. To reduce wear of the magnetic tape a long tape loop (14 feet) was used, making one revolution in about 15 seconds. The most satisfactory results were obtained with magnetic tape with a "Mylar" base† (least wear and no breaks reported). The tape wear was kept to a minimum by careful adjustment of the pressure of the tape against the heads. Having taken these precautions against tape wear it was found possible to operate for one week without tape replacement. However, it was found desirable for the heads to be cleaned more frequently, preferably once a day. Because of wear it was found necessary to replace the heads after every four to six weeks of continuous operation. To commence recording of the conditions as existing on the cable well before the start of the disturbance, and to allow ample time for the high-speed recorders to obtain full speed after a disturbance was detected, the delay between record and play-back heads was set to about three seconds. The instrument provided a zero db gain between input and output.

The recorders used were suitable for recording A.C. signals only. All recordings were taken on a standby coaxial tube (not carrying a remote power feeding current) and the disturbances incoming from the cable were therefore modulated in a transistorised D.C. modulator using a 1 kc/s carrier. The modulator was DC biased to permit recording of positive and negative disturbing voltages. After amplification in a three-stage transistorised amplifier the signal was applied to the delay magnetic tape recorder.

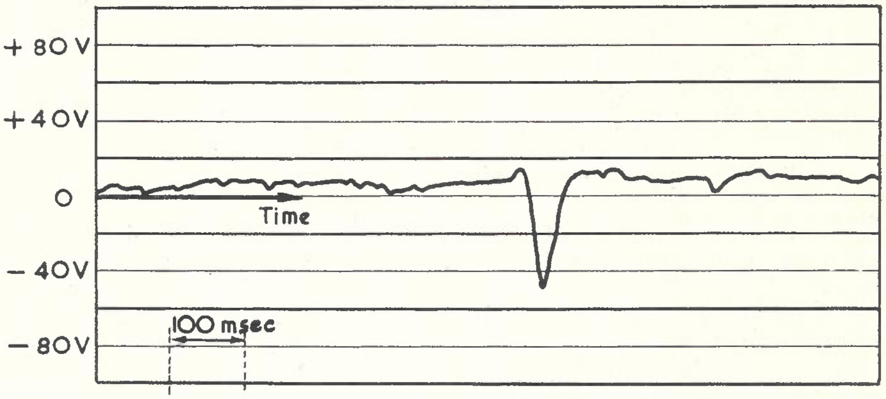
The high-speed paper recorder was a Bruel & Kjaer type 2304 recorder with a linear potentiometer used for the writing pen attachment. This instrument provides a recording by pressing a stylus on black paper covered with white wax. With no disturbance present, the level of the 1 kc/s signal from the modulator was adjusted to give a trace on the centre of the recording chart, thereby permitting the recording of positive and negative pulses. Full scale deflection, that is, 2.5 cm up or down on the chart, could be obtained for any given voltage range by setting a potentiometer at the input to the DC modulator, for instance for ± 200 Volt (+ 200 Volt at input to give a trace at the upper limit and — 200 Volt at the input to give a trace at the lower limit of the linear chart). The paper speed was set to 100 mm/sec. and the writing speed to 700 mm/sec. Thus, the high-speed paper recorder would not provide satisfactory records of pulses containing very sharp transients. A pulse consisting of half a period of a sinewave giving full scale deflection was recorded satisfactorily only when the pulse length exceeded about 40 milliseconds in duration. A study of disturbances of shorter duration could be made by analysing the recordings obtained on the "Byer 77" high-speed tape recorder (tape speed 15 inches/sec.). A photo of such disturbances could be made using a continuous moving film camera, recording the waveform displayed on a cathode ray oscilloscope when the information on the magnetic tape was played back and recorded on the oscilloscope with the time base made inoperative.

The two high-speed recorders were in operation as long as relays A and B were operated. These two relays were operated when a disturbance exceeding a certain voltage was received from the cable and had to be kept operated for the duration of the disturbance and at least three seconds after the end of the disturbance. The positive and negative voltage above which detection was required could be set by a potentiometer at the input. The disturbance detector could be strapped alternatively to trigger on incoming disturbances of a few milliseconds and for disturbances exceeding 70 milliseconds in duration. The pulse stretcher provided the necessary lengthening of the operation of relays A and B after the end of the disturbance. Both units were completely transistorised.

The power required for the recording equipment was obtained from 240 Volt A.C. To prevent the recording equipment from responding to variations in the power supply, a buffered A.C. supply was required. At Warragul this was obtained by the station no-break A.C. supply, in which an A.C. motor drives a separate A.C. generator.

RESULTS AND INTERPRETATIONS OF RECORDING DISTURBANCES ON COAXIAL CABLE

The disturbance recording equipment as described was in continuous operation at the Warragul attended repeater station of the Melbourne-Morwell coaxial cable system for a period of three months. Disturbances were recorded on a spare coaxial tube between Warragul and Nar Nar Goon with the inner conductor connected to the outer conductor at Nar Nar Goon and with metallic through-connections applied to this tube at all three intermediate unattended



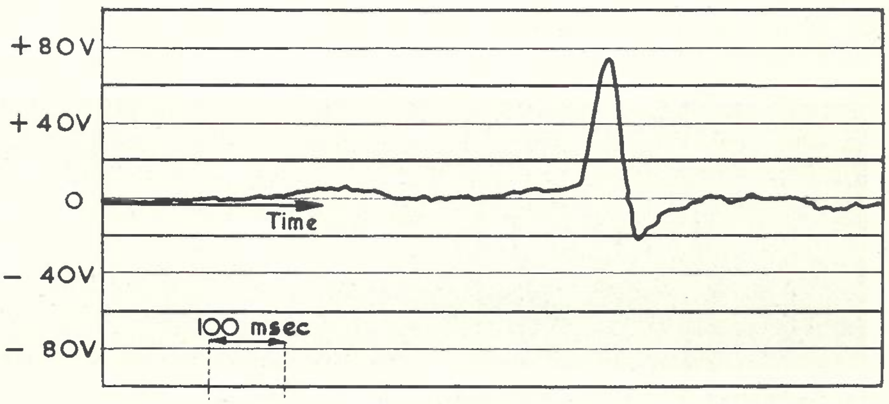


Fig. 2.—Disturbances Recorded on High-speed Paper Recorder. Caused by opening of 1500 Volt, 3000 A, circuit breaker on adjacent railway system.

† "Mylar" is Du Pont's registered trade mark for its brand of polyester film.

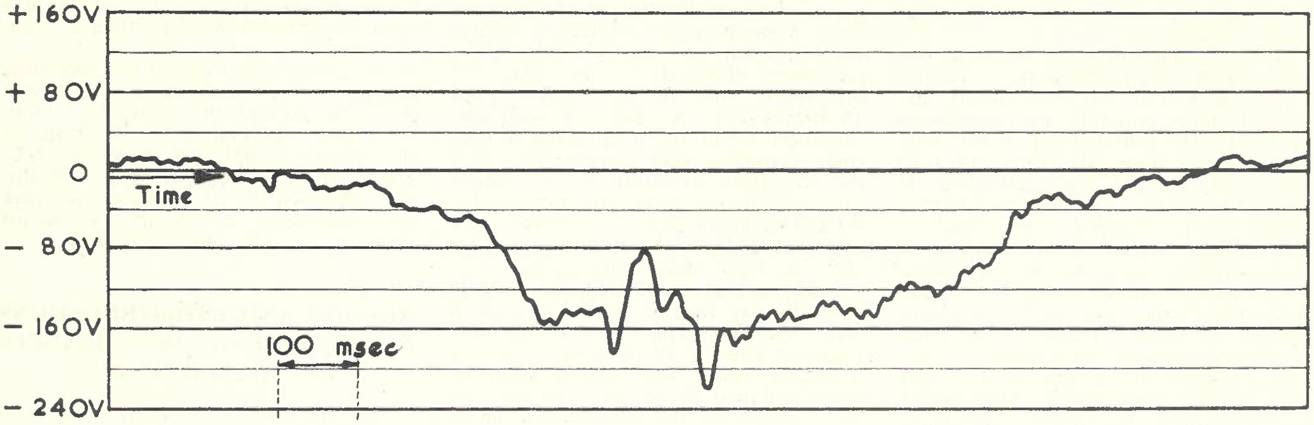


Fig. 3.—Disturbance Recorded on High-speed Paper Recorder. Probably caused by a 1500 Volt rectifier during faulty condition.

stations between Nar Nar Goon and Warragul. For a distance of at least 15 miles the route of the coaxial cable runs within 50 yards of the railway line. A total of 38 recordings of disturbances were obtained, and a close correlation was established between the incidence of these recordings and

(a) faults on the 1500 Volt D.C. power feeding to the electric traction system of the Melbourne-Morwell railway system, resulting in the opening of 3000 A protective circuit breakers;

(b) faults on the 22 kV, 50 c/s, distribution network of the State Electricity Commission of Victoria (this network feeds the 1500 Volt D.C. network of the Victorian Railways); and

(c) electrical storms (during electrical storms very short disturbances were detected satisfactorily by the disturbance detector, but no distinct pulses were recorded on the paper recorder).

Some typical recordings obtained on the high-speed paper recorder are shown in Figs. 2 and 3. Fig. 3 shows the highest interfering voltage recorded (approximately 220 Volt). Due to some mishap in the operation of the magnetic tape recorder no analysis could be made of the result of the recording of this disturbance on the high-speed tape recorder. This might have shown even higher transient voltages, not recorded on the high-speed paper recorder. On some disturbances caused by faults on the 22 kV distribution network, a very distinct 50 c/s ripple could be observed on the recording obtained on the high-speed paper recorder. The recording obtained on the high-speed tape recorder was then analysed. An example of the result of such a recording is given in Fig. 4.

The fluctuations in level visible on the 1 kc/s signal when no 50 c/s interference is present are thought to be due to variations in transmission loss in the delay magnetic tape recorder as a result of wear in the magnetic tape. An alternative type of "memory" with practically no wear in its recording medium is found in magnetic drum recorders similar to the type used for instance for speaking clock circuits. The use of such an instrument as "memory" was discarded, however, after tests had shown that the variation in transmission loss over one rotation of the drum was of the order of a few db. This type of memory would be quite advantageous if frequency modulated signals could be used. Between recording heads and magnetic drum surface a small air-gap (as used on memory units in some electronic computers) could then be introduced to obviate the problem of wear altogether.

Most recordings showed disturbances not exceeding 80 Volts in magnitude and 70 milliseconds in duration, the majority showing a single positive or negative pulse. On most of the disturbances which exceeded 70 milliseconds in duration, recordings of an oscillatory nature were obtained. Some disturbances in the range of one to three seconds with magnitudes up to 60 Volt were recorded during faults on the 22 kV distribution network of the S.E.C. of Victoria and also during electrical storms.

The disconnection of the remote power feeding due to disturbing voltages on the cable can be prevented if the supervision equipment is made to detect feeding current asymmetry only when the asymmetry is present for a period exceeding the duration of the longest disturbance encountered. After discussions with the equipment suppliers, the power feeding supervision equipment is being modified to introduce a delay of approximately 1 second in the disconnection in such cases.

ACKNOWLEDGEMENTS

The author wishes to acknowledge the assistance given with the design of the disturbance recorder by Mr. S. Dossing, Sectional Engineer, Long Line Equipment Section, Postmaster-General's Department, and also that given by the staff of the Victorian State Administration in attending to the recording equipment.

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(1) L. A. White, R. K. Edwards, I. L. McMillan and J. R. Walklate, "The Melbourne-Morwell Coaxial Cable System"; Telecommunication Journal of Australia, Vol. 13, No. 4, page 291, and No. 5, page 405.

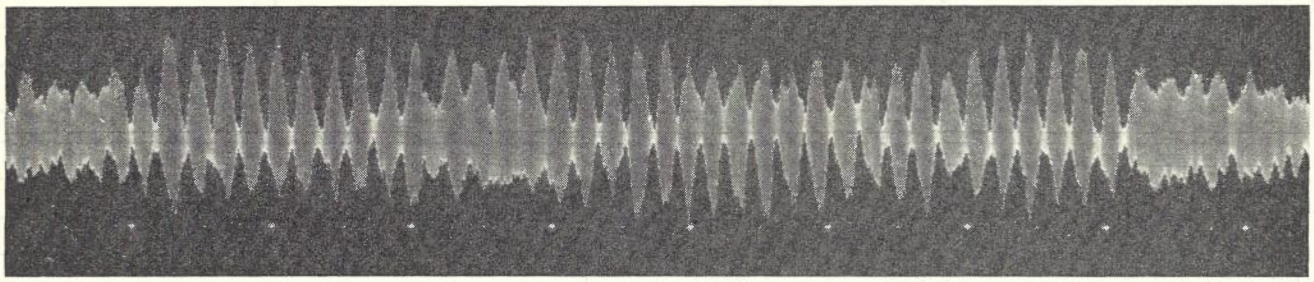

Fig. 4.—Recording Obtained from High-speed Tape Recorder. Caused by a fault on the 22kV, 50 c/s, distribution network of the S.E.C. of Victoria. This photo. shows a 1 kc/s signal modulated by 50 c/s to a modulation depth of about 100%. On the D.C. modulator setting used, this is equivalent to an interfering voltage of about 100 Volt A.C. Note fluctuations in level of 1 kc/s tone when no 50 c/s interference is present (see text). Time markers spaced at 25 millisecond intervals.

20-LINE EXPERIMENTAL ELECTRONIC TELEPHONE EXCHANGE

*H. S. WRAGGE, B.E.E., M.Eng.Sc., A.M.I.E.E., A.M.I.E.Aust.**

INTRODUCTION

The electronic telephone exchange described in this article was constructed initially as a 20-line closed system for experimental purposes. The exchange was placed in service in the 10 Lonsdale Street Annexe of the Postmaster-General's Department Research Laboratories in July, 1962, as a 20-line P.A.B.X. on lines selected to give as high a traffic loading as possible. Performance so far has been satisfactory. The exchange has been given the code S.C.A.T.S. Mk1.

The system has five links and provides normal dial service facilities except for one line which is equipped with a call diversion facility under dial control. The only outward feature which distinguishes it from a more conventional P.A.B.X. is that 17 c/s ring current and bells are not used for signalling purposes. Instead, tone calling is used; an acoustic sounder with a single stage amplifier is used in the telephone in place of the bell and a low level audio frequency tone is used instead of high level 17 c/s current as a signalling medium. This tone is amplitude and frequency modulated to give it an individual characteristic. Semiconductors (transistors and various types of diodes) have been used throughout the exchange. Voltage-switched logic as described in Reference 1 is used for all control circuitry. Power supply is derived from the mains.

The speech path is switched on a time division multiplex (t.d.m.) basis (2) over a 2-wire circuit without amplification. Common control is used with setting-up of a call on a "one at a time" basis. Control of the call after setting up is maintained on a space switched basis, giving rise to the term "Space Controlled and Time Switched" (S.C.A.T.S.) Exchange. In order to prevent undue delay in gaining access to the common control, an arbitrary limit of 12 seconds has been set as the maximum time available to complete dialling (two digits) after lifting the handset. If dialling is not completed before the 12 seconds have elapsed, the subscriber concerned is locked onto busy tone and the common control dissociated from that line until the subscriber replaces the handset and tries again. Release of a call is effected at any time without re-engaging the common control circuitry, including occasions when the common control is engaged during the setting up of a call.

SWITCHING OF THE SPEECH PATH

General Arrangement

The speech path utilises time division multiplexing of pulse amplitude modulated signals. The speech signal is sampled at successive intervals, and a train of pulses is generated in which the amplitude of each pulse corresponds to the amplitude of the sampled signal

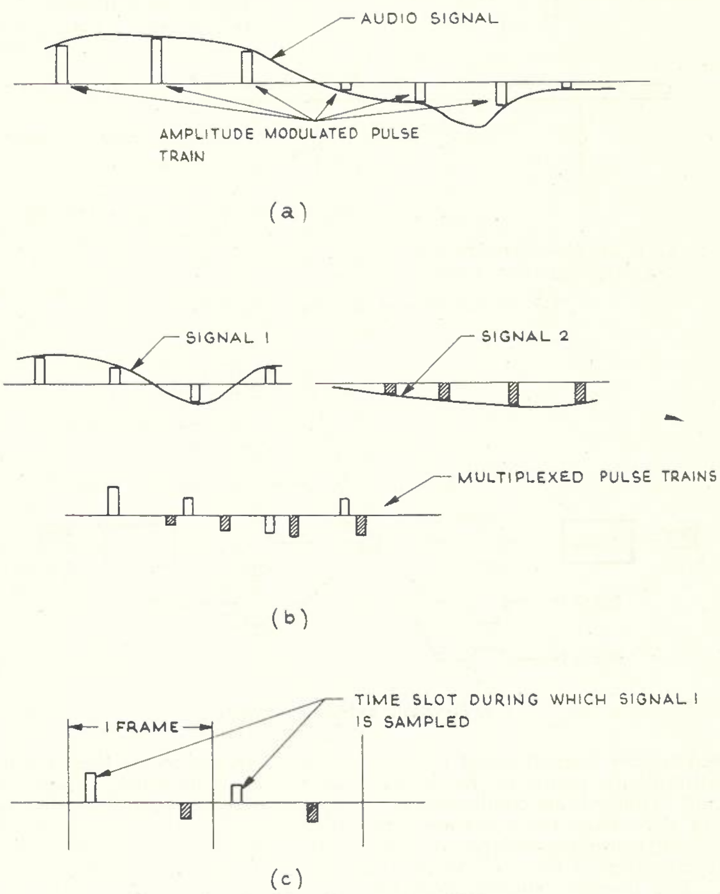

Fig. 1.—Time Division Multiplexing.

at the instant of sampling. Sampling is carried out each 100μsec., and each sampling interval occupies 2μsec., as shown in Fig. 1(a). If several signals are sampled, but at different instants, it is possible to transmit the various pulse trains over one conductor simultaneously (Fig. 1(b)).

For convenience, time is considered to be broken into blocks (or frames) of 100μsec. duration. Any particular pulse train can then be specified by noting the time within frames during which the signal is sampled. These particular times are known as time slots (Fig. 1(c)). Any particular wave train can then be selected from a conductor carrying several multiplexed pulse trains by periodically closing a switch connected to the conductor during the appropriate time slot (Fig. 2).

The switching arrangement used in this exchange is shown in Fig. 3. A connection can be provided between any pair of subscribers by periodically closing their line switches during one time slot. Five time slots only have been provided, thus only five simultaneous connections can be provided, one in each link time slot. Tones are distributed via the tone switches in appropriate time slots and can be distributed to several links at the one time if necessary.

The timing schedule is shown in Fig. 4. An extra time slot, TSG, is used as a control pulse. It is apparent that additional time slots can be provided in order to provide more links, if warranted by traffic or an increased number of subscribers.

Transmission Path

A complete transmission path between two subscribers is shown in Fig. 5. The transformers are used mainly as feeding bridges to supply line current to the subscribers and to provide D.C. isolation into the exchange. They also provide an impedance transformation. The filter extracts the audio frequency component from the P.A.M. signal, thus acting as a demodulator. The two line switches are both closed simultaneously and repetitively for the duration of the appropriate time slot when a connection is set up. When the switches are closed, the transfer inductors and the terminal capacitors of the filters form a series resonant circuit, and the switches

* See Vol. 13, No. 1, page 79.

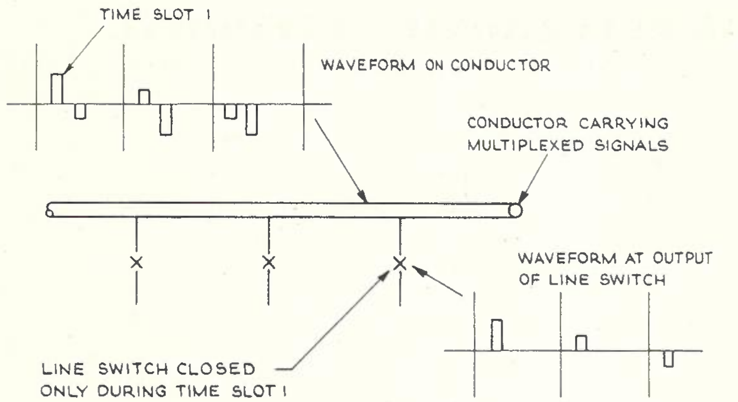

Fig. 2.—Selection of One Signal Pulse Train.

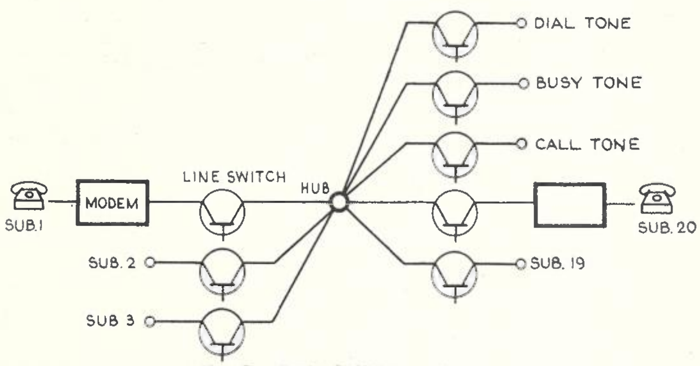

Fig. 3.—Basic Switching Layout.

are closed for an interval equal to half the duration of the period of this resonant circuit. Under these conditions, the closure of the switch for one time slot duration will cause the charges on the terminal capacitor of the filter to interchange. The impulses thus applied to the two filters are smoothed during the interval between time slot pulses by the filters. This enables a symmetrical channel to be obtained without the need for hybrids or amplification. This method of interconnection is known as resonant transfer, or energy sampling (3). The filters effectively store energy during the period when the line switches are open and then transfer the whole of this energy during the interval when the switches are closed, so that no energy is lost as is the case when voltage sampling is used. However, dissipation in the line transformers, filters, transfer inductors and line switches causes a loss, but this can be kept very small.

Control of the Transmission Path

The control of the line switches is achieved by the use of a memory unit (the subscriber's memory). A separate memory is used to control the three tone switches (the service tone memory). The functions of these memories are solely to distribute the appropriate link time slot pulses to the line and tone switches. The basic arrangement of the subscriber's memory is shown in Fig. 6. There is one horizontal lead in the subscriber's memory for each subscriber, and this lead is connected via some control circuits to the line switch of the subscriber concerned. There is one vertical lead for each time slot, and link time slots are always present on these leads. At each intersection of a time slot lead and a subscriber's lead is a special type of magnetic core which is used as a switch to either connect the link time slot pulse to the subscriber's memory or to isolate it depending whether that subscriber is using that link time slot or not. Thus, if subscribers 2 and 18 were connected and using link 3, the magnetic cores on the third vertical wire (corresponding to link 3) would be distributing link time slot pulses in the third time slot to subscribers 2 and 18 via their subscribers' leads. This memory is discussed more fully in Reference 4.

The same principle is used in the service tone memory, except that diode gates controlled by flip-flops are used at each intersection (or crosspoint) instead of magnetic cores. There are five vertical leads, one for each time slot, and three horizontal leads, one for each tone.

In both of these memories, the "crosspoints" are set by means of control pulses to either distribute or stop distributing link time slot pulses to either the subscriber's leads or the tone switches. It is the function of the remainder of the control circuits to supply these control pulses, which are required only when some event happens, such as a handset being picked up or replaced or the completion of dialling. During the remainder of the time the control circuitry is idle, hence the time that the common control equipment is held per call is very small.

CONTROL CIRCUITS

A simplified block schematic of the exchange is shown in Fig. 7. The purpose and method of operation of the various parts can best be explained by considering the steps involved in setting up and disconnecting a call. Further information is given in Reference 5.

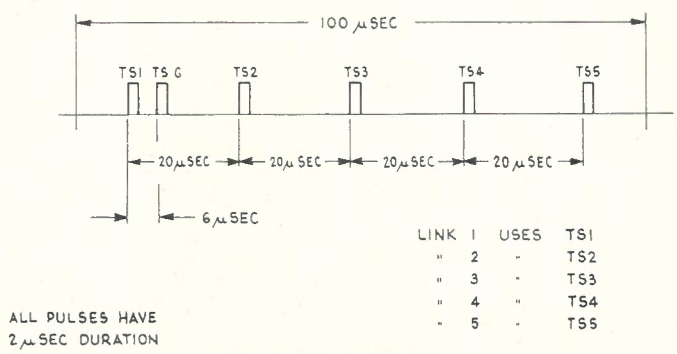

Fig. 4.—Timing Schedule.

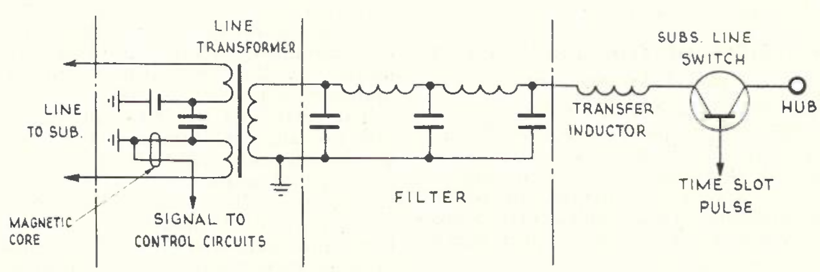

Fig. 5.—Transmission Path.

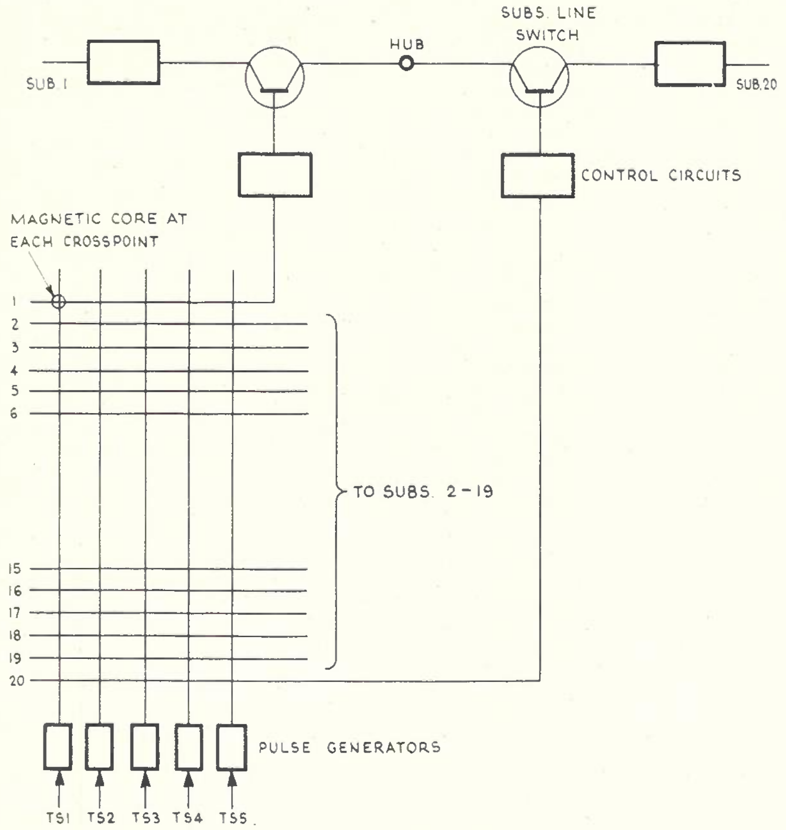

Fig. 6.—Memory Control of Line Switches.

While the exchange is in the rest position, that is no calls are being initiated or cleared, the link allotter (L.A.) will search for a free link, and having found one will seize and mark it for the next call. The marking signals are sent to both the service tone memory (S.T.M.) and the subscriber's memory (S.M.). After the link has been seized, a signal is sent from the L.A. to the identifier (I.) to enable it to operate.

When I receives this signal, a counter in it sends a scanning signal to the logic circuit (S.L.C.) associated with each subscriber's line circuit. If a subscriber lifts his handset, his S.L.C. will send a "pick-up" signal to the pick-up access gate which provides access to the identifier. This signal will immediately stop the I counter, which will then mark the calling subscriber. A signal is then sent to the S.T.M. to provide link time slot pulses (or more simply, link pulses) to the dial tone switch and to the S.M. to provide a link pulse to operate the subscriber's line switch. Dial tone is then returned to the subscriber. Dialled impulses are then transmitted via the I to the Y counter (Y), in which another counter is used to select the required subscriber in response to the code dialled. Codes used include 10 through 29. After the called number is selected, a test is carried out to determine whether the subscriber being called is on or off hook; if off hook, a signal is sent to the S.T.M. to replace dial tone by busy tone. If on hook, dial tone is replaced by call tone, and a link pulse is provided for the called subscriber by the S.M. Call tone is fed forward to the called subscriber and amplified in the telephone for use as a calling signal and backward for use in the same manner as ring tone in a conventional system. At this stage the identifier and Y counter are released, a memory flip-flop is set in each subscriber's logic circuit and an instruction is given to the L.A. to seize and mark a free link. The I is locked out until this has been done; if all links are busy, the L.A. will continue searching until a link becomes free. In the meantime, access to the I is barred.

When the called subscriber answers, a signal is sent from his S.L.C. to the answer access gate, causing the S.T.M. to disconnect call tone. The call can now progress normally. When a call is terminated, signals are sent from the S.L.C. via the clear access gate to the S.M. which causes the link being used to be cleared. Both the answer and clear signals actually consist of link pulses fed back to the common control. The selection of the link on which some variation of condition is to be effected is achieved by comparing the incoming link pulses with those of each link; a coincidence indicates the appropriate link. Clearing of the S.T.M. in the case of an abandoned call is automatically carried out by the S.M. when it is cleared.

The clock is a centralised timing unit which generates the basic waveforms necessary to operate the control circuitry. The basic outputs include the five time slot pulses and the control pulse, T.S.G., which is used for driving the counters in the identifier and L.A.

OPERATION OF THE IDENTIFIER

As an example of the type of circuitry and techniques used in this exchange, the operation of the identifier

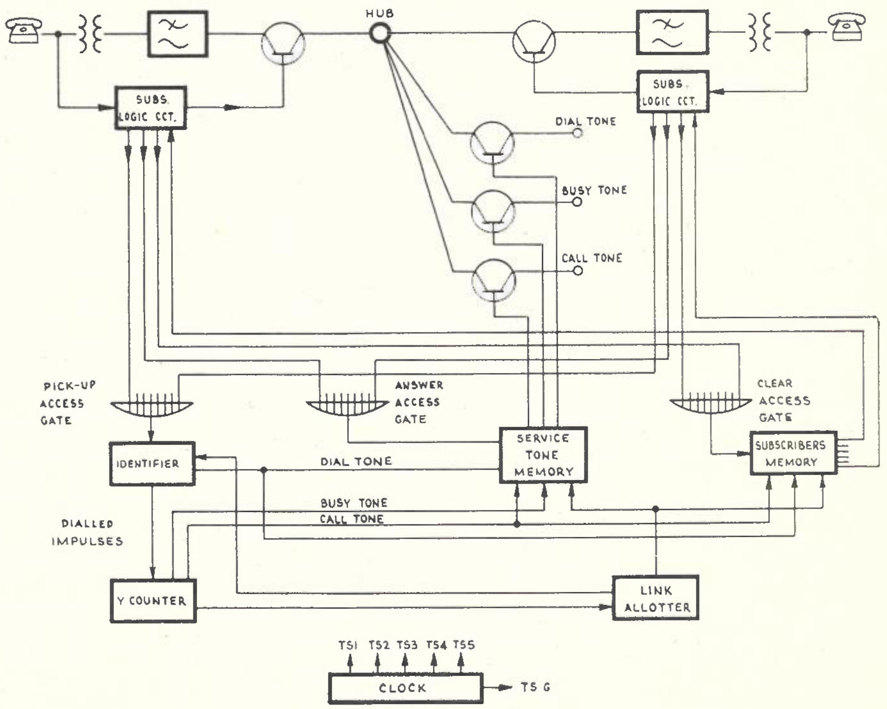

Fig. 7.—Basic Control Circuits.

will be described (Fig. 8). The main part of the identifier is the X counter which has 20 output leads. Only one of these leads has a "1" signal at any time, all the others having an "0" signal. 1 is represented by a potential of 0 volts and 0 by −8 volts. The control pulse T.S.G. is used to advance the counter by one count each frame, that is the 1 will appear on successive output leads provided that each other input to the X counter (AND) gate is a 1. One output lead is provided for each subscriber, and when a subscriber is awaiting attention, the 1 which will occur on the corresponding X counter output will cause a 1 to be applied to the P.U. access (OR) gate. This 1 will set the monostable multivibrator (mono) M.R. causing a 1 to appear on the right-hand output and an 0 on the left-hand output. (This is the convention adopted for all monos and flip-flops when set; when reset the signals are reversed.) The 1 on the M.R. output will set the flip-flop B.R. (set signals are applied to the left-hand side and reset signals to the right-hand side; the application of a 1 will cause set or reset to occur).

As soon as M.R. sets, it will apply a 0 to the X counter gate, thereby inhibiting the X counter from further counting; a 0 will also be produced from B.R. after it is set as an X counter gate input. The 1 output of B.R. is used as a signal to the subscriber's memory and service tone memory that the time slot marked by the link allotter is to be allocated to the subscriber indicated by the number stored in the X counter. The 1 output from the P.U. access gate is also used to set a "slug", S.F., which immediately produces a 0 on its output. (A slug is a circuit which will reset at a given time after the 1 on its input is removed.) At this stage the subscriber will have received dial tone and can commence dialling. The dialling impulses are represented as 33 millisecond 0s on the output of the P.U. access gate and these are passed to the Y counter.

After the completion of dialling, the 1 at the output of the P.U. access gate will be removed via the subscriber's logic circuits. After a fixed delay, the slug S.F. will reset, producing a 1 on its output. This will reset B.R., provide a reset signal for the Y counter and a signal to the link allotter indicating a free link is to be sought. The reset of B.R. will cause a 1 to appear on its 0 output, which is used to reset M.R. When M.R. and B.R. have reset, they will be providing 1 inputs to the X counter gate, and when a 1 is received for the link allotter, indicating a free link has been seized, the T.S.G. pulses will cause the X counter to count, thus permitting another subscriber to be identified.

The release of the identifier normally takes place when S.F. resets. If dialling is not completed, S.F. would normally be held, consequently a throwout facility has been provided which enables the identifier to be held only for the duration of the holding period of M.R. If it resets before B.R., the 1 from the 1 output of B.R. and the 1 from the 0 output of M.R. are combined in the throwout (AND) gate to set M.B., which inhibits the X counter gate and provides signals to the memories causing the subscriber to be locked onto busy tone and forcing the release of the P.U. access gate; this enables S.F. to reset, after which the common control reset proceeds normally.

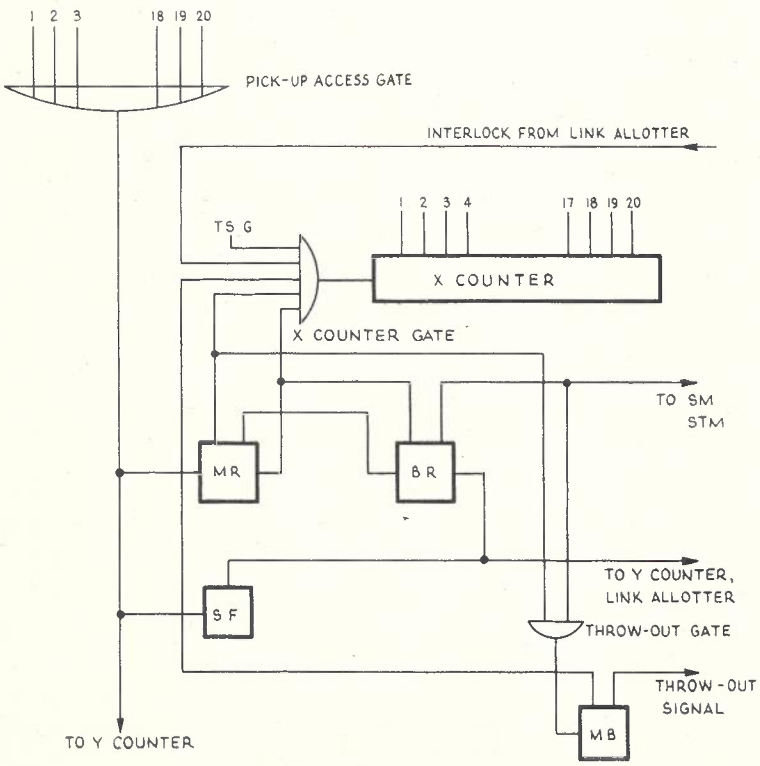

Fig. 8.—Identifier Block Schematic.

PERFORMANCE

Transmission Performance

The transmission performance is an important matter in an electronic telephone exchange with frame-to-frame insertion loss as the dominant parameter. Usually a significant loss is incurred in the two wire systems, but in this system the loss has been reduced to approximately 1db over most of the voice frequency range, which compares well with conventional electromechanical systems. The channel loss increases very sharply above about 4 kc/s due to the use of filters as modulating/demodulating elements. This is a characteristic feature of all T.D.M. exchanges. The delay characteristics (of interest in data transmission applications) have not been examined, but delay equalisation networks, if required, in general present very few problems.

The total harmonic distortion is about 0.5% for levels up to +7dbm at 1 kc/s, and is not significantly affected by frequency. The signal/noise ratio is affected mainly by the background noise level and the inverted sideband below 10 kc/s. Both of these can be controlled by appropriate filter design. The design parameters are a matter for subjective study. There is very little flexibility in the filter design if a minimal design of 5 elements is used, but the characteristic can be controlled to any desired degree if a sufficiently complex filter is used.

The crosstalk reduction between adjacent time slots (the worst case) is about 75db. Crosstalk due to hub and switch capacitance has been considerably reduced by clamping the hub to earth for a period of 2μsec. immediately after each time slot.

Reliability

The reliability of the exchange is a most important aspect. No redundancy has been included in the design of the system apart from the number of links; consequently any failure, except in the circuitry directly associated with a link, will probably put the system at least partially out of service.

However, failure rates for components operated in similar environments have been determined, and the use of these figures for the various types and numbers of components in this system indicate a mean time between failures of approximately 15,000 hours, or 1.7 years. This indicates that the probability of a system failure will not reach 50% until about 10,000 hours, or 1.2 years have elapsed (6). So far, with about 5½ months of operating experience, no failure of a component has occurred during normal operation of the exchange.

As an aid to rapid fault location, interlocks have been provided between

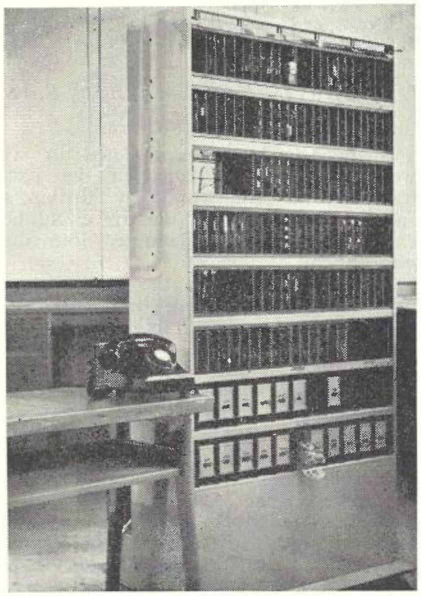

Fig. 9.—General View of Experimental Exchange.

all the major blocks in the common control equipment and will prevent a specific block working unless the other blocks are functional. U links have been provided in the interlocking connections to enable rapid diagnosis and isolation of the faulty block. Also, DM160 voltage indicating tubes are provided which enable the presence of 1 or 0 signals to be identified at key points throughout the C.C.E. These are shown along the top of the rack in Fig. 9.

CONCLUSION

This exchange has now been developed to the stage where it can be used as a working system, but it is not regarded as a system which is suitable for widespread application in the Post Office switching network in its present form. Its main function lies in the provision of experience in the design and operation of a system of this nature and the recognition and understanding of criteria by which this type of system must be judged.

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BRISBANE-TWEED HEADS COAXIAL CABLE – RIVER CROSSINGS

*J. H. CURTIS, B.E.(Hon.), B.Sc., B.A.**

INTRODUCTION

The installation of the Brisbane-Tweed Heads section of the Brisbane-Lismore coaxial cable involved, in a route distance of 68 miles, installation of cable across five tidal rivers, two shallow water estuaries and a number of creeks, some tidal and others fresh water. The crossings presented a variety of engineering problems, from excavating a trench 2 feet deep in the rock bed of a quickly flowing river to dredging a trench up to 18 feet deep in sand. This article discusses briefly some of the features associated with these river crossings.

BRISBANE RIVER

The Brisbane River was crossed in the City reach by using a section of coaxial cable which had been laid several years previously in conjunction with the provision of additional metropolitan junction circuits across the river. The Harbours and Marine Department then specified that the cables should be laid at sufficient depth to allow of future dredging of the river. A trench up to 15 feet deep was dredged by the Harbours and Marine Department and the cables were floated across and lowered into position.

LOGAN RIVER

At the Logan River, which is 20 miles south of Brisbane, the river bed for a distance of some 150 feet from the Northern bank, consists of bare rock, while towards the southern bank the rock dips away and is overlain by thick depths of mud. Comparison of soundings with those made some 30 years earlier, when a road bridge was being constructed nearby, showed that the mud bank on the southern side could be regarded as permanent. Other features of the river at the crossing point include a tidal range of approximately 5 feet, quite rapid flow during both tides and a period of slack water of about half an hour between tides. During periods of flood, the river rises by as much as 20 feet and carries large quantities of debris.

Consideration was given to installing the cable on the road bridge adjacent to the crossing point. However, the bridge was considered unsuitable as it was subject to more or less continuous vibration from heavy traffic, there is no footway and working on the bridge would be hazardous, and the approaches to the bridge are difficult. On the south bank, too, it is evident that the wooden approach structure to the bridge proper will have to be replaced at some stage. Having regard to all these factors, it was decided to install the cable in the rock bed of the river. A profile of the crossing is given in Fig. 1.

The rock concerned was a Schist which, though quite hard, could be broken readily by a jack hammer. After consideration of various alternatives, the method selected for cutting the trench was to have a diver work on the bottom of the river using a jack hammer. One difficulty in excavating in this way was that the river water was always muddy and the diver could, in effect, not see at all. To enable the trench to be cut in a straight line, a wire rope was stretched across the river bed and the diver felt his way along the rope. Another difficulty which the diver encountered was that, during the period of maximum tidal flow, he had difficulty, despite his lead weights, in remaining in an upright position. Nevertheless, steady progress was maintained and the trench was completed in six weeks. The performance of the jack hammer was improved by fitting a snorkel in order that the air could be exhausted from the hammer into the atmosphere.

When the trench in the rock section was completed, a drag line excavator was used to excavate the trench in the mud near both banks of the river. When all trenching was completed, the heavy wire armoured (H.W.A.) coaxial cable encased in a 3 inch polythene pipe to give additional protection against sharp rock edges, together with a minor trunk cable and a subscribers' cable, were floated across the river and, at slack water, floats were cut away and the cables were lowered into the trench. To ensure that the cables were placed directly in the trench, the diver followed across the river bed as the cables were being lowered and gave advice to the lowering party by telephone. Little difficulty was experienced in this stage of the work. As a final precaution to prevent any flood condition lifting the cables out of the relatively shallow trench, concrete blocks were poured at four separate points along the rock section.

MINOR CROSSINGS

The Albert River, three miles to the south of the Logan, is relatively small with mud banks. A trench 8 feet deep was cut in the mud by the use of a drag line with a tractor with logging winch on the opposite bank to haul the empty bucket out from the excavator. There were no particular features associated with this crossing.

Similar methods were employed at the Coomera River, which is approximately 200 yards wide, see Fig. 2. Here, the river bed consists of gravel, but with

* See page 501.

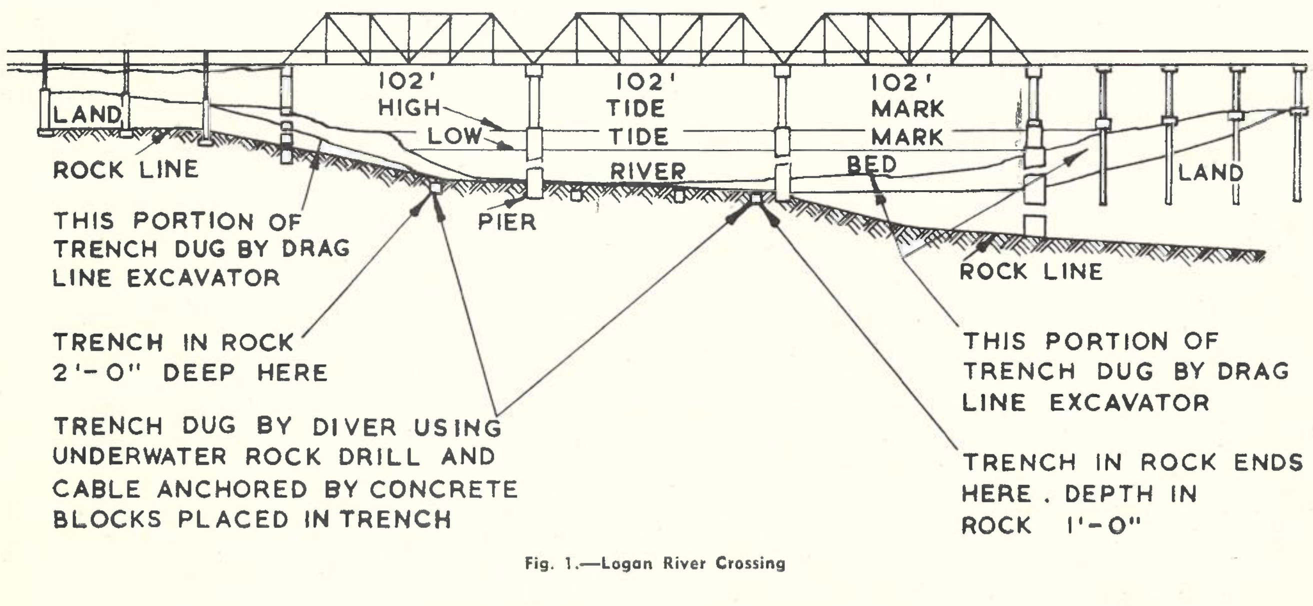

Fig. 1.—Logan River Crossing

Fig. 2.—Drag Line Excavator and Tractor at the Coomera River.

sufficient mud mixed through it to enable a steep-sided trench to be cut quite readily. After half the trench had been completed, the drag line and tractor were inter-changed and the balance of the trench cut from the opposite bank. There were certain difficulties connected with floating the cable across the river, while, if the cable were hauled across in the normal manner, the length of the crossing and the type of bottom were such as were likely to combine to produce an undesirable strain on the coaxial cable. To overcome this problem of tension, the winch was attached to a wire rope of the same length as the cable and the cable was lashed to this wire rope every 15 feet. The cable drum was set some yards back from the river bank and lashings were made without interruption to the process of hauling.

Somewhat similar methods for cutting a trench were employed at the various small fresh-water and tidal creeks. Conditions varied from gravel to mud to patches of rock. The first of these meant excavation of relatively large quantities of material, as the sides of the trench caved in. Soft rock was excavated by first drawing a suitably mounted ripper across the creek bed, but in one creek hard rock required a jack hammer.

At the Nerang River, between Southport and Surfers' Paradise, a crossing of one arm was made by drawing lead-covered cable into one of a nest of four polythene pipes which had previously been installed by jetting a trench in the sandy gravel bed. The installation of these polythene pipes was not a part of the coaxial cable project.

TALLEBUDGERA CREEK

The other crossings of interest were the shallow tidal estuaries of Tallebudgera and Currumbin Creeks. In both cases, the crossings were within a quarter of a mile of the point of entry of the creek to the Pacific Ocean. In the case of Tallebudgera Creek, at low tide the water is confined to a channel less than 2 chains wide against the northern bank, but at about the middle of the tide the creek spreads out to a distance of some 250 yards. The tidal run is quite swift. Investigations revealed that the main channel had, over a period of years, shifted its position from against the south bank to the north bank. It seems probable that it may shift its position again at some future date. The creek bed in both the channel and on the flat, which is covered only at high tide, consists of fine white sand with patches of water-worn rock, the rocks in general being about 1 foot in diameter. A feature of the creek is that dredging upstream from the crossing point, in the process of reclaiming low-lying land, has greatly increased the amount of water which flows in and out on each tide. This increased flow has, in turn, tended to increase the erosion rate in the bottom of the creek and the channel has deepened. As a result, the Southport-Tweed Heads trunk cable and a 300 pair subscribers' cable which were laid several years ago at a depth of 3 feet below the existing bed, at a time when the creek was heavily silted up, were found to be suspended about 2 feet above the bottom of the channel. However, a rock bar on the ocean side of the crossing will limit the depth to which the channel can deepen at the crossing at any future date. Fig. 3 is a profile of the crossing.

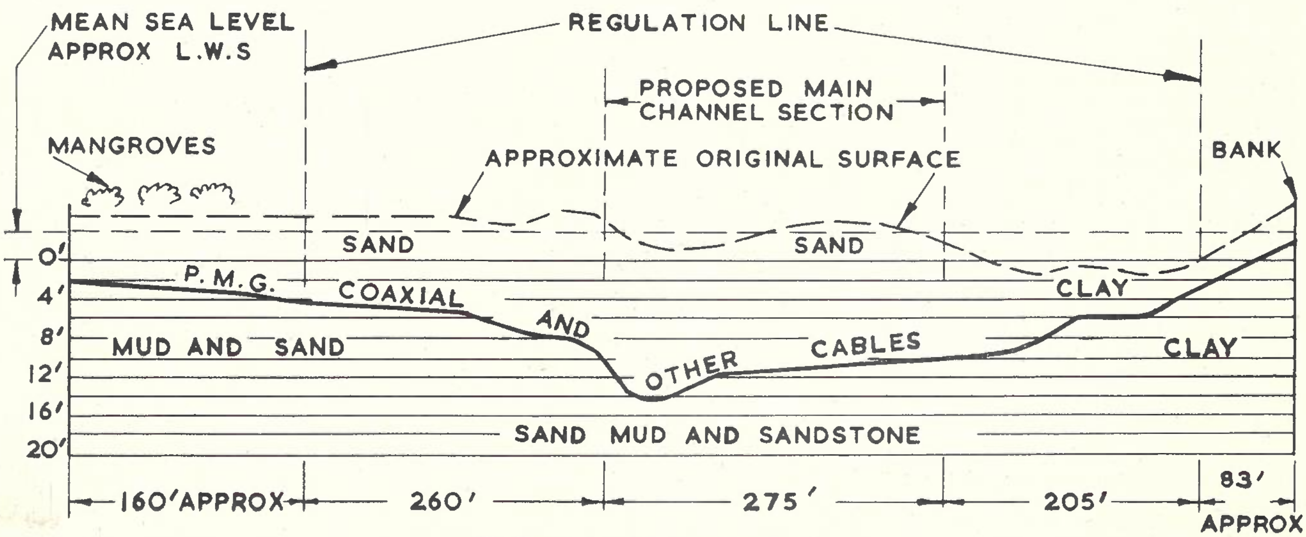

Fig. 3.—Profile of Tallebudgera Creek.

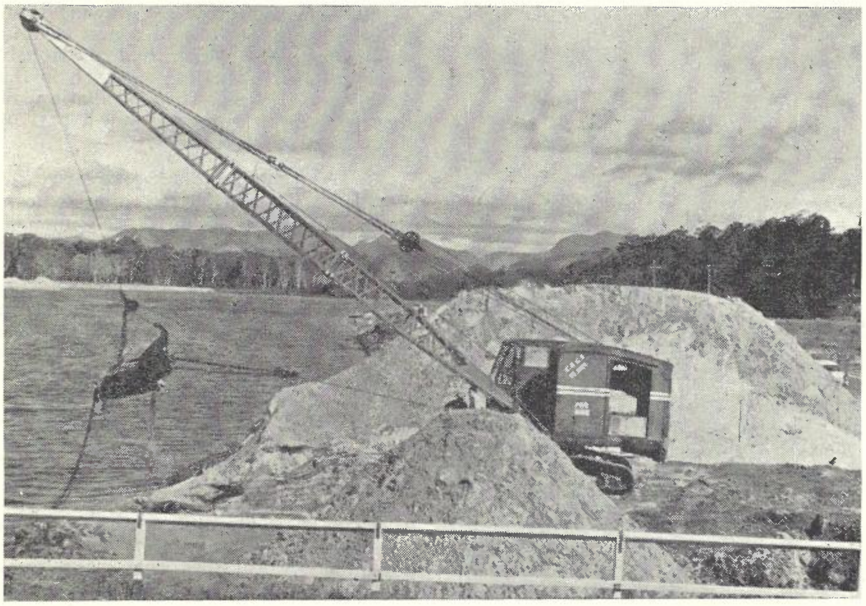

Fig. 4.—Drag Line Excavator Working on Main Channel of Tallebudgera Creek Crossing.

Taking all factors into consideration, it was decided to excavate a trench 8 feet deep for the whole distance of 250 yards. Because of the presence of the water-worn rocks referred to earlier, it was considered impracticable to employ a sand dredge and excavation was again carried out using a drag line excavator, see Fig. 4. A Case tractor with logging winch was used on the opposite bank to draw the bucket out. The channel section was excavated first and proved exceptionally difficult in that, under the influence of the fast-flowing tide, sand moved into the trench quite rapidly. Under static water conditions, the side of a trench cut in this class of sand has a slope of about one in three; but in the channel at Tallebudgera Creek a trench in the ordinary sense could not be obtained. Instead, as sand was removed from the trench line, the whole bed gradually deepened for almost a chain on either side of the line of excavation, see Fig. 5. On one day, when there was rough weather and small waves entered the creek, excavation was carried out continuously from 7 a.m. to 5 p.m. without obtaining any increase in depth on the line of excavation. With better weather, and by working long hours, the desired depth was finally obtained and the cable, which had previously been laid out, was floated across the trench and lowered into position. The drag line and tractor were then inter-changed and the balance of the trench was excavated. To protect the cable which had been laid, the tail rope between the bucket and the tractor was passed through a pulley attached to a pontoon anchored over the cable. Progress was slow. At low tide, to increase the excavation rate, the drag line was brought out on to the sand and excavation was done without use of the tail rope. As each section of trench was completed, the cable was lowered into position. This procedure was essential, as the trench refilled far too quickly to enable the whole length to be completed before installing the cable. Installation in sections produced one particular problem — the drag line bucket could not be taken to within several feet of the installed cable for fear of causing damage, and a ridge of sand therefore built up between the section in which the cable had been installed and the next section excavated. This ridge was removed by a skin diver using a siphon in the form of a length of 6 feet of 6 inch diameter pipe, open at both ends, and with an air hose from a compressor connected 1 foot from the lower end (see Fig. 6).

In recent years, a number of cables have been successfully installed across rivers and estuaries in Queensland using a technique which employs powerful water jets to cut a trench. The author was closely associated with a major undertaking using jets — the installation of the first Redcliffe-Sandgate junction cable when two 54/40 cables were jetted into the bed of Hayes Inlet for a distance of $1\frac{3}{4}$ miles. Careful consideration was given to the modification of previous methods to suit conditions at Tallebudgera and Currumbin Creeks. However, it became apparent that with the equipment available it would not be practicable to ensure that the cables were laid at the required depths. The rocks at Tallebudgera Creek would also have constituted a problem.

CURRUMBIN CREEK

The Currumbin Creek crossing was across an estuary some 600 yards wide, but a ditcher was employed for the first 250 yards, which is only covered by water during the highest tides. The main problems were associated with the remaining 350 yard section. Currumbin Creek is slow-flowing and more or less completely silted up except for a small channel against the southern bank. However, the Harbours and Marine Department advised of a proposal to deepen and widen the creek at some future date in a project to reclaim low-lying land on the northern shore. In order to ensure that the cable would have a minimum of 3 feet cover when this reclamation work is completed, it was necessary to place the cable at a depth of up to 18 feet below the existing surface.

Investigation showed that against the southern bank the bottom consisted of a tough clay overlying a soft sandstone and a trench a few feet deep could be cut by a drag line. As the distance out from the southern bank was increased, this clay bottom dipped away and was covered by a large depth of silt and sand. It was decided, therefore, to excavate the section at the southern bank

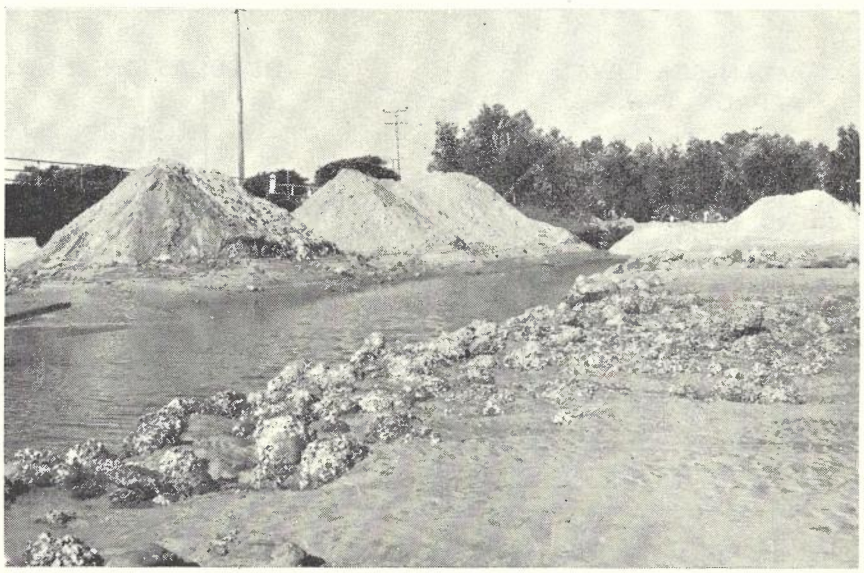

Fig. 5.—Trench at Tallebudgera Creek.

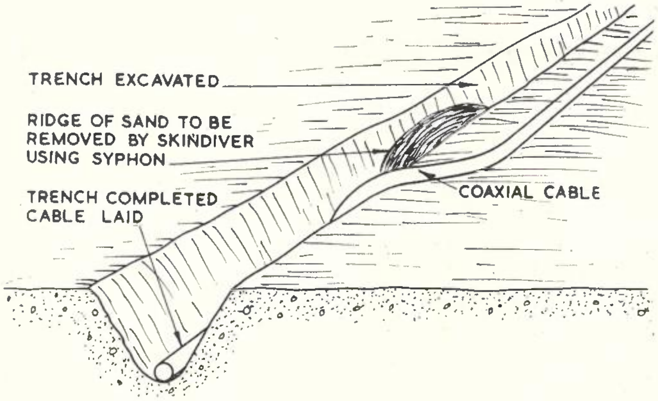

Fig. 6.—Installing Cable in Trench, Tallebudgera Creek.

first, using a drag line, and to then employ a sand dredge for the balance of the crossing. Plant of this type is widely used in the area for reclamation work and was therefore readily available. A dredge with a 6 inch pump inlet and with nominal capacity of 120 cubic yards per hour was employed. However, in the conditions encountered, the average rate of excavation achieved was much lower.

When the drag line section was completed, the H.W.A. cables, two 400/10 and one 100/10 in addition to the coaxial cable, were laid out along the trench line, passing underneath the dredge and supported on drums at the front of the dredge (see Fig. 7). As each length of trench was completed and the dredge was moved forward, the drum supports were moved also and the cable sank to the bottom of the finished trench. Patches of mud were encountered from time to time and greatly reduced excavation rate. At the same time, the depth of the clay bottom varied considerably and this also affected the rate of excavation. Dredges of this nature are only successful in a free-flowing sand and depend on fresh sand running to the pump inlet as excavation proceeds. In mud, the dredge merely makes a series of small holes with ridges in between. Moreover, from the method of operation of the dredge, it is not possible to excavate right down to a clay bottom, for as the pump inlet approaches this bottom there is no sand at the correct angle to flow to the inlet. In these conditions, too, a series of holes rather than a trench is produced.

A feature of the work was the large quantities of sand handled. With a side slope of about one in three, the surface width of the trench was as much as 100 feet, and about 100 cubic yards of sand had to be excavated for each yard of trench line.

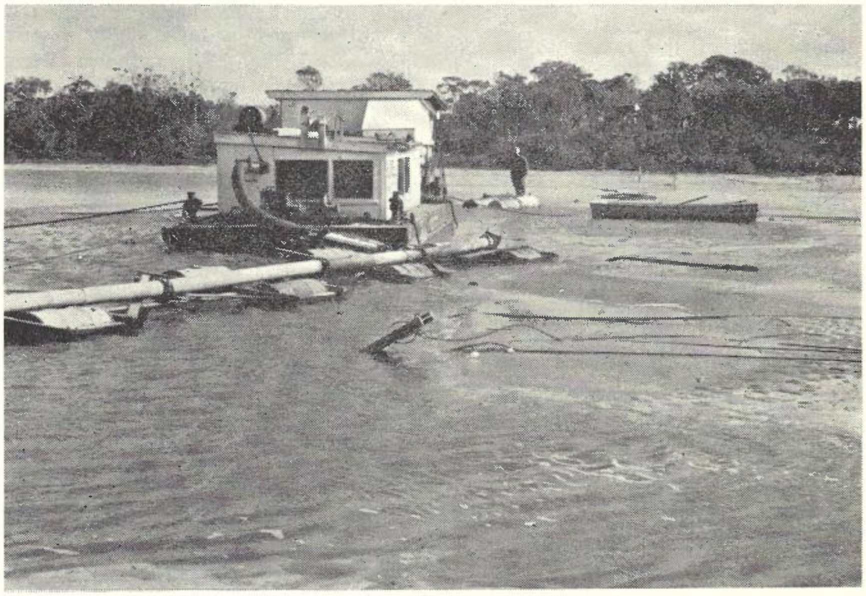

Fig. 7.—Dredge at Currumbin Creek. The drum supports for the cable can be seen at the far end of the dredge.

THE DESIGN OF PROGRAMME EQUALISERS FOR CABLE CIRCUITS

*A. E. JOHNSON, B.Sc.**

INTRODUCTION

The purpose of this article is to outline a simple and ready method which can be used for the design of constant impedance programme equalisers for cable circuits. The type of equaliser section used has three reactive elements in the series and shunt arms. This type of equaliser has been used in New South Wales for about 30 years (1), but it is only recently that the design process has been simplified to enable a rapid solution to be obtained. The use of this type of section enables the desired slope of the equaliser attenuation versus frequency characteristic, at the high frequency end of the range, to be obtained more readily than is the case if sections having one or two reactive elements in the series and shunt arms are used.

DESIGN THEORY

The unbalanced bridged – T configuration of the equaliser section is shown in Fig. 1. As the equaliser section is constant impedance, it is possible

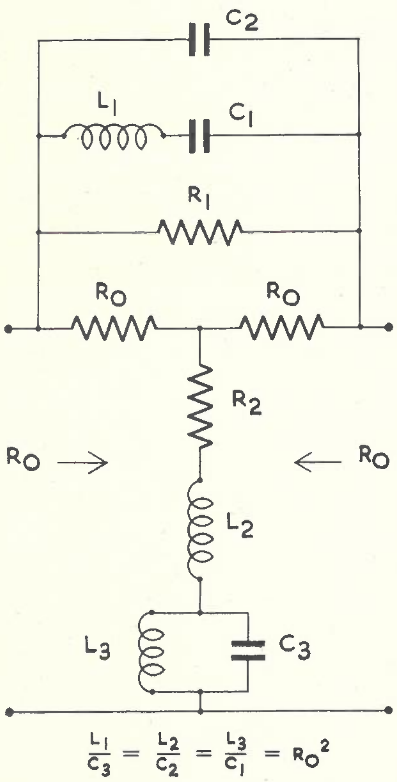

Fig. 1.—Unbalanced Bridged — T Section.

to calculate the attenuation versus frequency characteristic by considering the series arm only. At any given frequency the reactive elements may be replaced by a single reactance x, as shown in Fig. 2. The parallel combination of x and R_1 may be replaced by a series network X and R as shown where

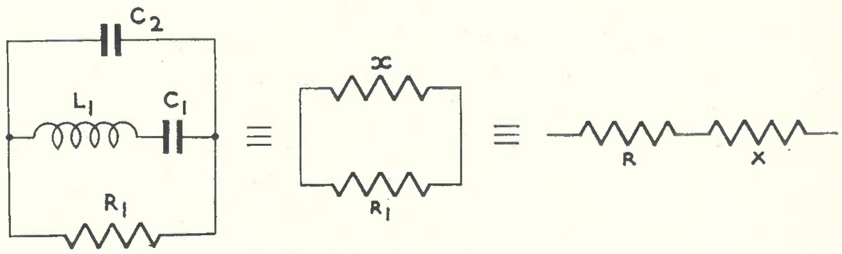

Fig. 2.—Series Arm Equivalent Circuit.

$$R = R_1 x^2/(R_1^2 + x^2) \text{ and}$$

$$X = R_1^2 x/(R_1^2 + x^2).$$

The attenuation of the network is then given by:

$$\text{attenuation (db)} = 10 \log_{10} \left[\left(1 + \frac{R}{R_0}\right)^2 + \left(\frac{X}{R_0}\right)^2\right].$$

It can be seen that when x = 0, there is no loss in the network and that when x = infinity, the attenuation is a maximum and the value is determined by R_1. The network degenerates to a simple attenuator (or pad) in these circumstances, and the attenuation value obtained is called the "pad loss" of the network. The attenuator network may be transformed from the bridged – T form to a simple T network to reduce the number of components. It is then possible to calculate, for any particular pad value, the attenuation produced as x varies from zero to infinity. Graphs have been prepared for 600 ohm impedance networks, for pad values from 2 db to 40 db. Computations for the graphs were carried out on the University of Sydney computer, Silliac, and a typical graph is shown in Fig. 3.

If, then, the pad value is chosen as the maximum loss required in the equaliser, it is possible to determine from such a graph, the x value required to produce a given attenuation at a particular frequency. It is then only necessary to know x at three different frequencies to uniquely determine the network L_1, C_1, C_2. If one of these frequencies is chosen as the upper frequency limit of equalisation, the value of x becomes zero at this frequency (that is the equaliser loss is zero) and this then determines the resonant frequency of L_1, C_1. The determination of the element values is then simplified, and given by:

$$C_1 = \frac{(1/2\pi f_1 x_1) - (1/2\pi f_2 x_2)}{[1/((f_1/f_3)^2 - 1)] - [1/((f_2/f_3)^2 - 1)]}$$

$$C_2 = [C_1/((f_2/f_3)^2 - 1)] - 1/2\pi f_2 x_2,$$

$$L_1 = 1/(2\pi f_3)^2 C_1,$$

where x_1 = reactance at f_1,
x_2 = reactance at f_2,
x_3 = reactance at f_3,
and $x_1 > x_2 > x_3 = 0$
that is $f_1 < f_2 < f_3$.

It is then possible, for a particular set of frequencies f_1, f_2, f_3, to calculate the

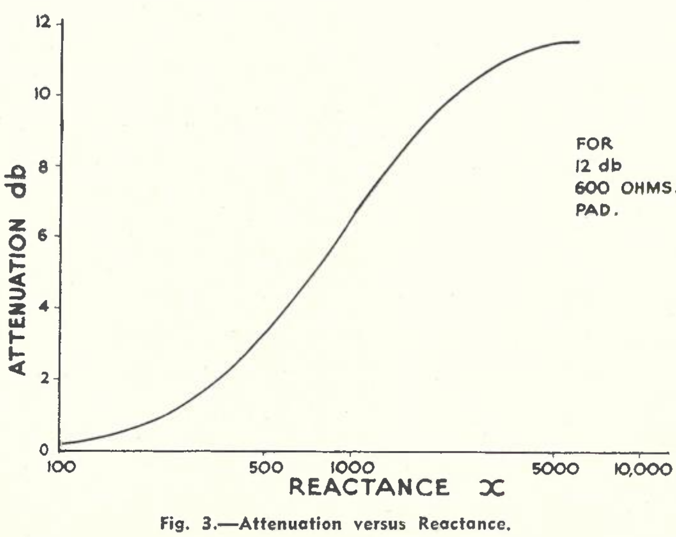

Fig. 3.—Attenuation versus Reactance.

* See page 503.

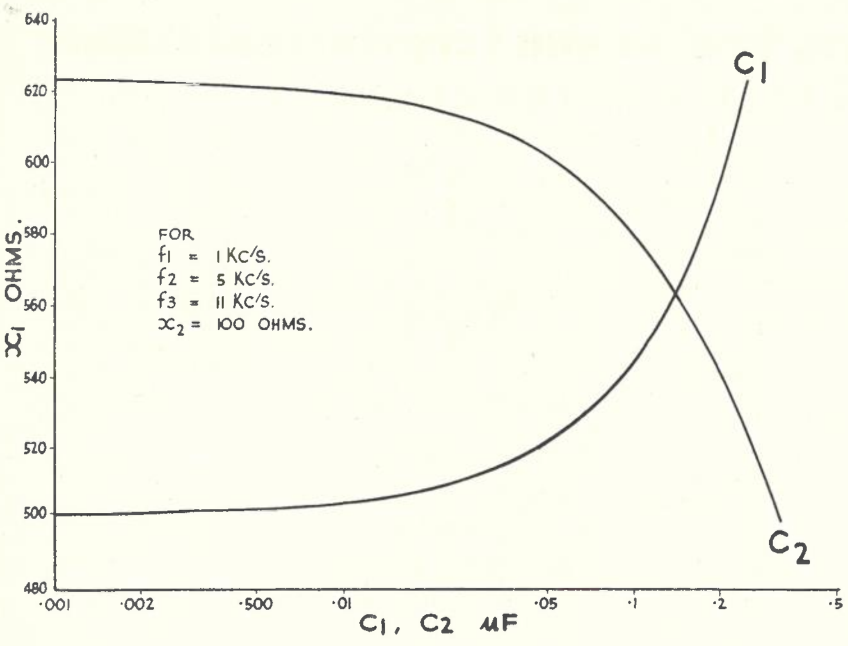

Fig. 4.—C1 and C2 versus x_1.

values of C_1 and C_2 (and hence L_1) for a given value of x_2 as x_1 varies.

Graphs of C_1 and C_2 versus x_1 have been prepared for the following sets of frequencies, for $x_2 = 100$ ohms:

(a) $f_1 = 1$ Kc/s, $f_2 = 3$ Kc/s, $f_3 = 5.5$ Kc/s.
(b) $f_1 = 1$ Kc/s, $f_2 = 5$ Kc/s, $f_3 = 11$ Kc/s.
(c) $f_1 = 1$ Kc/s, $f_2 = 7$ Kc/s, $f_3 = 16$ Kc/s.

These cover the normal frequency ranges for programme equalisation, that is 5 Kc/s, 10 Kc/s and 15 Kc/s. Computations for the preparation of these graphs were also carried out on the Silliac computer and a typical graph is shown in Fig. 4.

These are the only graphs necessary and they can be used to give values of C_1 and C_2 for any other value of x_2 by the following procedure, using conversion factors:

If $x_2 = n \times 100$, then obtain a new value $x_1' = x_1/n$. From the graph obtain values C_1' and C_2' for the value x_1'. Then $C_1 = C_1'/n$ and $C_2 = C_2'/n$.

DESIGN PROCEDURE

The design of an equaliser is then reduced to the following simple steps:

(a) Determine attenuation versus frequency characteristics required in the equaliser.
(b) From this, determine the pad value, which equals the maximum attenuation required.
(c) From graph of attenuation versus x for this particular pad value, determine x_1 and x_2 to produce the required attenuation at the appropriate f_1 and f_2.
(d) From graph of C_1 and C_2 versus x_1, for the particular f_1, f_2, f_3 and x_2, determine C_1 and C_2.
(e) Determine L_1 (calculate from $L_1 = 1/(2\pi f_3)^2 C_1$ or use nomograms of reference 2).
(f) Determine inverse network L_2, L_3, C_3 (calculate or use nomograms of reference 2).
(g) Transform, as required, to balanced form or different impedance value.

CONCLUSION

It can be seen that the design procedure is simple to use and this type of section will provide a ready solution at most times, for the design of programme equalisers for cable circuits. Equaliser sections of this type have been used successfully in New South Wales for many years, although it is only of recent years that the design curves have been extended to the 16 Kc/s frequency range and to cover a wider range of pad and x values. It is also possible to extend the range of application to carrier frequency cable circuits by the appropriate choice of the frequency parameters.

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TRANSISTOR CIRCUITS FOR GENERATION OF EXCHANGE SERVICE TONES AND BELL RINGING CURRENT

*F. W. WION, B.E.E., M.Eng.Sc.**

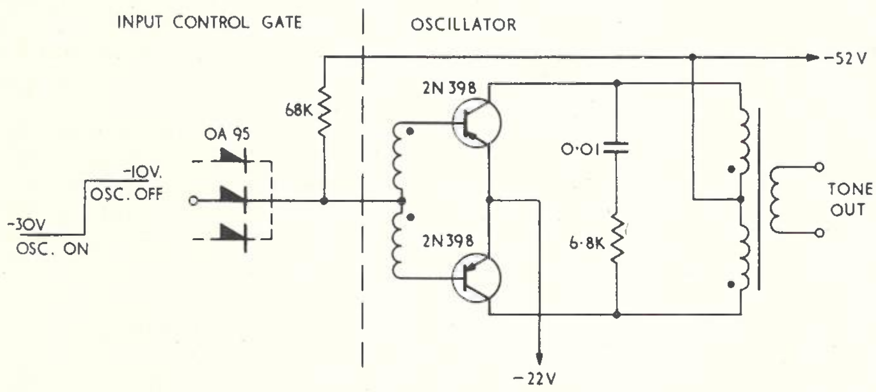


Fig. 1.—Tone Oscillator.

INTRODUCTION

Service tones and bell ringing current are produced by rotary converters in the majority of telephone exchanges. However, in some locations alternative services of ring and tone supply are required, and special devices have been used in the past to meet this need. These devices include vibrator and subcycle ring current generators, and vacuum tube tone oscillators switched by relay circuits.

The use of semi-conductor circuits for ring and tone generation is an attractive proposition, particularly with regard to their high reliability without routine maintenance, and such circuits have been developed recently by the Research Branch. Three different classes of circuit have been developed:

(a) Low powered tone oscillators which can be interrupted if necessary by a suitable input control voltage.

(b) High powered ring current generating oscillators which can also be interrupted by electronic control.

(c) Timing and logic circuits which can produce a wide variety of switching signals to control different oscillators as required.

Any desired service tone can be obtained by a suitable combination of oscillator and switching signal. New tones can be added readily with a minimum extension to existing circuitry, and just sufficient circuitry need be used to provide for a particular requirement. The equipment to be described provides one phase of ring current at 200 mA together with Dial, Ring, Busy, Number Unobtainable (N.U.), and Pip Tones. A more detailed description is given in Reference 1.

* See page 503.

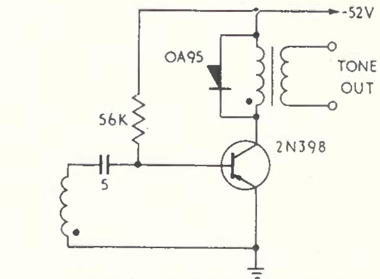


Fig. 2.—Dial Tone Oscillator.

TONE GENERATING CIRCUITS

General: Two different types of oscillators are used for tone generation. The first is a free-running blocking oscillator for dial tone. This type of oscillator is chosen to approximate the waveshape produced by conventional rotary machines. The second type of oscillator is a symmetrical saturating core square wave oscillator. The features of this

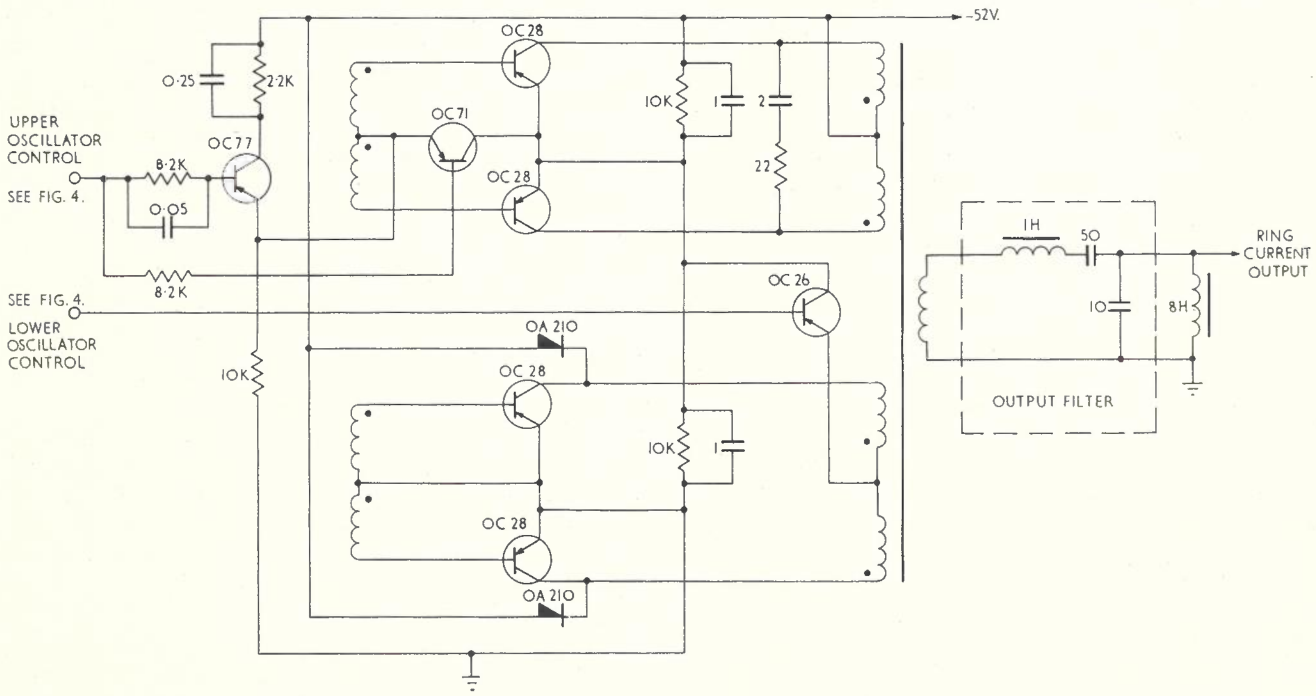


Fig. 3.—Ring Current Oscillators.

oscillator include excellent regulation, and low power on-off switching control. The design of these types of oscillator has been described in the literature (References 2 and 3) and will not be discussed here.

Square Wave Saturating Core Oscillators: A circuit of the oscillators used (and an input control gate) is shown in Fig. 1. The oscillators are fed from a 30 volt supply, the actual potentials being -22 volts and -52 volts, derived from the 52 volt negative supply used for the overall equipment. The frequency of these oscillators is chiefly dependent upon the transformer primary winding, and frequencies of 400 c/s and 900 c/s are used in the tone generating equipment. Other frequencies, if required, can be readily provided by suitable transformer design. The oscillator output voltage is approximately 3 volts peak and each oscillator will deliver in excess of 250 mW with negligible change in output voltage. The transformer is wound on a mumetal core with a maximum dimension of one inch.

Each oscillator is switched under the control of the resistor-diode input gate. Switching signals derived from the timing circuits are applied to the anode ends of the gate diodes. These switching signals have potentials of either -10 volts or -30 volts. If any one signal is at -10 volts, the oscillator will be inhibited, but if all signals are at -30 volts, the oscillator will switch on, the transistors deriving base current from the gate resistor. In the case of Pip and Busy tone oscillators only single inputs are used, but diodes are necessary for isolation purposes.

Dial Tone Blocking Oscillator: Dial Tone pulses are produced by a blocking oscillator, the circuit of which is shown in Fig. 2. The repetition period of 30 m.sec. is determined by the 56 K-ohm resistor and 5 μF capacitor network connected to the transistor base. The pulse duration of 0.67 m.sec. is determined by the transformer characteristics. The oscillator provides pulses of 10 volts peak amplitude, dropping to 5 volts when loaded with 50 ohms.

RING CURRENT GENERATOR

General: It is desirable that the ring current generator should provide up to

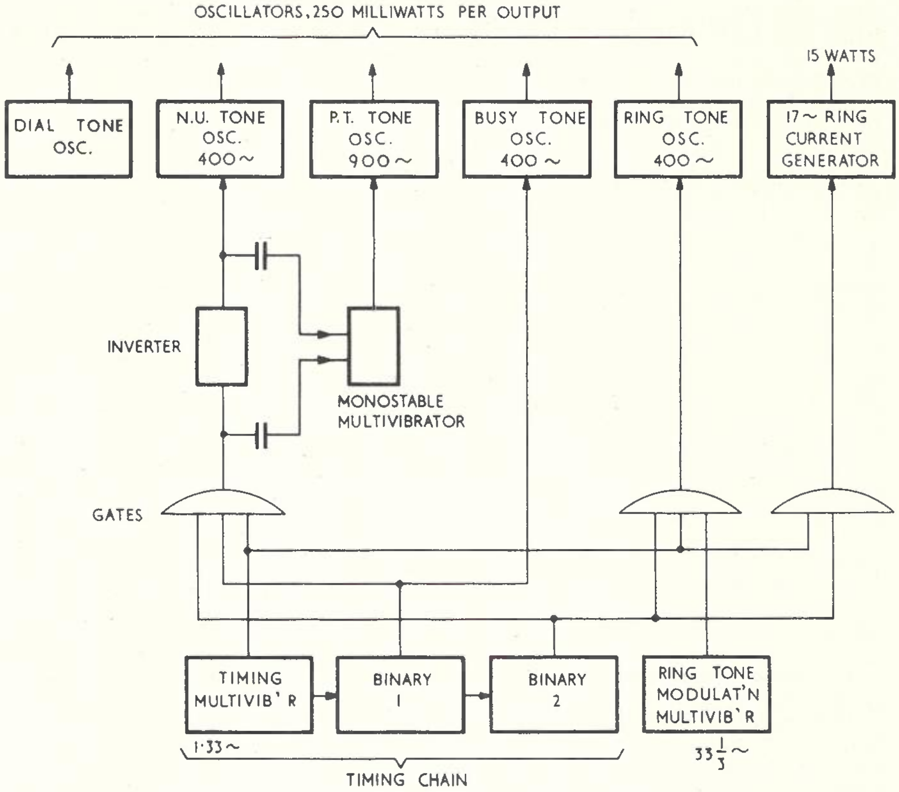


Fig. 5.—Timing Circuits.

15 watts of $16\frac{2}{3}$ c/s power with low harmonic content at frequencies above 100 c/s. The output regulation of a sinusoidal oscillator is poor compared to a saturating core square wave oscillator, the regulation of which is determined almost wholly by transformer winding resistances. A saturating core oscillator is accordingly used, but filtering of the output signal is necessary to obtain a sufficiently low harmonic content to avoid interference in adjacent circuits.

The supply voltage is 52 volts D.C. and to observe the voltage ratings of suitable transistors, two similar oscillators are connected in series across the supply, sharing a common transformer core. The two oscillators oscillate in synchronism, and draw equal currents; consequently the supply voltage is halved across each oscillator.

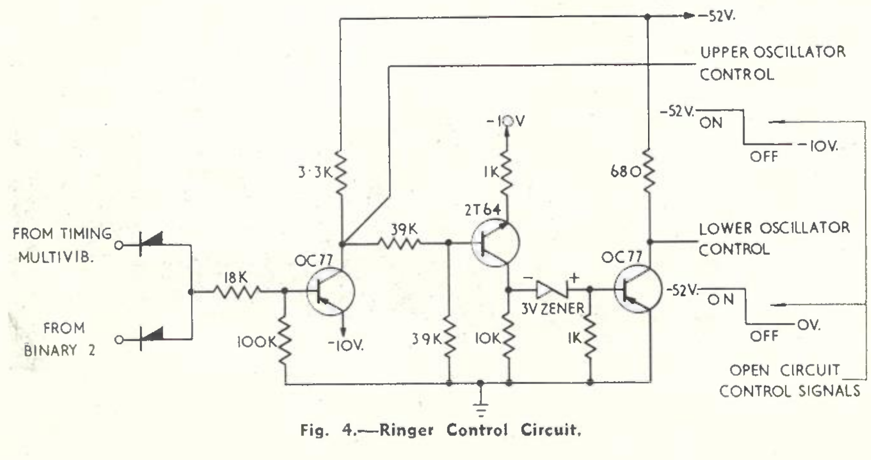


Fig. 4.—Ringer Control Circuit.

Oscillators: A schematic circuit of the oscillators is shown in Fig. 3. The two oscillators are basically the same, the chief difference being in the control arrangements. The only other difference is in the method used to suppress voltage spikes which the inductive loads tend to produce at the OC28 collectors. The lower oscillator has two silicon diodes clamping the OC28 collectors to -52 volts. The upper oscillator, however, uses an R–C quench circuit between the transistor collectors as there is no -104 volt potential available to which clamping diodes could be returned. The latter method is satisfactory, but not as effective as the first. A divider network of 10 Kohm resistors and 1 μF capacitors stabilises the potential of the midpoint between oscillators under turned off and transient conditions.

The lower oscillator is controlled by an OC26 transistor in the supply lead from the -26 volt midpoint. In effect, the transistor is an emitter follower with the oscillator as its load. If the OC26 base potential is maintained at -26 volts, the oscillator will operate correctly. However, if this base is switched to 0 volts, the oscillator supply is removed, and it ceases to oscillate.

The base circuit of the OC28 transistors in the upper oscillator is fed from a divider consisting of two transistors and a 2.2 Kohm resistor. When both transistors are 'ON', the 2.2 Kohm resistor provides starting bias for the oscillator. This bias is necessary if the oscillators are heavily loaded. When both transistors are 'OFF', the bias is removed and the non-conducting OC71 reduces loop gain below unity, stopping oscillations, even under no load conditions.

The transformer laminations are of stalloy, a cheap transformer steel, and the centre leg area is 1½ square inches.

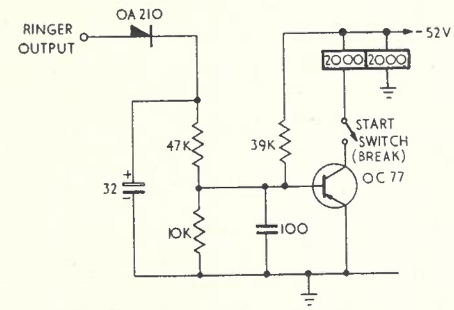


Fig. 6.—Ring Fail Alarm.

The filtered output is 15 watts at 75 volts r.m.s.

The output filter design represents a compromise between the necessity of controlling the open circuit and full load voltages, the costs of components, and the need to filter satisfactorily with a wide range of output terminations. The open circuit r.m.s. voltage is 116 volts, but the peak voltage is approximately equal to that of a 100 volts r.m.s. sine wave. The psophometrically weighted output is only 80 m.volts at full load, rising to 270 m.volts at no load. An eight henry output choke provides a D.C. path for external circuits, without affecting the filter performance.

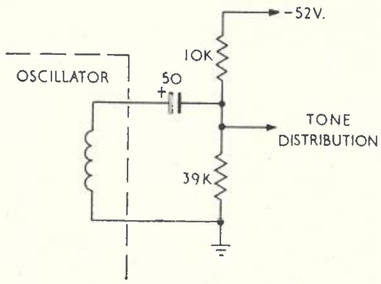


Fig. 7.—Contact Wetting Circuit.

Control Circuit: The outputs of the timing circuits switch between − 10 volts and − 30 volts. It is necessary to provide circuits which will adapt these voltage swings to control the oscillators of the ring current generator. The circuit used is shown in Fig. 4. A diode input gate produces the desired timing waveform. Inverting and power amplifying stages follow, to provide suitable control signals for the oscillators.

TIMING CIRCUITS

The timing circuits are shown in block schematic form in Fig. 5. Detailed circuits can be obtained from Reference 1. The heart of the timing circuits is a free-running asymmetrical multivibrator running with half periods of 0.5 second and 0.25 second. Two binaries are driven from this clock multivibrator in a divide-by-four circuit. The half periods of these two binaries are 0.75 second for the first and 1.5 seconds for the second.

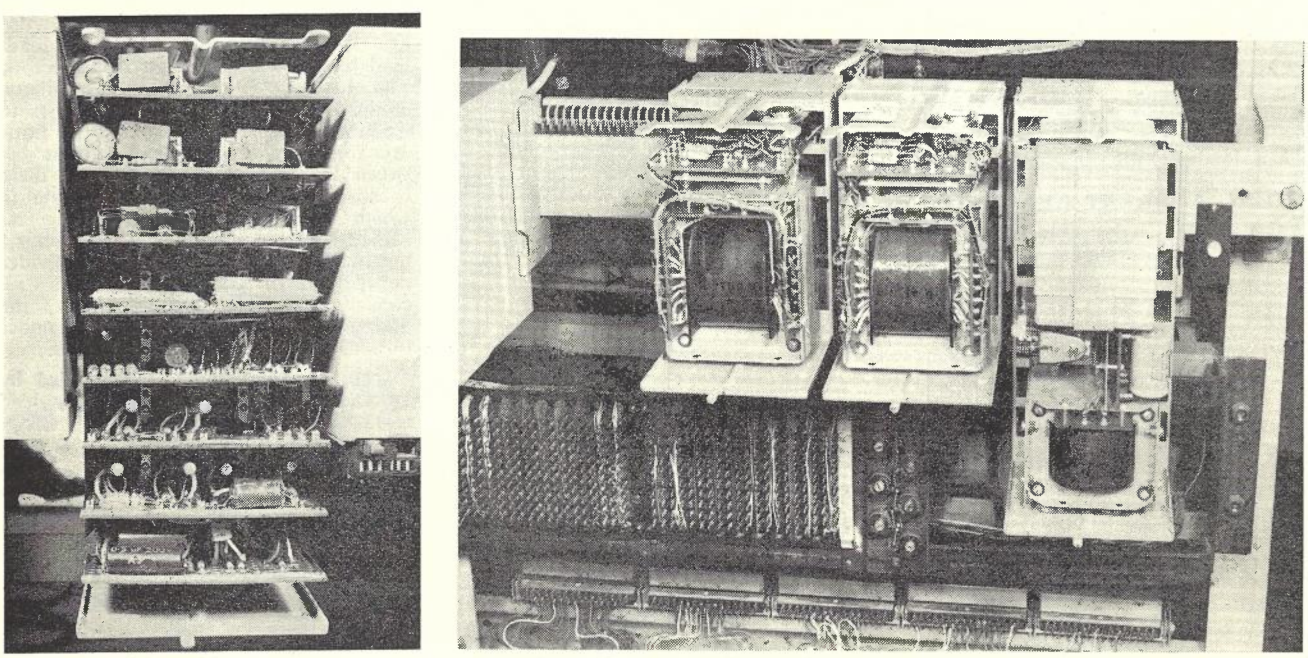
Busy tone is controlled directly from the first binary, giving periods of 0.75 second on, 0.75 second off. The ring-tone oscillator is controlled from (a) the clock multivibrator, (b) the second binary, (c) a free-running 33-⅓ c/s multivibrator, which provides the necessary modulation of ring-tone. The ring-tone period obtained is 0.4 second on, 0.2 second off, 0.4 second on, 2.0 seconds off. To provide the N.U. tone timing waveform, a three input diode gate, followed by an inverter is used, giving periods of 2.5 seconds on, 0.5 second off. This timing waveform could be provided more simply, but the inverter output is also used as one trigger source to a monostable multivibrator of 0.2 sec. pulse width, which provides the timing waveform for Pip-tone. The Pip-tone timing is 0.2 second on, 0.3 second off, 0.2 second on, 2.3 seconds off.

OTHER CIRCUITS

Ring Fail Alarm: The circuit of Fig. 6 is used to detect ring current failure giving an alarm and changing over to an alternative source of ring current. As long as the ringer is operating the transistor is held 'OFF', and the relay operates on one winding. Ring failure permits the transistor to conduct, and the relay releases because of opposed winding fluxes. The relay will also release in the event of power supply failure.

Supply Potentials: Intermediate potentials of − 10 volts, − 22 volts, and − 30 volts are required to supply different circuits, and must be derived from the 52 volt supply. These intermediate potentials have been obtained by the use of Zener diodes. Circuit details may be found in Reference 1.

Contact Wetting Circuits: The networks of Fig. 7 are connected between the output of each oscillator and the corresponding tone output. These networks isolate the oscillators from any D.C. in the external circuitry, and provide wetting potential for all mechanical contacts.



(a)—Tone Generation and Control Unit. (b)—Ringer Bases and Alarm Units.

Fig. 8.—Photographs of Trial Installation at Wantirna South, Victoria.

PERFORMANCE

The completed circuits perform satisfactorily at temperatures from –10° C. to + 50°C. The equipment will withstand repeated switchings of the power supply without failing. After extensive laboratory tests, units have been built up in standard relay bases, and are at present undergoing field trials in a Metropolitan Minor Exchange. Fig. 8 shows a photograph of the installation. The tone and timing circuits are mounted on one base, and two ringers have been provided on separate relay bases, one for standby purposes. The fourth base contains the ringer output filter and ring fail circuits. The performance to date has indicated a high order of reliability. There has been only one semi-conductor failure, and the cause of this was removed by improved circuit design.

CONCLUSION

It is possible to build ring and tone equipment with semi-conductor circuits. The equipment is compact and easy to mount, and can be produced by any manufacturer of electronic equipment. The equipment is particularly suited for locations where maintenance is infrequent, and a wide variety of circuit combinations is possible to suit particular applications. Equipment costs are roughly comparable with other available equipment.

ACKNOWLEDGMENT

The equipment described in this paper was developed jointly by Mr. H. S. Wragge and the author, in the Headquarters Research Branch.

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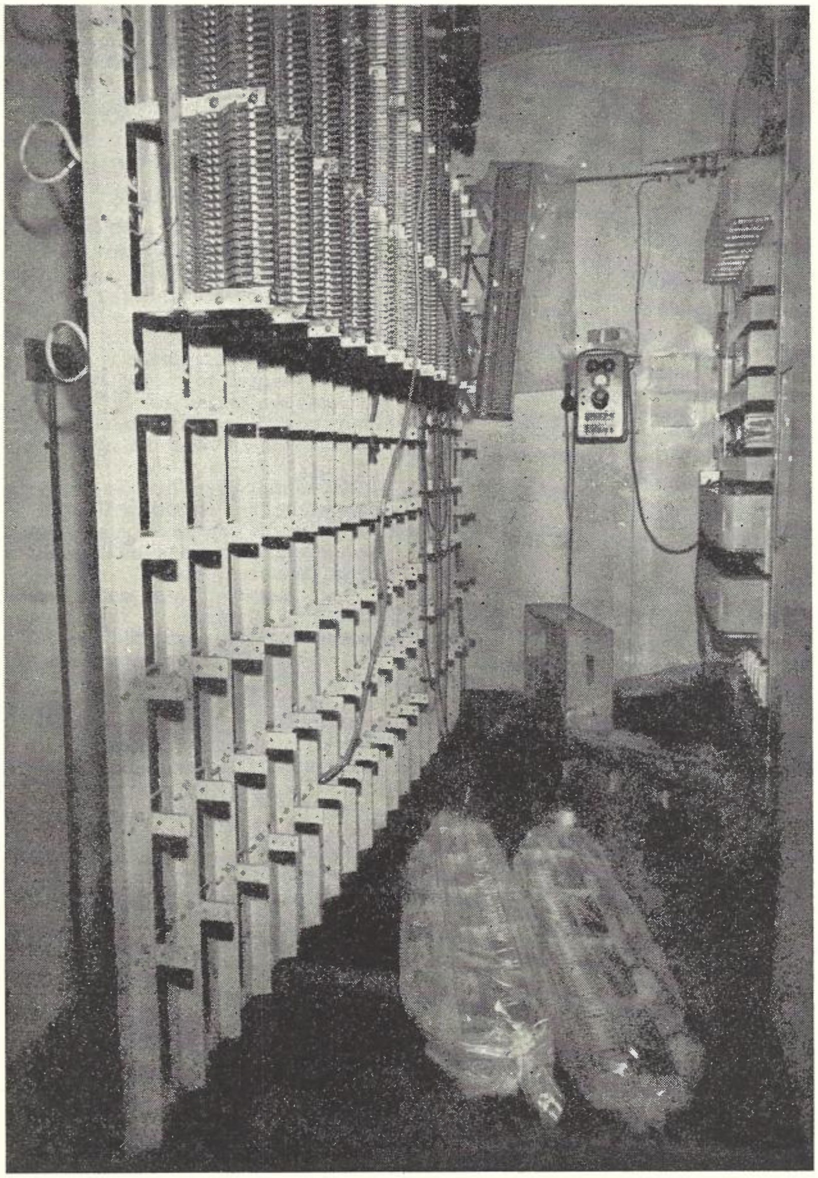
TECHNICAL NEWS ITEM



Fuse mountings being removed from M.D.F. and protected by Linemen's Plastic Protecting Sleeving.

TRANSPORT OF PORTABLE EXCHANGE— A METHOD OF FACILITATING CABLE RETERMINATING

Recently a portable 600 line automatic exchange, in working order, was transported within the Perth metropolitan area using conventional methods. The interesting features were the steps taken to complete the reinstallation in the shortest possible time.

Terminated on the M.D.F. were twenty-two 100 pair tails and these were jointed into three pot-head joints in the cable well. To facilitate removal, the fuse mountings and associated tail assemblies were completely removed from the exchange building. Terminating time of the cables at the new site was reduced by retaining the pot-head joints and leaving cable tails which were jointed to the external cables. The usual method for transporting a portable exchange was to cut the M.D.F. tails and abandon the pot-head joints. In this instance the old and new cable entry layouts were similar. Thus, unnecessary labour and delay were avoided by retaining the pot-head joints with cable tails and so requiring only straight paper joints to the external cable reticulation.

It was decided to remove the fuse mountings from the M.D.F. and out of the exchange building, rather than transport the pot-head joints with the building. Therefore a hole was cut in the wooden floor and the fuse mountings, wired together in units of five mountings each for rigidity, were lowered through this (see figure). At the point where the M.D.F. tail cable sheathing had been stripped back, a nine-inch piece of dowelling was laced along the cable to prevent chafing.

The fuse mountings had to be kept free of dust, soil and moisture. This was done by using Linemen's Plastic Protecting Sleeving, as shown in the photograph. Sleeves were cut to size, slipped over each of the units, and sealed at each end by means of a cord. Precautions were taken against the possibility of severe flexing of the M.D.F. tails by the use of a lattice frame of timber planks. The fuse mountings were secured to this frame and the whole assembly manhandled with ease.

D. HENSHAW.

DESIGN ASPECTS OF TRANSISTOR AND DIODE SWITCHING CIRCUITS — PART III

*F. W. ARTER B.E.E., M.Eng.Sc.**

10. CIRCUITS CLOSELY ALLIED TO GATING CIRCUITS

Having discussed the performance and design of diode and transistor gating circuits, other transistor circuits which are commonly associated with these types of circuit will now be discussed. Each type of circuit has its particular application in the field of switching and these will be indicated. The circuits in this category are listed below and are discussed in that order:

(i) The Emitter Follower.
(ii) The Eccles-Jordan Flip-Flop and its more particular applications in binary counters and shift registers.
(iii) The Astable Multivibrator.
(iv) The Monostable Multivibrator.
(v) The Blocking Oscillator.

11. THE EMITTER FOLLOWER

This circuit is not a switching circuit in that it does not use a transistor in the "switched" regions of its characteristics. The transistor remains in the active region. In switching circuits, direct coupled emitter followers can be used as current amplifiers which introduce only small changes in the D.C. switching potentials from input to output. They therefore find their principal use as impedance matching devices in long chains of gates, as has already been indicated in the previous articles of this series.

Such circuits can use either p-n-p or n-p-n transistors, and it is advantageous to make use of both types even when the remaining switching circuitry uses transistors of only one of these types. This is due to the fact that the resultant two types of emitter follower complement one another in regard to their output loading capabilities, the one being best suited to supplying output current in one direction and the other in the reverse direction. Circuits of both types of emitter follower are shown in Figs. 14(a) and 14(b).

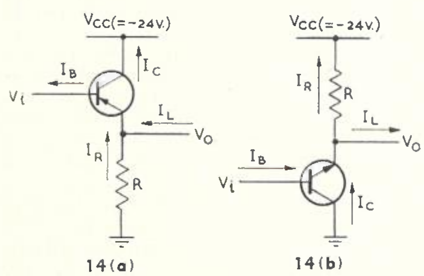


Fig. 14.—The D.C. Coupled Emitter Follower.

For both cases, using the designated current directions and symbols for the respective figures, the following relationships apply:

(i) $V_1 = V_o + V_{BE}$

where V_{BE} is the base to emitter voltage. The above potentials are negative for the p-n-p transistor and positive for the n-p-n transistor. Since V_{BE} is small (approximately 0.2 volts in magnitude for germanium transistors) it can usually be neglected. Hence the direct coupled emitter follower provides closely unity voltage gain (that is $V_o \doteqdot V_1$).

(ii) $I_C = I_L + I_R - I_B$

and $I_C = \beta I_B$

where β is the D.C. base to collector current gain. Generally β is larger than 25, and hence I_B can be neglected in the former equation to give:

$$I_C = I_L + I_R.$$

When I_L is positive, that is, in the respective directions as shown in the figures, it can be seen that I_C is always positive and is maximum when I_L is maximum. Since the maximum load is placed on the source driving the emitter follower when I_C is maximum, and hence when I_B is maximum, the loading requirements on this driving source can be computed for both switched potentials. In both cases, it is when I_L is positive in direction that the emitter followers are best used, the base drive requirements being positively determined by the load on the emitter follower, and hence power supply drain is economised. The value of the emitter resistor R in such cases is determined from consideration of the integrating effects on transient times of the finite but small output resistance of the emitter follower and the output shunt capacity. The value of R must be chosen small enough to reduce this effect to the required degree.

When I_L is negative in either figure, the magnitude of I_R must be so chosen that, in all loading conditions (I_L) for both switched potentials, I_C does not become zero. Keeping I_C positive ensures that the transistor controls the output potential. Hence, under these conditions, I_R must be chosen greater than $I_{L\,max}$ for both switched potentials. In this case, the greatest load on the source driving the emitter followers occurs when I_L is zero and I_C is maximum and equal to I_R. The maximum base drive requirements, $I_{B\,max}$, can thus be computed for both switched potentials.

Emitter followers do not use transistors in the switching mode and hence care must be taken not to exceed the device dissipation ratings at both potentials for all loading conditions. The total device dissipation is the sum of the base and collector dissipations and is given by:

$W_{max} = V_{CE} \cdot I_{C\,max} + V_{BE} \cdot I_{B\,max}$

where V_{CE} is the collector to emitter voltage, as given by

$$V_{CE} = V_o - V_{CC}$$

12. THE ECCLES-JORDAN FLIP-FLOP

This circuit is one of the multivibrator family. It exhibits two stable states and is therefore often called the "bistable multivibrator". It can be triggered from one stable state to the other by pulses derived from the outputs of switching circuits. Hence it can be used as a "memory" to record in a meaningful way the output of such circuits, by designating one stable state to represent the state of "1" and the other the state "0".

The circuit of a flip-flop without triggering inputs is shown in Fig. 15. From the figure, it can be seen that the flip-flop actually consists of two inverters cross connected output to input. Two outputs are available, one from each collector. Because of the cross connected inverted configuration, one output is always the complement of the other. This feature is often of advantage, as the flip-flop can be used as a memory device storing an input variable to a switching circuit, which also automatically stores the complement of

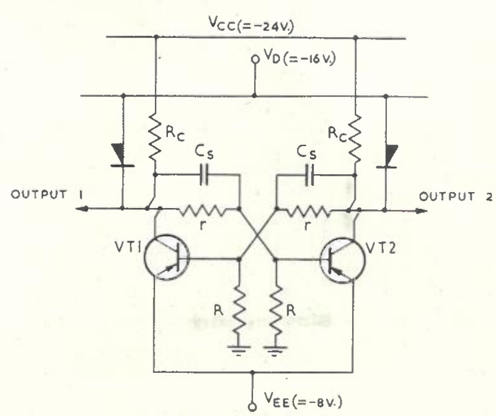


Fig.15.—The Flip-Flop.

* See Vol. 13, No. 4, page 350.

the variable. The output potentials and resistances of the flip-flop are identical to those of the NOR gate and Inverter circuits, and thus the flip-flop is ideally suited to applications involving such circuits and diode gates as outlined in the previous article of this series.

12.1. Circuit Operation and Design

The operation of the circuit is as follows. If no trigger pulse is applied, one transistor is saturated and, by virtue of the interlocking cross-connection, the other is cut-off. The base coupling resistors are so chosen to achieve these two stable states. The particular stable condition of the circuit at any instant depends on the previous history of the circuit. If now a positive trigger pulse is applied to the base of the saturated (p-n-p) transistor, it will be switched towards cut-off. The negative going change in potential at the collector of this transistor is applied via the cross coupling to the base of the other (cut-off) transistor, switching it towards saturation. The collector potential of this transistor changes positively and the cross coupling to the base of the first transistor further switches it towards cut-off. The positive feedback thus achieved during switching ensures a fast transition to the other stable state of the circuit. Even though the trigger pulse no longer exists, this state is maintained by the steady D.C. conditions existing between the interlocked inverters, and no further change occurs until a further positive trigger pulse is applied to the now saturated transistor to start the transition cycle once more, but now with the roles of the transistors reversed.

The design of the two halves of the flip-flop is, as mentioned, identical to that outlined for the NOR gate in the previous article of this series. The capacitors C_S shunting the base resistors r can be added (as in the NOR gate) to improve the transition speed of the flip-flop from state to state. These capacitors provide excess base drive during transitions, so reducing the turn-on and turn-off times of the transistors.

12.2. Triggering Methods

A wide variety of possible triggering circuits can be devised for flip-flops. In general, the triggering pulses can be applied from a common source alternately to one base and then to the other, or separate sources of pulses can be applied to the individual bases.

Common triggering from one source is used when the flip-flop acts as a binary counter. The flip-flop divides the input pulses by two since an output of the flip-flop provides only one pulse for every pair of input pulses. In such applications, it is desirable that the triggering circuit

(a) steer the trigger pulse to the particular base to be switched as determined by the state of the flip-flop and the polarity of the trigger pulse, and
(b) remove any unwanted pulses of opposite polarity to the trigger pulse resulting from the differentiating of a rectangular pulse by the trigger coupling capacitor.

In general, "turn-off" trigger pulses are used in flip-flops, that is positive pulses for p-n-p transistor circuits and negative pulses for n-p-n transistor circuits. This choice of polarity enables the steering requirement to be attained most easily by using the collector potentials to bias the trigger diodes to different extents. In this way, the diode most nearly conducting steers the pulse to the appropriate base. Several typical common-trigger circuits are shown in Figs. 16(a) and 16(b).

In Fig. 16(a), the triggering circuit components comprise the capacitor C_C and diodes D_1, D_2, D_3. Diode D_1 removes any unwanted negative pulses resulting from the differentiation of the input trigger pulse by the trigger coupling capacitor C_C. Diodes D_2 or D_3 steer the positive trigger pulse to the base of the saturated transistor to switch it to cut-off. For example if the transistor VT1 is saturated, that is its collector is at the potential V_{EE} (= – 8 V.), the other

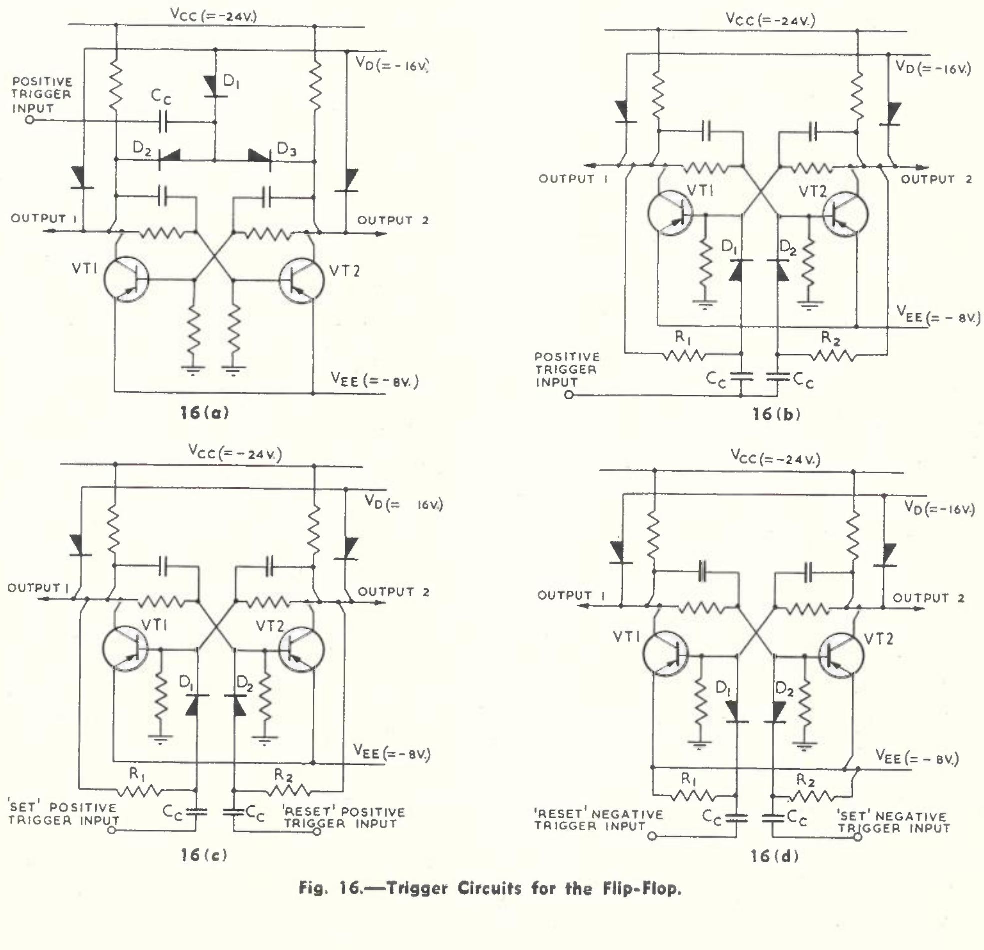


Fig. 16.—Trigger Circuits for the Flip-Flop.

transistor VT2 is cut-off and its collector potential is V_D (= −16 V.). The diode D_2 is then reverse biassed by a potential equal in magnitude to $(V_{EE} - V_D)$ volts, whereas the diode D_3 is closely zero biassed. Hence diode D_3 will conduct first when the positive trigger pulse appears. This pulse is thus steered by diode D_3 via the collector of the cut-off transistor VT2 and the cross-coupling resistor from this collector to the base of the saturated transistor VT1, switching it to cut-off. As this transistor switches to cut-off, it switches the other transistor VT2 to saturation, reversing the previous state of the circuit. The diode biassing conditions are now reversed and the next positive triggering pulse is steered by the now zero biassed diode D_2 to the now saturated base of the transistor VT2 via the collector of the now cut-off transistor VT1. This pulse switches the circuit back to its original state.

In Fig. 16(b), the triggering circuit components comprise the capacitors C_C, the resistors R_1 and R_2, and the diodes D_1 and D_2. Similar preferential biassing of the diodes D_1 and D_2 by the collector potentials via the resistors R_1 and R_2 respectively, steers the positive trigger pulse to the base of the saturated transistor. The negative pulses resulting from differentiation of the trigger input are blocked by both diodes as such pulses drive them to conditions of reverse bias. The trigger resistors R_1 and R_2 provide a D.C. return path to the diode-capacitor junction and these resistors are generally kept large compared with the collector load resistors. This second method of triggering from a common source is more sensitive than the first since the pulses are fed direct to the bases. The sensitivity of the first method is dependent upon the size of the speed-up capacitors C_S shunting the resistors r in Fig. 15. These are generally required in such a case to reduce the attenuation of the trigger pulse by the cross coupling resistors from collector to opposite base.

When the flip-flop is used as a memory, it is usual to feed trigger pulses from separate sources. In such cases, one stable condition of the flip-flop is designated as that when a "1" is stored and the other stable condition is referred to as the "0" state. In any one state, the flip-flop provides at one collector a "1" potential and at the other a "0" potential. Thus, if one collector is considered as that storing a variable A, the other collector automatically stores its complement A^1, and both variables are available as outputs, one from each collector. In such applications of the flip-flop, it is no longer necessary to provide for trigger pulse steering but it is still desirable to remove, by clipping or blocking, trigger pulses of unwanted polarity, so that pulses of one polarity only cause triggering. Since steering is no longer necessary, pulses of either polarity can be used to trigger the flip-flop. It should be noted that if a series of trigger pulses is applied to one side only, the flip-flop will only be affected by the first of these, the others being ineffective until pulses are applied to the opposite side of the flip-flop to reset it to its original condition. Several typical triggering circuits for two separate sources are shown in Figs. 16(c) and 16(d). Fig. 16(c) shows a circuit for positive pulse triggering and Fig. 16(d) shows a circuit for negative pulse triggering. The resistors R once again are generally kept large.

The use of the flip-flop as a memory occurs in digital computers whose arithmetic is carried out in the binary system, in which case the flip-flops are used to store the binary digits "0" or "1". This notion of storage is slightly different from that when the flip-flop is used to store a two-state switching variable, when it then stores a "1" or a "0" state for the control of gates. The notions involved in these two memory roles of the flip-flop are slightly different, but the circuit aspects of both are similar.

12.3 Counter Applications

Waveforms of the flip-flop when operated as a counter are shown in Fig. 17 for the circuit of Fig. 16(a). The property of binary division can be seen from these waveforms. If trigger pulses are derived by differentiating one collector output of such a flip-flop and these are used to trigger a second flip-flop, the overall division performed by the two stages is $2^2 = 4$. If a third stage is added, the three stages divide by $2^3 = 8$, and so on. By including visual indicators in each of the flip-flop circuits to indicate their states, such circuits can be used to count the number

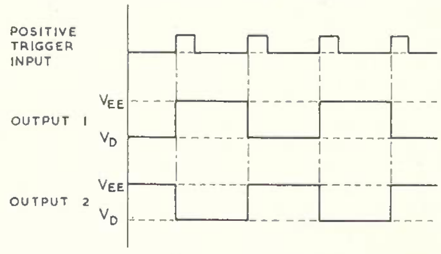


Fig. 17.—Waveforms for the Flip-Flop with Common Triggering.

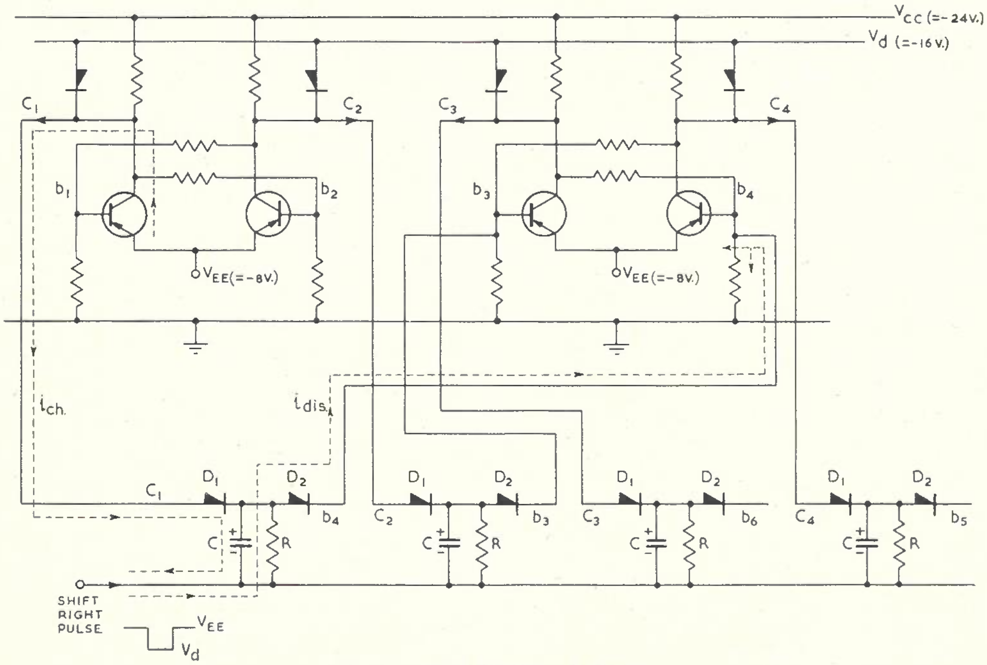


Fig. 18.—Shift Register (2 stages).

of pulses entering the first flip-flop in the chain. The count is obtained in binary form, that is $a2^0 + b2^1 + c2^2 + d2^3 + \ldots$, where a, b, c, d . . . . are two-valued (0 or 1) and are represented by particular states of the flip-flops, "a" by the first flip-flop in the chain, "b" by the second, "c" by the third, and so on.

An alternative use of flip-flops cascaded as above in the form of a counter is in providing sequences of control pulses for operating gates in a particular sequence. In such cases, the "counter" is driven by a source of "clock" pulses, and suitable gating of the collector outputs of the counter flip-flops is provided to derive the sequences of control pulses.

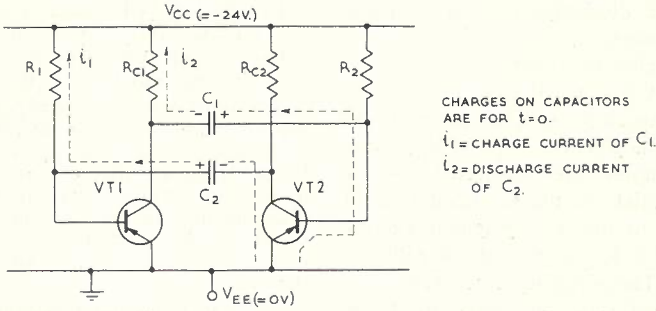
12.4 Shift Registers

Another use of the flip-flop is in Shift Registers. In such circuits, the "memory" property of flip-flops is utilised and additional "shift" circuits are provided between flip-flops to enable the binary information stored in the flip-flops to be shifted bodily, one place to the right or left, under the control of an appropriate "shift" pulse. Two flip-flops with the appropriate shift circuits are shown in Fig. 18. Shift circuits to enable the stored information in the flip-flops to be shifted to the right are shown, each flip-flop requiring two such circuits, each comprising the diodes D_1 and D_2, the capacitor C and the resistor R.

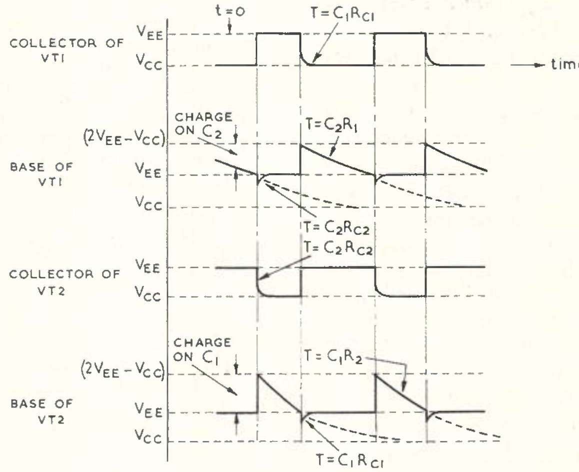
The shifting operation is as follows. Consider that the collectors C_1 and C_4 are saturated, that is at the V_{EE} (or "1") potential, and thus the collectors C_2 and C_3 are cut-off at the V_d (or "0") potential. While the shift pulse line is at the more positive V_{EE} potential all diodes D_1, D_2 are reverse biassed—the resistors R providing D.C. paths to the diode junctions. When the shift pulse is applied, the shift line is dropped to the more negative V_d potential, the diodes D_1 associated with collectors C_1 and C_4 are forward biassed, and the charging current i_{ch} flows (as indicated in the circuit) to charge the capacitors C associated with collectors C_1 and C_4, on the leading edge of the shift pulse. The similar diodes D_1 associated with collectors C_2 and C_3 are not forward biassed since C_1 and C_2 are at the same potential as the shift line. Hence the capacitors C associated with C_2 and C_3 are not charged.

When the appropriate capacitors C are charged to a potential ($V_{EE} - V_d$), stable conditions ensue until the trailing edge of the shift pulse. When the shift line is returned to the V_{EE} potential, the diodes D_1 are again reverse biassed. The diodes D_2 associated with charged capacitors C now become forward biassed to discharge the capacitors into the bases of their respective right-hand neighbours. The positive pulse applied to the flip-flop bases triggers them to the state which was that of its neighbour to the left if the pattern of connection from collectors to bases of adjacent flip-flops is as shown in the figure. The discharge current i_{dis} flows along the path dotted in the circuit. It can be noted that only one of the pair of shift circuits associated with a flip-flop is operative during a particular shift pulse. Similar circuits, but connected from flip-flop to flip-flop in the reverse direction, can be used to obtain a shift left facility.

It can be seen that the capacitors C act as temporary stores of the information contained in the flip-flops to their left for the duration of the shift pulse trailing edge transition. The diodes D_1 are provided especially when fast charging of the capacitors C is required in high speed circuits; in slower applications they can be replaced by suitable resistors. The resistors R merely provide a D.C. path to the diode junction to ensure their proper biassing and these are generally kept large. The choice of the magnitude of the capacitors C depends on the speed of shifting. It must be sufficiently large to trigger the following flip-flop (as determined by considerations such as those in Reference 9) but not so large that its charge and discharge times are in excess of the duration of the shift pulse.



19(a)



19(b)

Fig. 19.—The Astable Multivibrator.

13. THE ASTABLE MULTIVIBRATOR

This member of the multivibrator family is a free-running oscillator with an approximately square-wave output voltage waveform. This feature makes the circuit useful as a "clock" which produces suitable pulses for application to the trigger inputs of flip-flops. A typical circuit of an astable multivibrator is shown in Fig. 19(a) and typical waveforms in Fig. 19(b). Outputs can be taken from either or both collectors. The operation of the circuit is now explained with reference to Fig. 19.

13.1 Operation

Consider the circuit to be operative and let our considerations begin at the time $t = 0$ as shown on the waveforms. At this time, the collector waveforms show VT1 to be cut-off and VT2 to be saturated. This condition is maintained by the discharging capacitor C_2 (which is holding the base of VT1 positive with respect to its emitter and thus holding VT1 cut-off) and by the steady base current flowing in R_2 holding VT2 saturated. The potentials across the two charged capacitors C_1 and C_2 are indicated at $t = 0$ on the base waveforms.

Capacitor C_2 is discharging towards the supply potential V_{CC}, via the saturated collector of VT2 and the resistor

R_1 – the discharge current i_1 being shown. Hence,

Discharging time constant
of $C_2 \doteqdot C_2 R_1$.

The capacitor C_1 is charged, as shown, to a potential $(V_{EE} - V_{CC})$ since its extremities are connected to the V_E potential via the saturated base of VT2 and to the V_{CC} potential via the load resistor R_{C1} of the cut-off collector of VT2. The charging current path to achieve this state of charge on C_1 is shown $-i_2$ – and the charging time constant of C_1 can be seen to be closely equal to C_1R_{C1}, neglecting the resistance of the saturated base of VT2.

As the capacitor C_2 discharges, the potential of the base of VT1 reaches V_{EE}—the emitter potential. At this stage VT1 begins to conduct and regeneration around the circuit rapidly switches VT1 to saturation and VT2 to cut-off. The charge on C_1 now raises the potential of the base of VT2 to a potential more positive than the emitter potential by $(V_E - V_{CC})$ volts, establishing and holding VT2 cut-off as it now starts to discharge via the saturated collector of VT1 and R_2. Hence,

Discharging time constant
of $C_1 \doteqdot C_1R_2$.

As VT1 is saturated, the capacitor C_2 must charge to a potential similar to that across C_1 before switching, one end of C_2 being at the saturated potential (V_{EE}) of the base of VT1 and the other connected to the collector supply potential V_{CC} via the collector load resistor R_{C2} of the now cut-off transistor VT2. This charging time constant of C_2 is thus approximately C_2R_{C2} and the charging current flowing through R_{C2} rounds the negative going part of the collector waveform of VT2. (Similar considerations apply to the collector of VT1 as VT1 is cut-off later.) Transistor VT1 is held saturated by the steady base current flowing through the base resistor R_1 after the additional surge of current due to the charging of C_2 has passed.

As previously for the discharge of C_2, C_1 now discharges towards the collector supply potential V_{CC}, and when the base potential of VT2 reaches the emitter potential V_{EE}, switching occurs again—VT2 saturates and VT1 cuts off. This causes C_1 to charge and the charge on C_2 to hold the base of VT1 positive with respect to its emitter for a period as previously mentioned at our starting point.

The part-periods are thus controlled by the discharging of the capacitors and the governing relationships are:

Part-Period (VT1 Saturated, VT2 Cut-off) $\doteqdot C_1R_2 \ln 2$.
Part-Period (VT1 Cut-off, VT2 Saturated) $\doteqdot C_2R_1 \ln 2$.

The sum of the two part-periods gives the full period of this multivibrator.

Mark-space ratios of up to 5 : 1 can be achieved by this circuit, the maximum ratio being reached when the charging time of one capacitor is almost equal to the discharging time of the other capacitor in the shorter part-period.

13.2. Design Procedure

The design follows the following steps:

(i) Choose R_{C1} and R_{C2} so that they are less than any external load to avoid effects of loading on the circuit operation.

(ii) Choose R_1 and R_2 so that adequate base drive is available under steady conditions to supply the collector current at saturation, that is choose $R_1 < \beta R_{C1}$ and $R_2 < \beta R_{C2}$.
A minimum value of D.C. current gain likely to be found in a batch of transistors should be substituted for β in the above to ensure saturation with any transistor selected from that batch.

(iii) Determine C_1 and C_2 to achieve the required part-period durations.

(iv) Check the transistor dissipation at saturation, and voltage ratings at cut-off. It should be noted that the collector-to-base potential as the transistor switches to cut-off is at a maximum and equals $2(V_{CC} - V_{EE})$ volts in this circuit.

13.3. Mark-Space Ratio

If the smaller part-period is to be determined by the discharge time constant C_1R_2 and the longer by C_2R_1, and it requires three charging time constants for each capacitor to recharge fully, the maximum mark-space ratio can be determined as follows. The circuit operation becomes unreliable when the capacitor C_2 is not fully charged when C_1 has discharged sufficiently to allow switching to start. When the times for both these occurrences become equal the maximum mark-space ratio is reached. That is, the maximum mark-space ratio is reached when:

$$3C_2 R_{C2} = C_1R_2 \ln 2.$$

If we assume $\beta = 20$, this gives:

$$R_2 = 20 R_{C2}$$

and the equation above yields

$$C_2 \doteqdot 5 C_1.$$

If the collector resistors and base resistors are symmetrical, the part-periods are in the ratios of these capacitors and hence a maximum mark-space ratio of about 5:1 can be achieved with a circuit of Fig. 19(a).

13.4. Some Circuit Refinements

The first refinement to this circuit is shown in Fig. 20(a). The addition of the diodes, D, and resistors, R, to the collector circuits removes the rounding of the negative-going edges of the collector waveforms due to the charging currents of the capacitors. The diodes during this part of the cycle are reverse biassed and the charging current flows through the resistor R instead of R_C. The waveforms at the collectors are thus

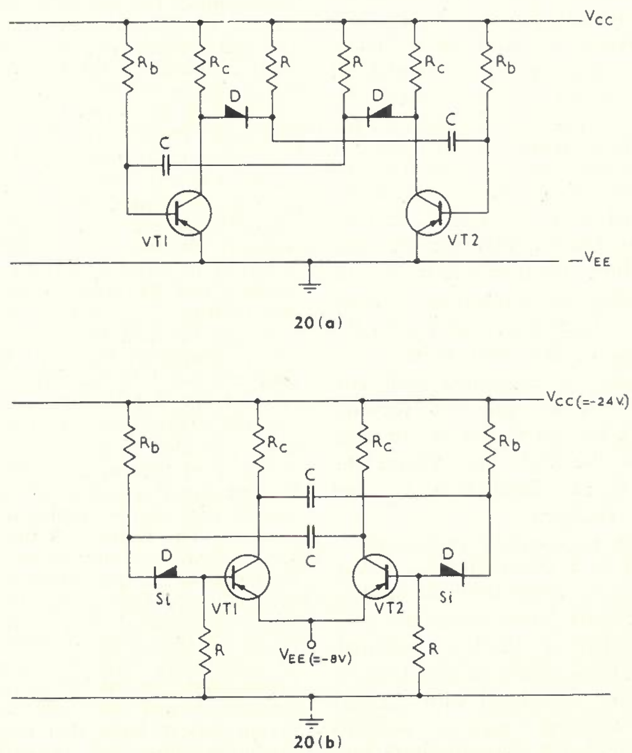


Fig. 20.—Refinements to the Astable Multivibrator Circuit.

squared. The resistors R are generally chosen approximately equal to the collector resistors R_C (from one to four times R_C depending on the required mark-space ratio), and the base drive resistors R_b must be decreased slightly to provide for the increased steady collector current at saturation which now flows through both R_C and R.

The second refinement is shown in Fig. 20 (b) and is used to improve the frequency stability when germanium transistors are used. The discharge time constant is subject to change with temperature in the normal circuit since the I_{CO} current flowing in the cut-off base has the effect of shunting the resistors R_b with another temperature dependent resistor representing this I_{CO} effect. This means that, as the temperature rises, the part-period durations will decrease. To remove this effect a silicon diode D, with very low leakage and thermal current under reverse bias conditions, and resistor R can be inserted in each base circuit. As each capacitor goes through its discharge cycle, the associated base of the transistor no longer shunts the resistor R_b, since the silicon diode becomes reverse biassed and isolates the base circuit from the capacitor discharge circuit. While the diode is reverse biassed the transistor is held cut-off by the resistor R which is returned to a supply potential more positive than the emitter supply potential. As for considerations of cut-off in NOR gates in the previous article, this resistor R is chosen to ensure safe cut-off up to the maximum temperature of operation of the circuit by making

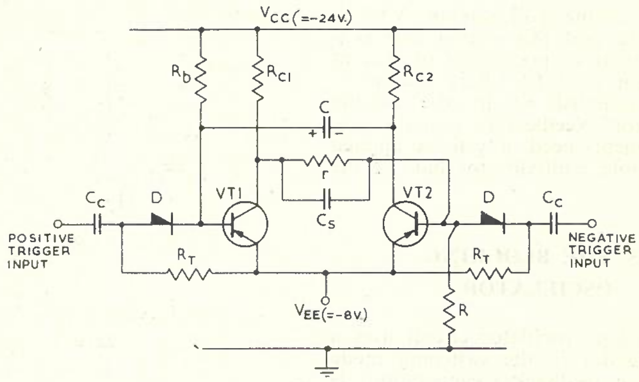
$$R < | V_{EE}/I_{CO\ max} |.$$

Catching diodes can be attached to the collectors as in the flip-flop. These stabilise the more negative potential at the collector outputs under load, but the formula for the part-period is changed due to the modified collector voltage swing, to become:

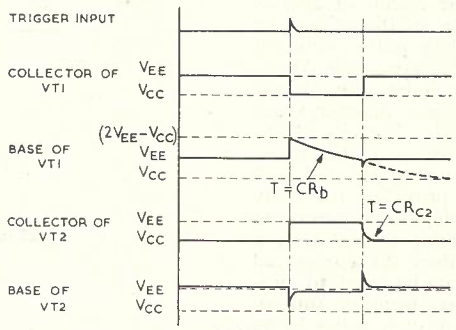
$$\text{Part-Period} = CR_b \ln \{ [(V_{EE} - V_D) + (V_{EE} - V_{CC})] / (V_{EE} - V_{CC}) \}.$$

14. THE MONOSTABLE MULTIVIBRATOR

This member of the multivibrator family has one stable state. It can be triggered to its astable state for a controllable period after which it returns to its original and stable state. This feature makes the circuit useful as a delay device. A typical circuit of a monostable multivibrator is shown in Fig. 21(a) and typical waveforms at the collectors and bases are shown in Fig. 21(b). It can be seen that the circuit is a combination of one half of a flip-flop with one half of an astable multivibrator. The circuit shows two alternative trigger inputs, one for negative pulses and one for positive pulses. These are applied to opposite bases and the one appropriate to the source of trigger pulses can be chosen. Out-puts may be taken from either or both collectors, one output being the complement of the other.



21 (a)



21 (b)

Fig. 21.—The Monostable Multivibrator.

14.1 Circuit Operation and Design

In the stable condition of the circuit, transistor VT1 is saturated with sufficient base current flowing through R_b to the collector supply if $R_b < \beta R_{C1}$, as in the astable multivibrator. Similarly transistor VT2 is held cut-off by suitable choice of the resistor R as in the design for cut-off in a NOR gate (that is $|V_{EE}| > I_{CO\ max} R$). The resistor r is also chosen to ensure saturation of VT2 when VT1 is cut-off as outlined in the design procedure for the NOR gate. With VT1 in its normal saturated state, the capacitor C is charged to a potential of $(V_{EE} - V_{CC})$ volts as shown in Fig. 19(a).

When an appropriate trigger pulse is applied (positive pulse to the base of VT1 or negative pulse to the base of VT2 via the respective trigger capacitor C_c, resistor R_T and diode D), the circuit is switched to its astable state with VT2 saturated and VT1 cut-off. The capacitor C commences to discharge via the now saturated collector of VT2 and the base resistor R_b as in the astable multivibrator. The charge on the capacitor C holds VT1 cut-off until C has sufficiently discharged to make the potential at the base of VT1 equal to its emitter potential. Transistor VT1 then begins to conduct and regeneration in the cross connected circuit rapidly drives VT1 to saturation and VT2 to cut-off.

This is the stable state of the circuit and it remains in this state until the next trigger pulse is applied. The capacitor C must recharge via the saturated base of VT1 and R_{C2} and hence the negative-going edge of the collector waveform of VT2 is rounded by the charging current. The next trigger pulse should not be applied until this capacitor is fully recharged. This takes about three or four time constants (that is $3CR_{C2}$ or $4CR_{C2}$) and this represents the recovery time of the circuit.

As for the astable multivibrator, the duration of the period in which the circuit is in its astable state is governed by the discharge time constant of C, which closely equals CR_b, and the similar formula given for the part-period of the astable multivibrator applies, that is:

$$\text{Time delay} \doteqdot CR_b \ln 2.$$

Similar considerations of transistor dissipation and voltage ratings apply to the two halves of this circuit as apply to their counterparts in the flip-flop and astable multivibrator.

14.2 Circuit Refinements

Similar circuit refinements can be made to this circuit as have already been indicated for the astable multivibrator, with similar modifications where required in the circuit design. However, the need for squaring the collector output voltage waveform is decreased with this circuit, since the waveform at the collector of VT1 is quite square and this output can generally be used in preference to that at the collector of VT2 where the waveform is rounded as in the astable multivibrator. Needless to say, the first two refinements need only to be applied to the astable multivibrator half of the circuit.

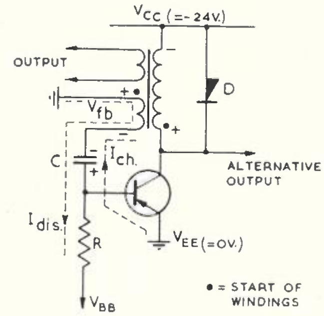
15. THE BLOCKING OSCILLATOR

The blocking oscillator circuit uses a single transistor in the switching mode and positive feedback (regeneration) is achieved by means of transformer coupling from the collector output circuit to either the base circuit or emitter circuit. The blocking oscillator can be used as a free running pulse oscillator or as a triggered pulse generator. When used as an oscillator, it has the advantage that quite large mark-to-space ratios can be obtained. The circuit has low output impedance and the transformer coupling allows an isolated output winding to be provided with any desired step-up or step-down ratio. As an oscillator, the circuit is useful as a source of "clock" pulses. As a triggered circuit, the circuit can be used to produce pulses of short duration (microseconds and even less), such pulses being particularly suited to driving ferrite memory and switching cores because of the low output impedance and transformer coupled output. The pulse duration can be controlled by controlling various circuit parameters.

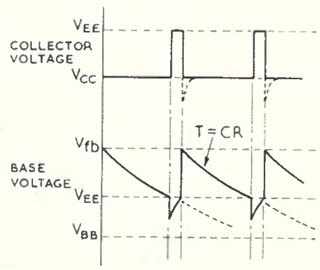
A typical circuit of a blocking oscillator with collector to base feedback is shown in Fig. 22(a). The circuit operates as a free-running oscillator if V_{BB} is made negative with respect to V_{EE} (generally V_{BB} is made equal to V_{CC} in this case). Typical voltage waveforms for this condition of operation are shown in Fig. 22(b). If V_{BB} is made positive with respect to V_{EE}, triggered operation of the circuit is obtained by applying negative trigger pulses to the base of the (p-n-p) transistor to turn it on from its stable cut-off state.

The diode D is shunted across the transformer to remove negative overshoot at the collector as the transistor turns off. This negative overshoot is due to the stored energy in the inductance of the transformer and is shown dotted in the collector waveform of Fig. 22(b). The diode tends to slow down the operation of the circuit due to its slugging action across the transformer winding. However, if it is omitted, there is the possibility of exceeding the transistor collector-to-base voltage rating as the transistor switches off. A compromise operation can be achieved by increasing the forward resistance of the diode by adding a suitable resistor.

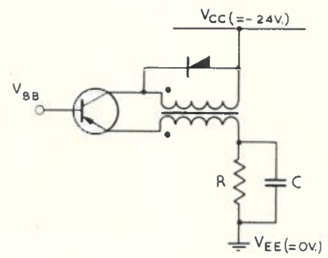
When the transistor saturates, the whole of the collector supply voltage ($V_{EE} - V_{CC}$) appears across the collector winding with the polarity shown. The base winding is so oriented and the turns ratio so adjusted (generally about



22 (a)



22 (b)



22 (c)

Fig. 22.—The Blocking Oscillator.

5 : 1) that the base voltage is increased negatively via the capacitor C by an amount V_{fb}, that is where ($V_{CC} - V_{EE}$) approximates $5V_{fb}$. This provides positive feedback and pulse regeneration commences.

The charging current I_{ch} flowing into the capacitor C provides base drive to maintain the transistor saturated for the duration of the positive going pulse obtained at the collector. The collector current increases approximately linearly with time into the transformer inductance during the pulse.

Regeneration in this direction in the circuit ceases when any of three conditions are reached. These are:

(i) The base drive to the transistor as determined by the turns ratio of the transformer is no longer sufficient to keep the transistor saturated with its increasing current. When this occurs, the collector voltage increases negatively and the circuit regeneration rapidly switches the transistor to cut-off.

(ii) The magnetising ampere-turns in the transformer collector winding increase to a point where the core material saturates (magnetically). This implies that the knee in the B-H loop of the core material has been passed, and the incremental inductance of the transformer is rapidly decreasing. Thus the potential across the transformer collector winding decreases and regeneration rapidly switches the transistor to cut-off.

(iii) The capacitor C in the base circuit in charging via the saturated base as shown, absorbs all base drive by becoming fully charged. It can be seen that the charging time constant of C is short and is determined largely by the product of C and the resistance of the saturated base-emitter junction. When C charges rapidly in this way, removing the base drive, the transistor drops out of saturation, the collector voltage rises negatively and circuit regeneration rapidly switches the transistor to cut-off.

Whatever condition is the final cause, the transistor is finally switched to cut-off and the positive-going pulse duration is at an end. The charge built up on capacitor C during the pulse is now sufficient to reverse bias the base and hold the transistor cut-off for a time. The capacitor discharges, as indicated, through the resistor R (with time constant CR) towards the V_{BB} potential. If V_{BB} is positive with respect to V_{EE}, the capacitor will actually go on charging. The circuit remains stable in the cut-off state with reverse bias from V_{BB} applied to the base via R, until a negative going trigger pulse is applied to the base to turn it on and thus re-initiate the regeneration of a pulse. If V_{BB} is negative the capacitor discharges towards V_{BB} until the base potential becomes just slightly more negative than V_{EE}. This causes the transistor to start conducting and the regeneration process just described recommences, the circuit then maintaining its own oscillation with a frequency determined by the time constant CR.

It can be seen that the pulse duration is determined by the condition which finally limits collector saturation. It is not proposed to go into these conditions deeply here but it could be briefly pointed out that a pulse duration determined by the first condition above is subject to wide variation since it is largely determined by the base to collector current gain β of the transistor. As previously mentioned this parameter can vary widely between transistors. A circuit as shown in Fig. 22(c) using collector to emitter feedback is much less susceptible to this variation in pulse duration if the first condition determines the pulse length, since the less variable emitter to collector current gain α is the transistor parameter concerned. However, this circuit is best used in the triggered mode. More discussion of this circuit can be found in Reference 10. Similar references are to be found in the literature to provide greater detail on the determination of the pulse duration. Typical of these are References 11 and 12.

16. CONCLUSION

This series of three articles on transister-diode switching circuit design is now complete. The philosophy of the Boolean algebra approach to obtaining a block schematic circuit to perform a given switching function was introduced, and then the different types of "gates" and associated circuits which make up the individual blocks of such a circuit were considered. Inspection of a particular block schematic circuit indicates the various loading capacities required of the individual blocks and these circuits are then designed as indicated to withstand all loading conditions. When this is completed the integrated series of individual blocks yields the complete switching circuit.

It should be pointed out that this series of articles is not a complete treatment of the topic. It is intended as an introduction to a new and important field of application of the transistor and the related semi-conductor diode. Greater detail is available on many aspects of the topic in textbooks and technical literature, and it is hoped that this series of articles provides a suitable stepping-stone to further study of the topic from these sources.

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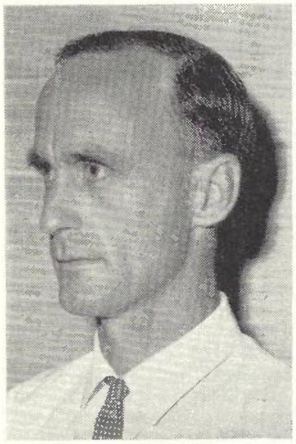
OUR CONTRIBUTORS



J. H. CURTIS

A. H. FREEMAN

L. F. PEARSON

D. MacQUEEN

J. H. CURTIS, author of the article "Brisbane-Tweed Heads Coaxial Cable —River Crossings" joined the Postmaster-General's Department in Brisbane as an Engineer in 1949. He worked initially in the Lines Section and later transferred to the Planning Section where he holds the position of Divisional Engineer, Bearer Provision and External (Country) Sub-Section. In 1960 he returned temporarily to the Lines Section to take charge of the installation of the Brisbane-Tweed Heads coaxial cable. He holds the degrees B.E.(Hon.), B.Sc., and B.A. from the University of Queensland.

A. H. FREEMAN, author of the article "The Evolution of Junction Networks," joined the Postmaster-General's Department in 1938 as a Cadet Draftsman in Sydney. In 1942 he enlisted in the R.A.A.F., resuming duty with the Department in 1946 as an Engineer in the Buildings Branch. Between 1947 and 1956 he was employed in the New South Wales Broadcasting Section, mainly on the installation and operation of the National Broadcasting Stations. In 1954 he received the P.O.A. Award of Merit for a report on frequency allocations in the broadcast bands.

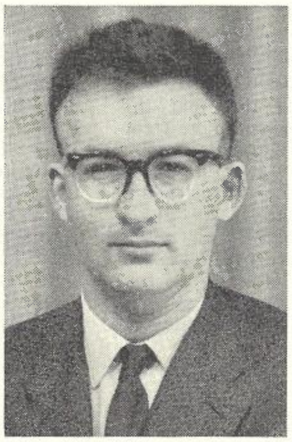
In 1956 Mr. Freeman transferred to the Transmission Planning Section, and since 1960 has been Supervising Engineer, Transmission Planning. While in the Planning Section he has made a number of contributions to the design of metropolitan and country exchange networks, and is currently engaged, among other duties, in the redesign of the Sydney network for crossbar operation.

L. F. PEARSON, author of the article "The Australian Outpost Radio Communication System," joined the Postmaster-General's Department as a Telegraph Messenger in 1919. After passing the Clerical examination he was promoted to Telegraphist in the Central Telegraph Office, Melbourne, in 1924. He obtained the First Class Commercial Operator's Radio Proficiency Certificate and was promoted to Assistant Radio Inspector, Radio Branch, Melbourne, in 1939.

Mr. Pearson was promoted to Radio Inspector, Grade 1, in charge of the Frequency Measuring Centre, Mont Park, in 1943. Further promotions followed to Radio Inspector, Grade 2, Central Staff in 1947, Senior Radio Inspector in 1948 and Controller, Radio Branch, Telecommunications Division in 1955. Mr. Pearson led the Australian delegation to the Radio Frequency Conference at Wellington, New Zealand, in 1951, and was Deputy Leader of the Australian delegation to the Administrative Radio Conference, Geneva, in 1959.

D. MacQUEEN, author of the article "Some Aspects of the Design and Use of Cable Ploughs," hails from Scotland. After experience as an Engineer in Britain and Africa he joined the Postmaster-General's Department in 1955 as Group Engineer, Primary Works, Sydney, on large cable projects. In 1957 he transferred to the Automotive Plant Section. He has made a number of significant contributions to the design of cable-laying equipment and the development of new methods and machines. Mr. MacQueen is an Associate Member of both the Institution of Mechanical Engineers, and the Institution of Engineers, Australia.

R. J. KOLBE



N. M. H. SMITH

H. T. DAVIS

D. J. OMOND

R. J. KOLBE, author of the article "The Type 801 Telephone," occupies the position of Sectional Engineer, Substation Equipment and Components Design in the Telephone Equipment Section of Headquarters, Engineering Division. He holds an Honours Degree in Electrical Engineering from the Technical University Vienna, a degree in Mechanical Engineering from the Technical University Berlin-Charlottenburg and an Honours Degree in Industrial Economy from the Commerce University Vienna. Mr. Kolbe was employed by Siemens and Halske as a telecommunication engineer up to 1938 and gained a wide experience serving in many sections dealing with various aspects of telecommunication engineering. His experience included work in the Central Research Laboratories Berlin-Siemens-Stadt, the Design Laboratories for automatic switching plant, the installation and testing of automatic exchanges in Berlin and Belgrade, and the Project Section of the Siemens Works in Vienna. For part of this time he was also engineer in charge of installations contracted through subsidiary firms in Czechoslovakia and Jugoslavia.

Mr. Kolbe entered the Postmaster-General's Department in January 1946 after discharge from the Australian Military Forces with which he served during the war. He worked as a technician in the Material Test Laboratory, Melbourne, and late that year transferred to Headquarters Telephone Equipment Section as an engineer. He was concerned with finalisation of drawings and specifications for 300 type telephones manufactured in Australia and with development and procurement of substation apparatus and components. From September 1949 he occupied the position of Divisional Engineer (Procurement, Substation Apparatus). With the formation of the Headquarters Supplies Section in 1954 he was appointed Divisional Engineer (Procurement, Internal Plant). He introduced the technique of "combined programme and material reviews" (ME-7 group) for power plant, and special procedures for estimating the requirements of all testing instruments. He also initiated the fundamental design of multi-purpose test instruments for manufacture in Australia (Multimeters A.P.O. No. 2 and A.P.O. No. 3). These instruments proved to be successful replacements for imported instruments and the manufacturer has since developed a further version of this design for the Australian Army. In February, 1961, he returned to Telephone Equipment Section and has been concerned with design and development of the new telephone instrument. Mr. Kolbe is an Associate Member of the Institution of Engineers, Australia.

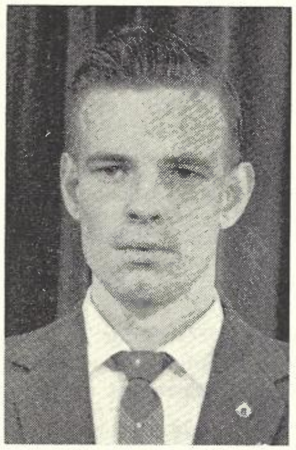
N. M. H. SMITH, author of the article "More Accurate Calculation of Overflow Traffic from Crossbar Group Selectors," is the Sectional Engineer, Traffic Engineering, in the Headquarters Planning Branch of the Postmaster-General's Department. He joined the Department as a Cadet Engineer in 1951 and completed the degree of B.E.E. at the University of Melbourne in 1953. After completing one year of graduate training as a cadet he spent short periods gaining experience as a Grade I Engineer in Victorian Country Installation and Metropolitan District Works Divisions before being invited to become the first Secretary of the Central Office Traffic Engineering Committee, in March 1956. Since this time, he has since been continuously associated with traffic engineering and equipment systems engineering projects, the most notable of which has so far been the detailed technical investigations which led to the adoption of the L M Ericsson Crossbar Systems by the Department.

Latterly, Mr. Smith has been concerned with setting up a new section to cope with the traffic engineering aspects of the changeover to crossbar, the development of a three-stage first group selector for use in large ARF.102 exchanges (or as an alternative to ARM.20's and ARM.50's in the intermediate size ranges), and the development of an IBM.7090 programme for network optimisation investigations.

H. T. DAVIS, co-author of the article "Co-ordination of Power and Telecommunication Systems in Australia," commenced training as a Cadet Engineer in 1946 when released from service with the R.A.A.F. He graduated Bachelor of Science from Melbourne University in 1949 and completed the Departmental training in 1950. During five years' field experience in Tasmania as Group and Divisional Engineer, Mr. Davis became acquainted with the practical problems of power co-ordination and was a foundation member of the State Joint Committee for Power Co-ordination. In 1955 he was appointed to the Lines Section Central Office as Divisional Engineer, Aerial Maintenance, and subsequently as Sectional Engineer, Service. Since 1959 Mr. Davis, as Convener of the Central Joint Committee for Power Co-ordination, has been associated with the development and introduction of various codes of practice used by both the power authorities and the Postmaster-General's Department. The article was presented by Mr. Harvey and Mr. Davis as a paper to the convention of C.I.G.R.E. held in Paris in May, 1962.

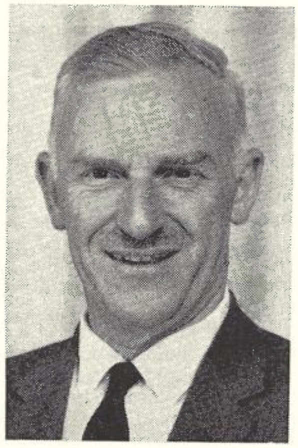
Mr. Davis is an Associate Member of the Institution of Engineers, Australia.

D. J. OMOND, author of the article "An Introduction to the Analysis of Subscribers' Complaints," graduated from the University of Adelaide with the degree of Bachelor of Engineering in 1949, and entered the Postmaster-General's Department as an Engineer in the Transmission Section, Adelaide. In 1950 he was transferred to the Wallaroo Country Division and subsequently to the Darwin, Murray Bridge and Mt. Gambier Divisions. In 1957 he returned to Adelaide as Group Engineer, P.A.B.X. Installation and after a period relieving as Divisional Engineer. Exchange Service, was given charge of the Subscriber's Complaints Analysis experiment as a special project. In June, 1961, he was transferred to the Management Services Section, Headquarters. where he is now acting as Divisional Engineer, Work Study.



F. W. WION

A. E. JOHNSON



J. L. W. HARVEY

J. LAMMERS

F. W. WION, author of the article "Transistor Circuits for Generation of Exchange Service Tones and Bell Ringing Current" joined the Postmaster-General's Department in 1950 as a Cadet Engineer, subsequently obtaining the degrees of B.E.E. and M.Eng.Sc. at the University of Melbourne. Mr. Wion has been attached to the Research Laboratories since 1956, where he has worked on the development of transistor circuits for plant installations. Recently he has been involved in the development of electronic switching circuits, including an experimental electronic P.A.B.X.

A. E. JOHNSON, author of the article "The Design of Programme Equalisers for Cable Circuits," is a Class 2 Engineer in the Transmission Planning Section of the New South Wales Engineering Division. He joined the Postmaster-General's Department in Queensland in 1947 as a Technician-in-Training, transferred as Clerk in 1948 and was appointed Cadet Engineer in 1949. He graduated Bachelor of Science from the University of Queensland and commenced duty as an Engineer in the Trunk Service Division, Brisbane in 1953. In this position he was responsible for the control of the maintenance standards of carrier equipment throughout Queensland. In 1956 he transferred to the Transmission Planning Section, New South Wales, where he has been associated with line measurements, the Transmission Laboratory, and trunk line planning for the southern part of New South Wales. During his association with the Transmission Laboratory, he was engaged on equaliser design for cable and open wire circuits, and the development of transistorised transmission equipment, including oscillators, amplifiers, voltage regulators and D.C. converters for power supplies.

In 1960 Mr. Johnson transferred to the Planning Section, Tasmania, for six months, where he was engaged on trunk line planning for the State. Since his return to New South Wales he has been engaged on trunk line planning, including the introduction of Sydney-Melbourne coaxial cable facilities into the trunk network.

J. L. W. HARVEY, co-author of the article "Co-ordination of Power and Telecommunication Systems in Australia," was Assistant Chief Distribution Engineer, Electricity Supply Department, State Electricity Commission of Victoria, at the time the article was prepared and is now Assistant Electrical Engineer (Design), Electrical Branch in the Design and Construction Department of the same organisation.

After graduating as Bachelor of Civil Engineering and Bachelor of Electrical Engineering from the University of Melbourne, he joined the State Electricity Commission of Victoria in 1934. In 1949 he became Protection Engineer, Distribution Division, Electricity Supply Department, and in 1959 Divisional Engineer, Distribution.

Mr. Harvey has been associated with investigations involving power-telecommunication co-ordination since 1939. In 1953 he was appointed as the nominee of the Electricity Supply Association of Australia to the Joint Sub-Committee of that Association and the Postmaster-General's Department, which was set up to investigate induction into telecommunication circuits from power line earth fault currents. When the Joint Committee organisation was formed to carry on co-ordination work, he was nominated to membership of the Central Joint Committee by the Electricity Supply Association of Australia. He is also the Convener of the Electricity Supply Association's Committee on "Co-ordination of Power and Telecommunication Systems". In 1956, in the course of an overseas investigation for the State Electricity Commission of Victoria, Mr. Harvey made inquiries into co-ordination practices in Europe and North America. Some further inquiries were made during an overseas tour in 1962, during which he presented the article as a paper to the C.I.G.R.E. Convention held in Paris. He is an Associate Member of the Institution of Engineers, Australia.

J. LAMMERS, author of the article "High-speed Recordings of Power and Railway Traction Interference with Coaxial Power Feeding," received his M.Sc.(E.E.) degree from the Institute of Technology, Delft, Holland, in 1952. For a period of $3\frac{1}{2}$ years he was employed in the Dutch Post Office as an Engineer, Trunk Service, on the operation and maintenance of cable carrier systems and automatic telex exchanges at the Amsterdam Trunk Terminal.

In 1956, he joined the Central Office Long Line Equipment Section of the Australian Post Office, and for a period of two years was engaged on the analysis of special maintenance problems and procedures associated with line transmission equipment installed in the field. Since that time, he has been concerned mainly with laboratory investigations on long line equipment problems. Mr. Lammers is at present acting Divisional Engineer, Systems, in the Design Subsection of the Long Line Equipment Section and his duties include the inspection and evaluation of various types of new Line Transmission Equipment.

ANSWERS TO EXAMINATION QUESTIONS

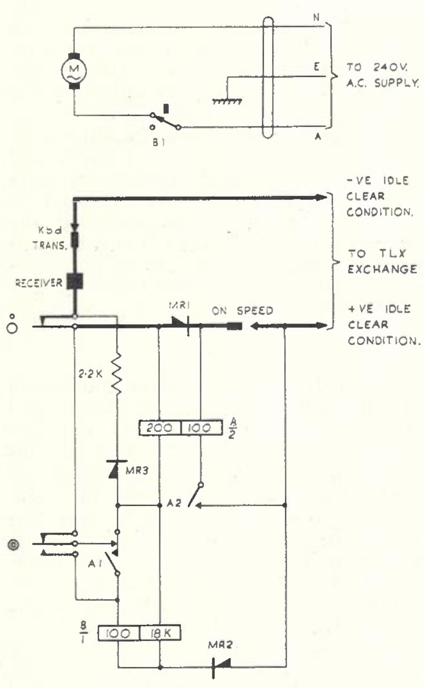
Examination No. 4957: Senior Technician (Telecommunications) Telegraphs. 1st July, 1961 and subsequent dates.

SECTION B

QUESTION 7.

Draw and describe the subscriber's terminal unit circuit employed with the Siemens & Halske T type 100 page printer used on manual telex service for single current unattended working without local run facilities.

Should the 240-volt A.C. mains supply to the subscriber's terminal fail, is it possible for the subscriber to call the telex exchange over his telex circuit; if so would a switchboard operator answering that call be able to immediately observe that a fault condition exists? Explain your answers.



SUBSCRIBERS TERMINAL UNIT (CG-492) EXPLANATORY ONLY.

ANSWER:

Comment: The question calls for a sketch of the circuit, a description of how the circuit works, and brief answers to two questions designed to further test the candidate's knowledge of how the circuit works. In sketching, the circuit details such as the connector coupling of the machine to the terminal unit should be omitted, the essentials only being shown.

Circuit Description

"Idle Clear" Condition:

In the "idle clear" condition, current from the exchange termination is poled such that the "B" relay is operated. B.1 operated stops the teleprinter motor.

Subscriber Calls the Exchange:

Momentary operation of the CALL key removes a short circuit across one coil of the "A" relay and connects it in series with the low resistance coil of "B". Current flowing in this circuit operates "A" and A1 maintains the circuit after the CALL key is released. "B" holds operated via its low resistance holding winding. The loop current increases (due to the lower loop resistance) and "L" relay at the exchange operates. This lights the answer lamp in the switchboard.

Exchange Answers:

When the exchange answers, the potential of the loop is reversed, releasing "B". "A" remains held via its second coil and contact A2 (current in the first coil is blocked by MR.2). B1 released starts the teleprinter motor and when up to speed, the ON SPEED contacts close.

The "making" ON SPEED contacts short circuit "A" causing it to release. Signalling now proceeds.

Subscriber Clears:

At the end of a call the operator presses the CLEAR key until the teleprinter motor stops.

Operation of the CLEAR key opens the loop lighting the cord circuit supervisory lamp and after approximately four seconds the potential of the loop reverses.

Current now flows from the exchange through the 2.2K resistor, MR.3 and "B" relay to the exchange.

B relay operates and B1 operated stops the teleprinter motor. The extension ha snow returned to the "idle clear" condition.

Call from Telex Exchange:

When the operator plugs a call into the extension, the potential applied to the line reverses and "B" relay in the terminal unit releases. B1 released starts the motor. When the motor is up to speed on ON SPEED contacts close and complete the loop to the exchange. The CALL cord supervisory lamp is extinguished.

If the 240V A.C. mains supply fails to the terminal, a subscriber could still call the switchboard since the current used to operate and hold the "A" and "L" relays is derived from the exchange battery.

The switchboard operator would **not** be able to immediately recognise this fault condition. When plugging up to answer the call, the sub's. answer lamp will be extinguished and the potential of the extension line reverses. Relay "A" in the sub's. terminal unit will continue to hold operated. With an A.C. power failure the motor will not start when "B" releases therefore the ON SPEED contacts will not make and short circuit the "A" relay. The resistance of the terminal at this stage is low and would be recognised by the exchange equipment as a MARK therefore the cords supervisory lamp will be extinguished.

Detection that a fault condition exists would only be recognised when the operator called for ANSWER-BACK.

Examination No. 4958: Senior Technician (Telecommunications) Radio.—1st July, 1961 and subsequent dates.

SECTION A

QUESTION 3.

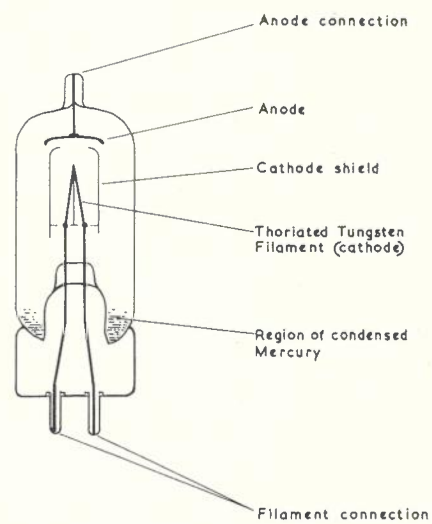
(a) With the aid of a diagram describe the construction of a mercury vapour rectifier valve.

(b) What precautions must be observed in operating these valves?

(c) What is the voltage drop across this type of valve?

ANSWER.

3(a)



A mercury vapour rectifier valve is a thermionic diode composed of a thoriated tungsten filament (cathode) and an anode enclosed in a bulb from which all air is evacuated and replaced by mercury vapour at low pressure. There is usually free liquid mercury present and a cathode shield is usually provided except in low rated valves.

3(b) The following precautions must be observed:

(i) The filament must be operated at its correct voltage (± 5%).

(ii) The valve must be allowed an adequate warm-up period before applying anode voltage (from 5 minutes to 30 minutes, depending on circumstances).

(iii) On initial placing into service, an adequate warm-up period must be allowed to permit evaporation of liquid mercury from electrode surfaces.

(iv) The valve must be operated within its rated temperature range, e.g. 20-50°C.
(v) High power rectifier valves require air-blast cooling and this must be working before any potentials are applied.
(vi) The rated peak inverse voltage must not be exceeded, e.g. 10kV at 20-50°C, 7kV at 20-60°C.
(vii) The rated average and rated peak emission currents must not be exceeded.
(viii) Some form of quick acting protection must be provided to limit the duration of possible short circuits.
(ix) Some form of arc-back indication is desirable with high power valves.
(x) Mercury vapour rectifiers must be shielded from the effects of strong R.F. fields.

(Five answers only, if including the more important, qualify for full marks in this section.)

3(c) Owing to the ionisation effect, the voltage drop across this type of tube is very small, varying from 10 to 18 volts.

Examinations Nos. 5043, 5044, 5045 and 5046

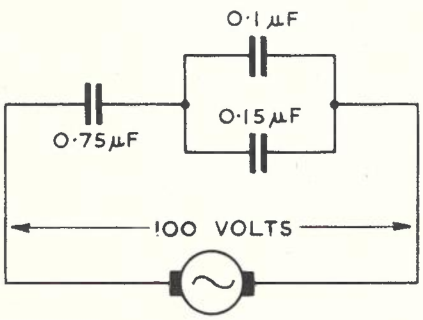
SENIOR TECHNICIAN (TELECOMMUNICATIONS), TELEPHONE, TELEGRAPHS, RADIO AND RESEARCH—JULY 1962.

TELECOMMUNICATION PRINCIPLES—PAPER No. 1.

QUESTION 2.

(a) What are the different values of capacitance which could be obtained if you were supplied with one 0.2uF and one 0.3uF capacitor?

(b) A 100 volt 796 c/s ($\omega = 5000$ rad/sec) sinusoidal supply is connected to a network of three capacitors as shown—



Calculate—

(i) the voltage across the 0.75uF capacitor;

(ii) the R.M.S. current in the 0.1uF capacitor.

ANSWER 2 (D. G. KENNER).

(a) 0.2μF,
0.5μF (in parallel),
0.3μF,
0.12μF (in series).

(b) Capacitance of parallel section

$= C1 + C2$

$= 0.1 + 0.15$

$= 0.25\mu F$

X_c of parallel section

$$= \frac{1}{\omega c}$$

$$= \frac{10^6}{5000 \times .25}$$

$$= 800\Omega.$$

X_c of 0.75μF

$$= \frac{1}{\omega c}$$

$$= \frac{10^6}{5000 \times .75}$$

$$= \frac{800}{3}\ \Omega$$

(i) As the voltages across reactances in series are in the same proportion as the reactances (1:3), the voltage across the 0.75μF capacitor

$= 1/4$ of 100

$= 25$ volts.

(ii) Voltage across parallel

$= 3/4$ of 100

$= 75$ volts.

$$X_c \text{ of } 0.1\mu F = \frac{1}{\omega c}$$

$$= \frac{10^6}{5000 \times .1}$$

$$= 2000\Omega.$$

$$I \text{ in } 0.1\mu F = \frac{E}{X_c}$$

$$= \frac{75}{2000} \times \frac{1000}{1}$$

$$= 37.5\text{mA}.$$

QUESTION 4.

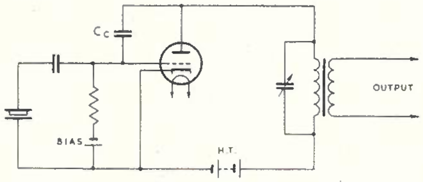
(a) Briefly explain what is meant by the term PIEZO ELECTRIC EFFECT.

(b) With the aid of a simple diagram describe the basic principles of operation of a crystal controlled oscillator.

ANSWER 4 (D. WHITESIDE).

(a) It is the effect exhibited by certain crystalline materials, whereby a mechanical force or stress applied to the crystal will cause an electric charge to be developed on its opposite faces.
Conversely, when an electric charge is applied to the opposite faces, a mechanical force is set up which changes the shape of the crystal.

(b)



The frequency of the oscillator is determined by the crystal, which acts as a resonant circuit with a high "Q".

The anode circuit is tuned to a frequency slightly higher than that of the crystal to ensure that the feedback through the coupling capacitor C_c is positive.

Variations of the grid voltage at the resonant frequency of the crystal are amplified and fed to the tuned anode circuit. Portion is fed to the output via the secondary winding, while portion is fed back via C_c to the grid circuit in correct phase to maintain oscillations.

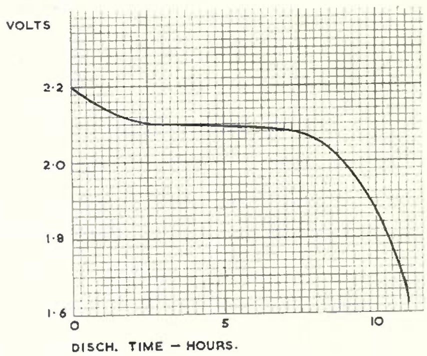
QUESTION 6.

(a) Draw a graph showing how the P.D. of a fully charged lead-acid secondary cell varies as the cell is DISCHARGED.
Show typical voltage values.

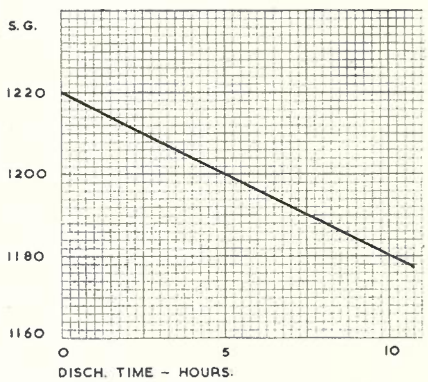
(b) Draw a graph showing how the specific gravity of the electrolyte in a lead-acid cell changes as the cell is DISCHARGED.
Briefly explain the cause of this change.

ANSWER 6 (D. G. KENNER).

(a)



(b)



On discharge, the sulphuric acid electrolyte combines with the lead in the material of both positive and negative plates, and lead sulphate is formed on their surfaces.

The electrolyte becomes diluted due to the loss of acid during the chemical change, and the formation of water by the combination of the hydrogen and oxygen in the cell.

QUESTION 7.

When a network, which consists of a capacitor and a resistor, is connected across a 150 Volt D.C. supply, a current of 0.15 Amps flows.

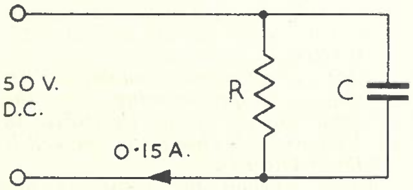
When the network is connected across a 150 Volt A.C. supply, the measured R.M.S. current is 0.25A.

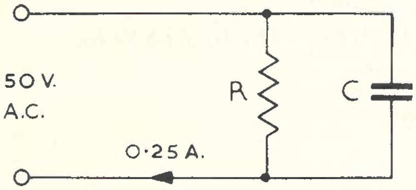
(a) Sketch how the two components are connected. What is the value of the resistor?

(b) Calculate the current flowing through the capacitor when the network is connected across the 150 Volt A.C. supply.

ANSWER 7 (D. G. KENNER).

(a)





In D.C. case, I only through resistor.

$$\therefore R = \frac{E}{I} = \frac{150}{.15} = 1000\Omega.$$

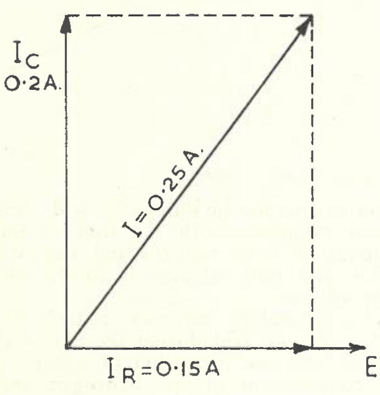
Value of Resistor = 1000 ohms.

(b) In A.C. case, total I is the vector sum of the two branch currents, I_C, I_R.

$$I\ \text{total} = \sqrt{I_R{}^2 + I_C{}^2}$$

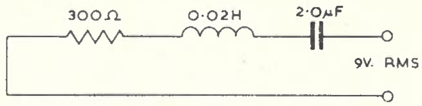
$$\therefore I_C = \sqrt{(I_T)^2 - (I_R)^2}$$
$$= \sqrt{(.25)^2 - (.15)^2}$$
$$= \sqrt{.0625 - .0225}$$
$$= \sqrt{.04}$$

= .2A, i.e. I through Capacitor = .2A.



QUESTION 8.

A relay coil having a resistance of 300 ohms and an inductance of 0.02 henry is connected in series with a capacitor of 2uF across a sinusoidal A.C. supply of 9 volts R.M.S.



(a) Calculate the current in the circuit at resonance.

(b) Calculate the resonant frequency of the circuit and the voltage across the capacitor at resonance.

ANSWER 8 (D. G. KENNER).

$$\text{(a)}\ I = \frac{E}{Z}$$

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

At resonance $Z = R$

$= 300\Omega.$

$$I = \frac{9}{300} \times \frac{1000}{1}$$

= 30mA.

$$\text{(b)}\ f_r = \frac{1}{2\pi\sqrt{LC}}$$

$$= \frac{1}{2\pi\sqrt{.02 \times \frac{2}{10^6}}}$$

$$= \frac{10^3}{6.28 \times .2}$$

= 796 c/s.

$$X_C = \frac{1}{2\pi f C}$$

$$= \frac{10^6}{5000 \times 2}$$

$= 100\Omega.$

$$E = I \times X_C$$

$$= \frac{30}{1000} \times \frac{100}{1}$$

= 3 Volts.

QUESTION 9.

(a) When using the Varley bridge method to localise an earth fault, balance was obtained when all the resistance arms on the bridge were 100 ohms each.

If the loop resistance of the line under test was 540 ohms, calculate the distance of the fault from the testing point.

(The line conductor resistance is 88 ohms per mile loop.)

(b) Draw the circuit of the Varley bridge and show how the principle is based on that of the Wheatstone bridge.

ANSWER 9 (D. G. KENNER).

(a) With equal ratio arms, the loop resistance to the fault

= L – R.

= 540 – 100

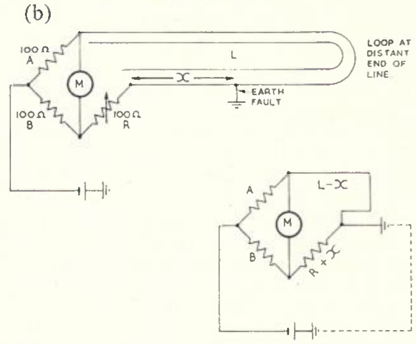
= 440 ohms.

$$\text{Distance to fault (miles)} = \frac{\text{Loop Resistance to fault}}{\text{Ohms per mile loop}}$$

$$= \frac{440}{88}$$

= 5 miles.

(b)



Testing battery is applied to the bridge via the mid-point between ratio arms A and B on one side and the earth fault on the other.

The sketches show the relationship between the Varley and Wheatstone Bridges. The two arms on the right side consists of R + x and L — x, and a balanced condition is obtained (meter is connected across points of equal potential)

when A (R + x) = B (L – x).

When ratio arms A and B are equal,

$$R + x = L - x$$
$$2x = L - R$$
$$x = \frac{L - R}{2}$$

x = resistance of single wire to the fault.

When both wires of the pair are the same,

Loop resistance to the fault (2x)

= L – R.

QUESTION 10.

(a) The voltmeter method of measuring resistance is widely used in the Department.

State the formula used in this method to calculate the value of an unknown resistance.

The meaning of each symbol in the formula must be given.

(b) From a number of unmarked resistors you have to select all those between 5,000 and 6,000 ohms (both values included).

An 0 to 10 volt voltmeter (resistance 10,000 ohms) and a 6 volt battery are available.

Sketch the circuit you would use and calculate the range of voltmeter readings which correspond to the range of resistance values to be selected.

ANSWER 10 (D. G. KENNER).

(a)

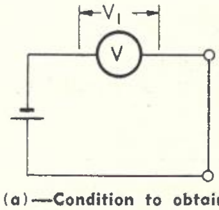


Fig. (a)—Condition to obtain V1.

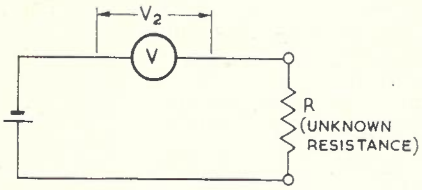


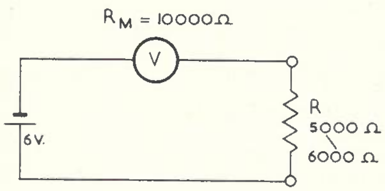
Fig (b)—Condition to obtain V2.

The formula for calculating the unknown resistance "R" is given as—

$$R = R_M \frac{(V1 - V2)}{(\ V2\ )} \quad \text{where}$$

R $=$ unknown resistance
R_M $=$ voltmeter resistance
V1 $=$ Deflection without resistance
V2 $=$ Deflection with meter in series with unknown resistance.

(b)



$$R = R_M \left(\frac{V1 - V2}{V2}\right)$$

$$\therefore V2 = \frac{R_M\, V1}{R + R_M}$$

when R $= 5000\Omega$

$$V2 = \frac{10{,}000 \times 6}{5000 + 10{,}000} = \frac{60{,}000}{15{,}000} = 4 \text{ Volts.}$$

when R $= 6000\Omega$

$$V2 = \frac{10{,}000 \times 6}{6000 + 10{,}000} = \frac{60{,}000}{16{,}000} = 3.75 \text{ Volts.}$$

$\therefore$ The resistors to be selected are those giving V2 readings between 3.75V and 4V.

QUESTION 11.

(a) Describe the principle of a thermo-couple meter.

(b) Explain briefly why a thermo-couple meter—

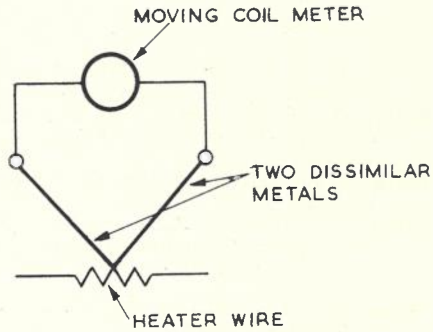
(i) gives the same reading on A.C. and on D.C.;

(ii) can be used at frequencies up to several megacycles/sec.;

(iii) requires special care when using it.

ANSWER 11 (G. BASS).

(a) A thermo-couple instrument consists of a thermo-couple and a sensitive moving coil meter. The thermo-couple is made up of two fine wires of dissimilar metals (such as eureka and iron). The wires are welded together at one end to form a junction which is placed in thermal contact with a heater wire. The other ends of the wires are connected to the meter as shown.



The current to be measured passes through the heater wire and the heat produced raises the temperature of the junction. (Heat is proportional to the square of current through heater.)

With the rise in temperature a thermal e.m.f., which is proportional to heat, is produced. This causes a D.C. current to pass through the meter.

The resultant deflection on the meter is therefore proportional to the square of the current to be measured.

(b) (i) As the heating effect is independent of the direction of current, the instrument can be used for measurement of A.C. as well as D.C.

(ii) As the heater wire possesses an extremely small value of inductance and capacitance, reactive effects are negligible at frequencies up to several megacycles/sec.

(iii) Utmost care must be taken to prevent even the slightest overload as this can burn out the heater wire. Most instruments are calibrated for a particular thermo-couple; when this unit has to be replaced the meter usually has to be re-calibrated.

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REFERENCES:

(T.N.I.) refers to a short Technical News Item or a Letter to the Editors.

A

Answers to Examination Questions

(Complete answers to all questions in examination papers are not given. Instead the journal now includes answers to a few questions only from a number of recent papers. The questions selected for inclusion are those answered poorly, or of special interest or of a type not covered in recent issues of the Journal.)

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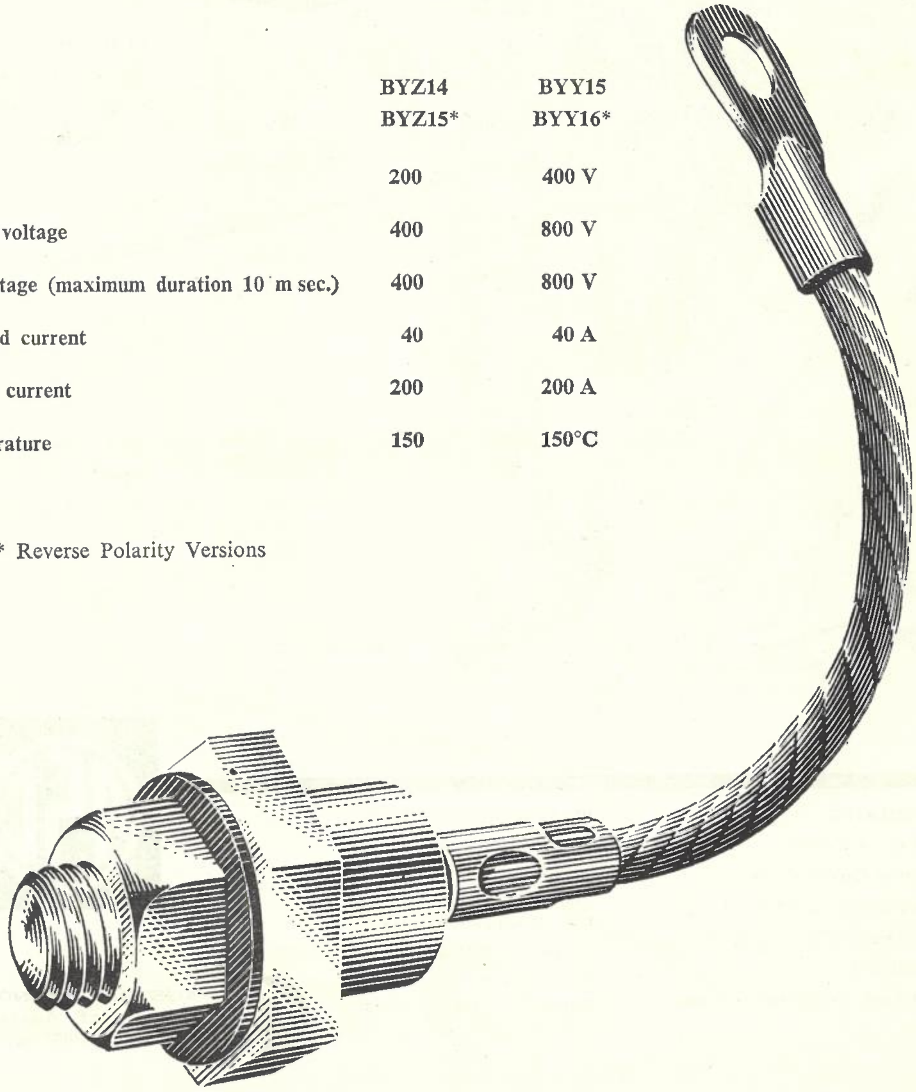
Maximum junction temperature	150	150°C

* Reverse Polarity Versions



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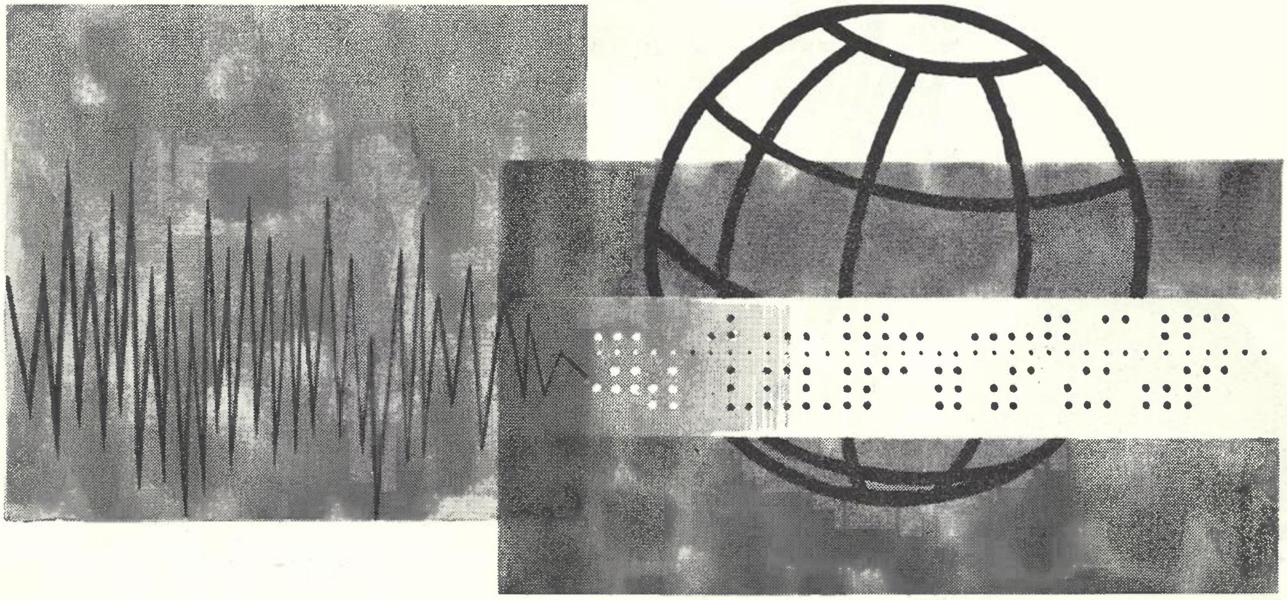


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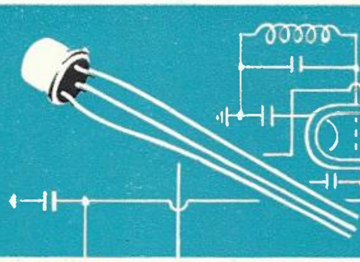

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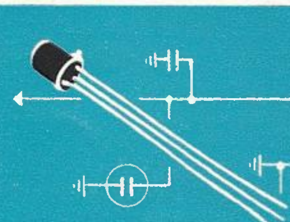

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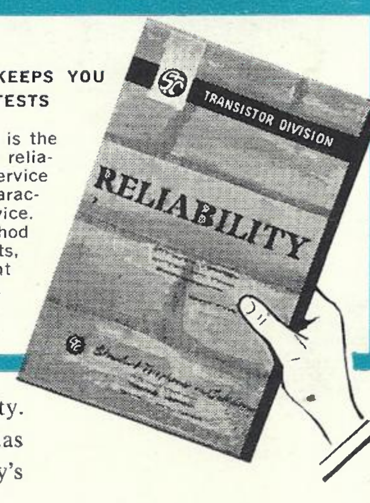

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