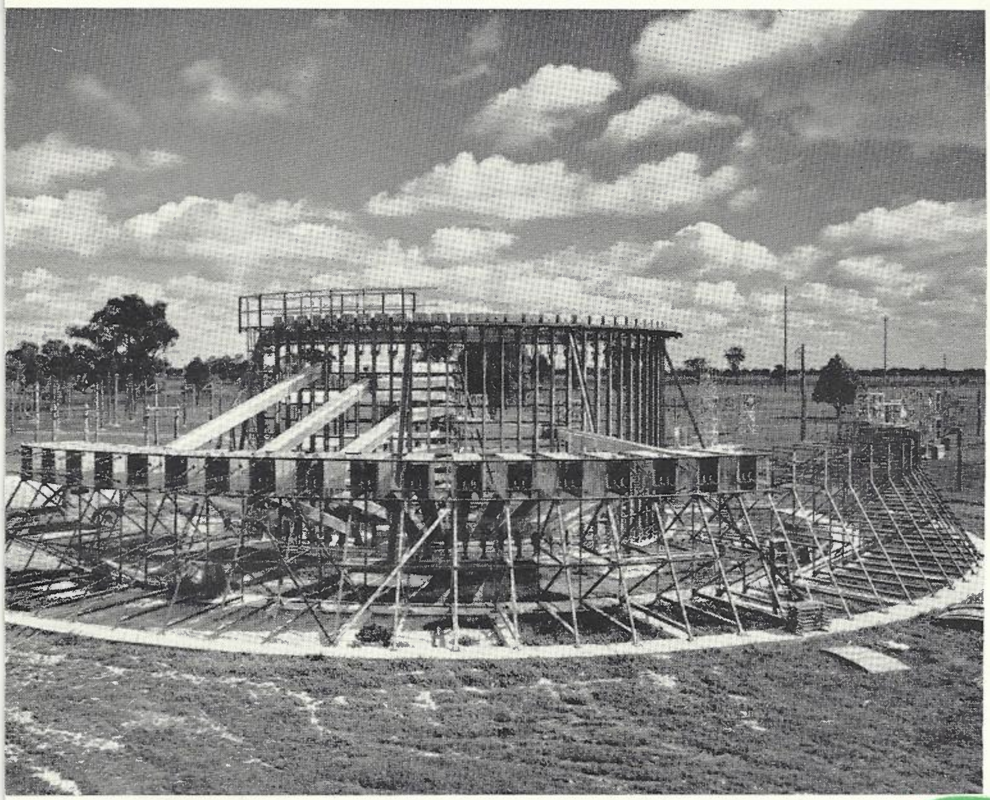
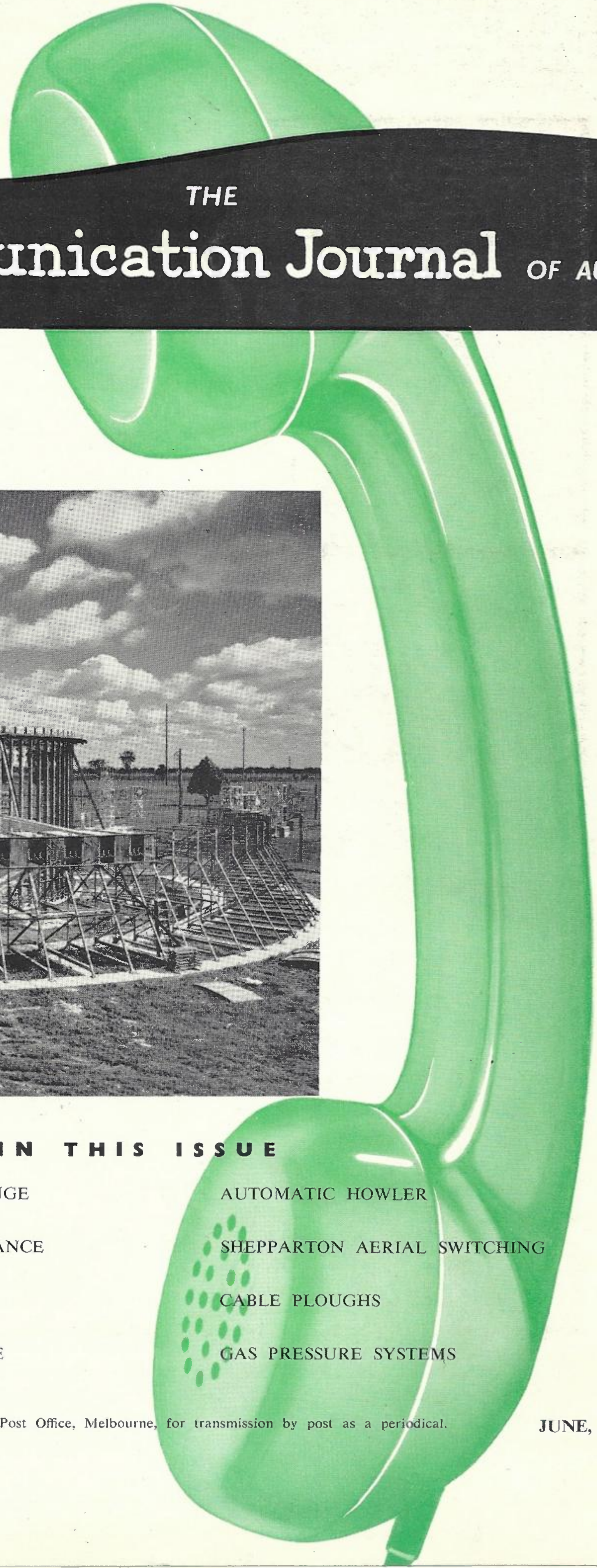
THE

Telecommunication Journal OF AUSTRALIA





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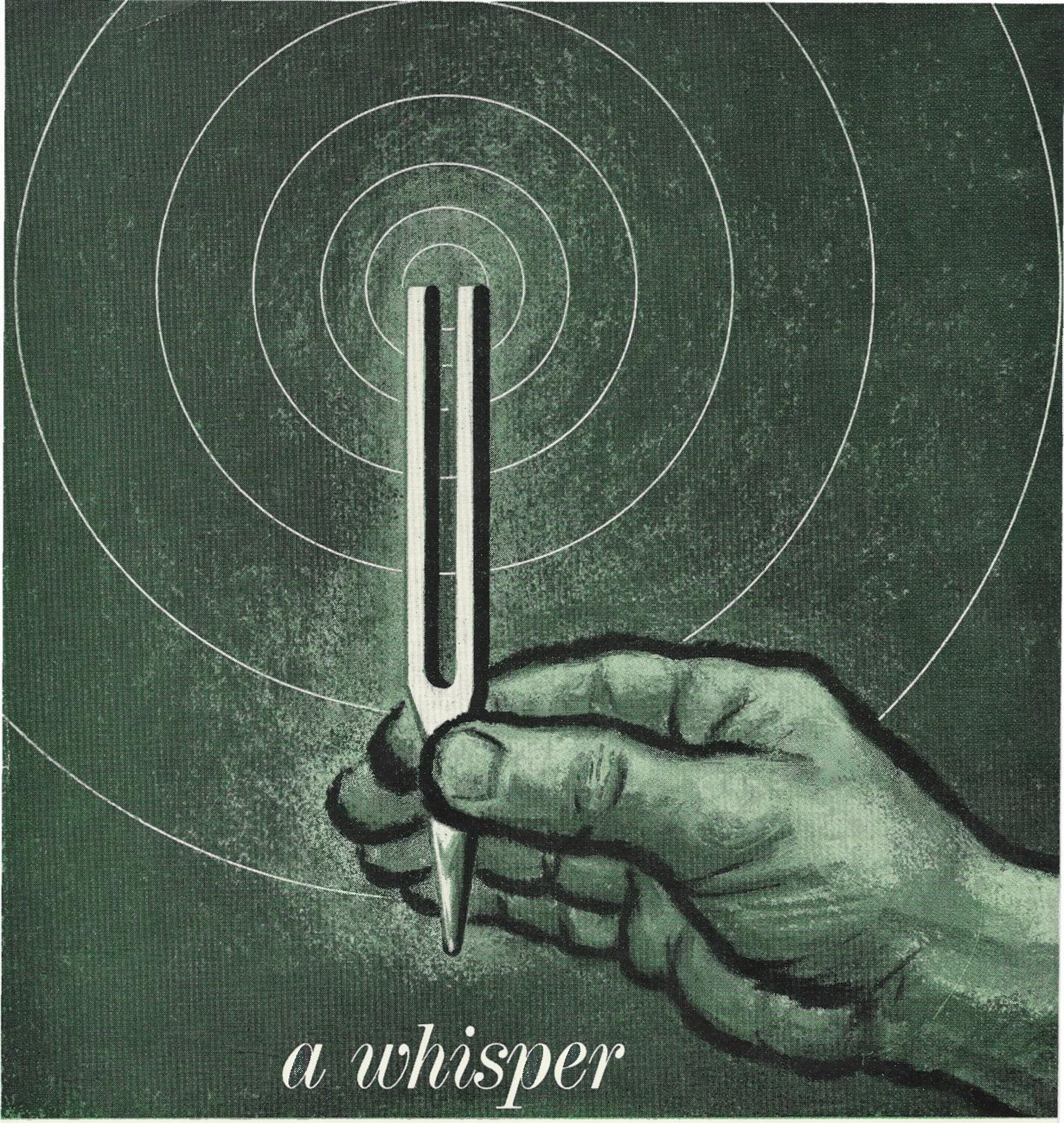
VOL. 14, No. 1 Registered at the General Post Office, Melbourne, for transmission by post as a periodical. JUNE, 1963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As explained on page 475 of the previous (February, 1963) issue of this Journal, the following monographs will be available for distribution within the next two months:

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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.

Residents of Australia may order the Journal from the State secretary* of their State of residence; others should apply to the General Secretary.* The subscription fee is 10 shillings per year (Australian currency) or 4 shillings each for single numbers. Back numbers are available at the rate of 10 shillings for any three, or 4 shillings for single numbers. Remittances should be made payable to the Telecommunication Society of Australia; exchange need not be added to Australian cheques.

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FEATURES OF THE KEW PENTACONTA EXCHANGE

*B. J. CARROLL, A.R.M.I.T.**

INTRODUCTION

On September the 15th, 1962, the first Pentaconta crossbar telephone exchange to be installed in Australia was cut into service at Kew, Victoria. The equipment, manufactured by the Compagnie Générale de Constructions Téléphoniques of Paris (C.G.C.T.), consisted of a standard Pentaconta City Exchange which was modified to work as a terminal exchange in the Melbourne network. Included with the equipment were some of the most modern maintenance aids yet to be installed in this country. Apart from being Australia's first Pentaconta telephone exchange, widespread interest was taken in this project as it was one of the very few public telephone exchanges to be installed here by private contract. The purpose of this article is to introduce the general features of the Pentaconta crossbar exchange as installed at Kew, and to describe its construction, operation and maintenance methods.

The introduction of the crossbar selector and the development of common control circuitry have made possible fundamental changes in the design of telephone switching equipment. By the elimination of the mechanical switching mechanisms and the segregation of the control and connecting circuits, considerable savings can be effected in costs with a marked improvement in switching performance. Switching noise is considerably reduced as bimotional switch base metal wipers are replaced by precious metal contacts which have a pressure action only. The elimination of noise at each switching point is of considerable importance. particularly with the introduction of subscriber trunk dialling. As relays are one of the most reliable elements in any switching system and their speed of operation is between 10 and 50 milliseconds as compared to the longer search time of a bimotional switch mechanism, the crossbar system, which is primarily a relay switching system, is fast and reliable in its operation. By using common control equipment, the use of automatic alternate routing is facilitated.

These advantages, coupled with the fact that the subscriber will not be connected to the same faulty apparatus on consecutive attempts to originate a call, combine to provide a very high grade of service to the public and an increase in switching efficiency. As these features, which are common to all crossbar systems, have been described in previous articles, the following paragraphs will deal with the Pentaconta crossbar system in particular.

DESIGN FEATURES OF PENTACONTA SYSTEM

Choice of a Multiselector of Optimum Capacity.

The capacity of the Pentaconta switch is 22 verticals with each vertical having access to 52 outlets. This is arranged by using the 14 horizontal bars. These consist of 13 selecting bars each operating 2 rows of contacts or cross points, and 1 common switching bar for selecting one of two separate contact pile-ups per crosspoint in any row. In cases where the number of wires to be switched at any cross point exceeds 5, the 14 bars are used for straight selection, giving 28 outlets per vertical. By giving the Pentaconta multiswitch a capacity of 52 outlets per vertical not only is the total number of cross points reduced, but the number of switching stages required for a given size of exchange is also reduced.

Marking and Control by Highly Specialised Common Control Equipment.

As the multiselector is a passive unit incapable of making a connection by itself the establishment of a connection is ordered by common control circuitry. The control of the establishment of a connection is preceded by the application of a marking condition to the incoming and outgoing lines to be connected, and the search for, and selection of, a free connection path between the lines concerned. These functions are performed by a marker. The remaining functions entailed in the setting up of a connection are performed by common control circuits known as registers and translators which are connected by means of register finders, couplers, and faisceau connectors. Each type of common control equipment incorporates memory devices and logic circuits which constitute the intelligence of the system. The use of specialised functional units enables the size and cost of the common control equipment to be reduced. This is exemplified in the relationship between translators and registers. The register is in use throughout the setting up time of the call.

This is a short time in relation to the duration of the call, but long relative to the time taken for individual selection and auxiliary operations. The number of registers is therefore high compared with other items of common control equipment. The register will obtain from the translator and markers the information it lacks. The register will call in a translator, refer to the translator the characteristics of the required connection, the wanted number, and class of service and it will immediately receive from the translator the routing information for setting up the connection, and the metering charge. The time for question and answer is not greater than 250 milliseconds. Two translators can handle the average traffic for a 10,000 line exchange.

Conditional Selection.

This condition applies to a double stage of interconnected selectors. A double stage comprises a primary section and a secondary section. The vertical selectors of the primary group constitute the inlets of the double stage and the horizontal multiples of the secondary stage are the outlets. The horizontal multiples of the primary

* See Page 82

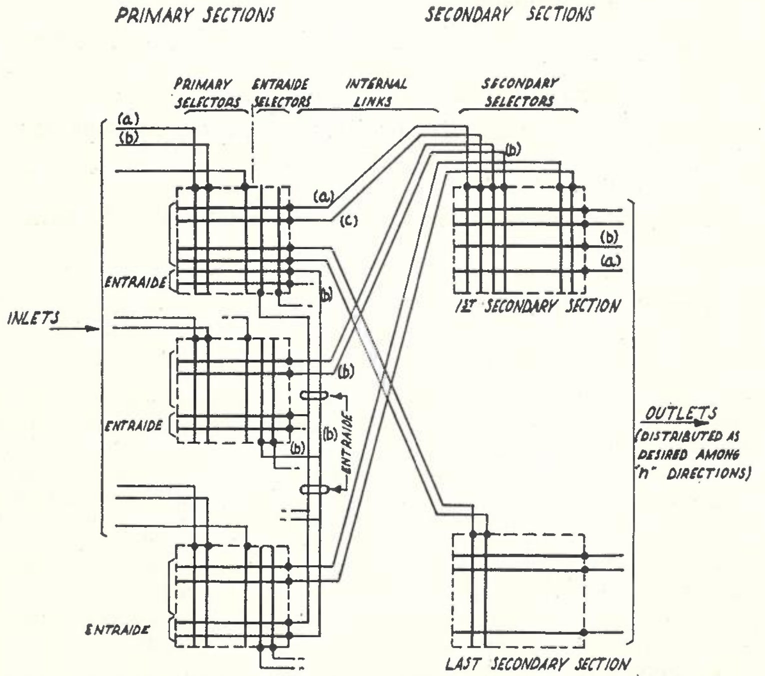

Fig. 1.—Typical Diagram of a Selector Equipment in the Pentaconta System.

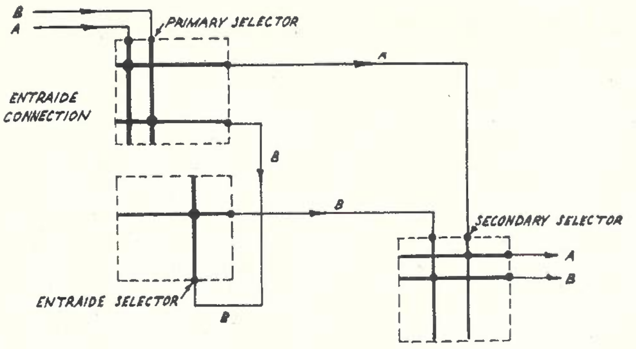

Fig. 2.—Entraide Principle.

group are connected in numerical order to the verticals of the secondary group in such a manner that there are at least 2 direct paths from each primary sub-section to each secondary sub-section. This arrangement can be seen in Fig. 1. The principle of conditional selection consists in selecting a secondary selector which is not only accessible from the primary selector concerned, but which has access to a free outlet in the required direction. This method of selection avoids lost calls due to momentary busying of selectors. Combined with "entraide", discussed later and which increases the number of paths still further, conditional selection makes practicable the condition of a "full availability group". Conditional selection also helps to increase the speed of selection since it allows the earliest possible determination of the most appropriate selection path to be used.

"Entraide" or Mutual Assistance.

The principle of "entraide" which is peculiar to the Pentaconta system, can be seen in Fig. 2. If when making a selection, the primary section in question has no direct access to a secondary section capable of setting up the connection but other primary sections can give the required access, the call is routed by a horizontal in the original primary section to an "entraide" vertical in the section which has the required access. This can be seen in Fig. 1 in which connection "B" is made by an entraide selector. To provide for "entraide" connections, a number of horizontal levels are reserved and connected to "entraide verticals" or selectors in other groups. The application of "entraide" results automatically from the marking operations and does not add appreciably to the selection time. By utilising the principles of entraide and conditional selection, internal blocking is almost completely eliminated.

Automatic Re-routing in Case of Congestion.

In the case of an outgoing call, should all outlets in the direct route be busy the marker after a slight delay automatically tests the alternate route. Should this route also encounter congestion, the register receives information to re-transmit the required number on the backbone route. If the call still cannot be connected, the subscriber receives the try again tone.

Automatic Second Attempt in Case of a Fault.

Later in this article, it will be seen that the complete switching operation of each call is under the supervision of a Maintenance Robot which automatically issues a card to record any "incident" in selection. Should an incident occur, the robot records the required information and the faulty equipment is released. A second attempt to complete the call is made automatically without the subscriber having to restore the receiver. The card punch machine is switched on as required, which is usually for 1 to 1½ hours a day.

Storage and Transmission of Information by Simple Self-checking Code

Crossbar systems require that the digits in decimal form received from the subscriber's dial by the register, be stored in some suitable form so the information can be used when required for selection. In the Pentaconta system each digit is translated into a 2 out of 5 code. This code is simple and self-checking. As the transmission of any digit requires an earth on two leads and on two only, should one or more than 2 code relays operate a fault condition is signalled and a second attempt is made. This type of code is also used for transmitting the calling information from the register to the translator and from translator to markers. It is also used for category identification in line and group selection. The elements used in the code are called A,B,C,D, and E, and the manner in which these elements are used is shown in Table I.

TABLE I.

CODE	DIGIT	CODE	DIGIT	CODE
A = 1	1	AE	6	BC
B = 2	2	BE	7	CD
C = 4	3	AB	8	DE
D = 8	4	CE	9	AD
E = 0	5	AC	10	BD

TRUNKING PRINCIPLES

For the purpose of describing the trunking of the Kew exchange, the switching equipment can be divided into three main sections, the line selection unit, group selection unit, and the common control section. A further sub-section is included in the case of incoming calls as the incoming junctions are connected to special incoming registers. Under this section mention is also made of the ample provision of trunk distributing frames and the probability of a lost call based on the switching equipment calculations.

Line Selection Unit

The line selection element, Fig. 3, is arranged to handle all the incoming and originating traffic for 1,000 lines and is controlled by 2 markers. It is arranged in 2 sections referred to as primary and secondary sections. The

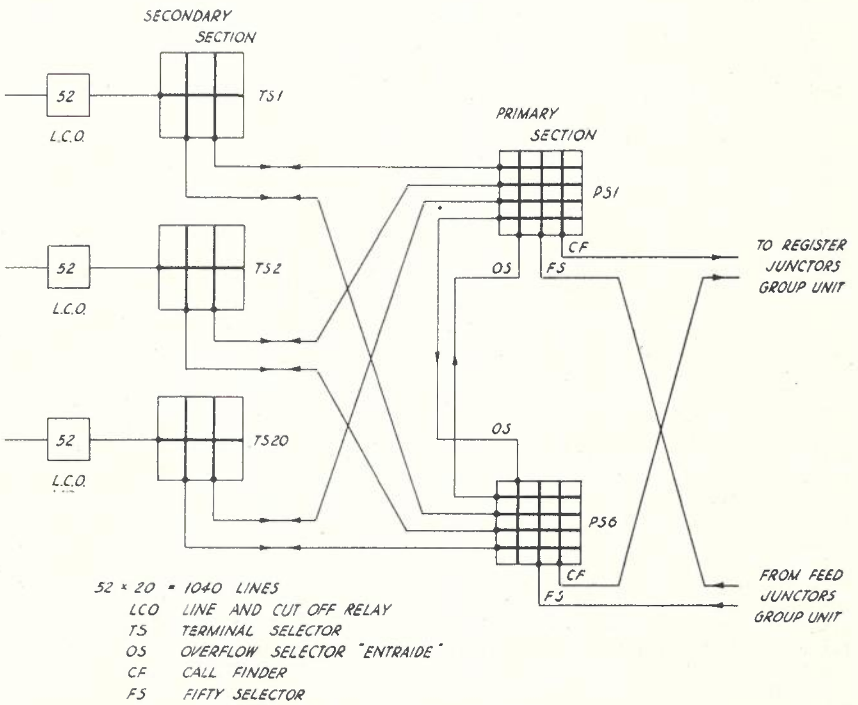

Fig. 3.—Line Selection Unit.

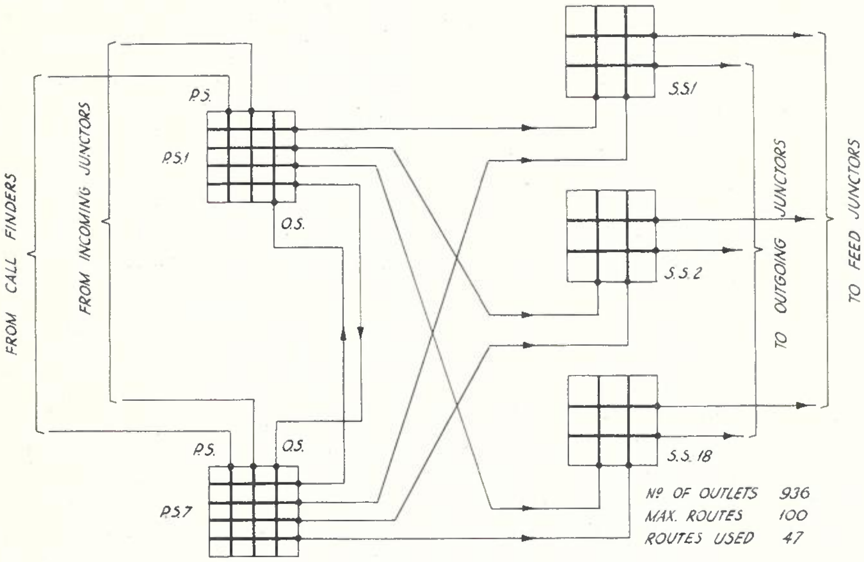

Fig. 4.—Group Selection Unit.

secondary section is divided into 20 subsections or frames. Each frame has the capacity for 52 lines. 50 of these are in the numbering scheme of the exchange. The remaining 2 lines can be used for special purposes, such as one-way lines from switchboards, or for public telephones, etc.

Each frame contains 52 line junctors — the equivalent of the line and cut off relays. Also in the same frame is a multiselector having 12 verticals (the maximum number of verticals being 16). These verticals are called terminal selectors. These 12 terminal selectors handle all the traffic, incoming and originating, for the 50 lines in that particular frame.

The number of verticals provided depends on the traffic requirements of the particular group. The verticals from the secondary section are connected to the horizontal multiples of the primary section. Where the number of verticals per terminal selector is 12, the primary section consists of 6 frames.

Each frame in the primary section is equipped with 22 verticals. At Kew, 10 call finder verticals are used for originating traffic and 9 "50 selector" verticals are used for incoming traffic. The remaining 3 verticals in a frame are used for "entraide" selection. As there are 20 terminal selector frames, each having 2 direct outlets to each primary subsection, only 40 circuits are used in each primary frame. This leaves 12 outlets in each frame available for entraide selection, which can operate in both directions. If, when a line makes a call, there is no free call finder in the sections directly accessible from the terminal selectors in the 50 line group to which the subscriber belongs, the connection can be made via an auxiliary primary selector frame. This also applies to "called lines" if the "50 selector" has no direct access to the wanted 50 line group.

Group Selection Unit

The typical connection of a group selection unit is illustrated in Figs. 3 and 4. The primary section at Kew consists of 7 subsections. Each subsection consists of 2 frames of 22 verticals, in order to provide 44 verticals. 39 of these verticals are used for inlets and the remaining 5 for entraide. This gives a total of 7 x 39 = 273 inlets. Each primary subsection has 40 outlets which are connected to verticals in the secondary section, the remaining 12 outlets being used for "entraide" selectors. The secondary section consists of 18 frames, each equipped with 14 verticals and 52 outlets.

Thus the total number of outlets in the secondary section is 18 x 52 = 936. These outlets are connected to outgoing junctors, special circuits, or, in the case of local calls, to local feed junctors. The local feed junctor provides the battery feed, signalling and metering functions of a final selector in the step-by-step system. The incoming traffic to the group stage comes from local register junctors and incoming junctors. In order to obtain a sufficient number of inlets in the group stage at Kew, two group selection stages are connected in parallel. The inlets are independent but the outlets are commoned. Each stage is controlled by two group markers. The maximum number of outlets in a single group stage is 1040, and these can be distributed over 100 routes, with full availability. At Kew 47 routes are in use.

Common Control Section

It will be seen from Fig. 5, which indicates the trunking arrangements for the Kew Pentaconta exchange, that the main elements in the common control section are registers and translators. These are connected to each other and to the markers by means of connecting circuits known as couplers and faisceau connectors. A faisceau connector is a circuit designed to connect any coupler to any marker on one of two circuits. The faisceau connector has a holding time of approximately 200 milliseconds. The registers, designed to store 9 digits, are connected to the outlets of the line selection stage by means of register junctors which are mounted on the same frame as the register finder multiswitch. From Fig. 6 it will be seen that the 10 call finder verticals (that is, outlet from L.S. stage) in each primary frame are connected over two register finder frames, 5 odd verticals to one frame, and 5 evens to the other frame. At Kew the 36 local registers are connected to the six verticals in each of 6 register finders, and as the horizontal multiple is split, each register is multipled over both sides of the register finder and each subscriber has access to any register. The registers are equipped to regenerate the digits stored in them as a decimal code with an interdigital pause adjustable from 450 to 800 milliseconds. Multi-frequency signalling is not provided at present but can be added if required by using relay sets known as senders. The register junctor serves to hold the call during the setting up time and separates the line and group selector stages.

Incoming Calls

Forty incoming registers and 10 register finders are provided for the incoming traffic. The incoming junctors are connected each to two register finder frames in such a way that the junctor appearing as No. 1 in the first frame is No. 28 in the second frame (see Fig. 7). The order of appearance is reversed to compensate for the delay which might arise from the fact that the first horizontal bar in each frame receives priority. The incoming junctors are designed to store up to one impulse train. If a register has not been selected by this time the calling party receives try again tone from the incoming junctor. As the incoming registers work with the same translators as used on local calls, the code 86 (the local exchange code) is automatically stored in the register as the first and second impulse train. The time to connect an incoming call to a register is approximately 400 milliseconds.

Intermediate Distributing Frames

From the trunking diagram, Fig. 5, it will be seen that IDF's are provided between each switching section in order to balance the traffic, ensure that the maximum possible efficiency is obtained from the equipment, and obtain the best grade of service for a given traffic.

Probability of a Lost Call.

It is not intended in this article to include the calculations required for the provision of the switching equipment but it is of interest to note the loss probability based on the equipment supplied for the traffic at Kew. This is shown in Table II.

OPERATION

Local Call

When the subscriber lifts his handset his "1b" relay in the line junctor

TABLE II

(1) Local Call	
Preselection	= 0.3 x 10^{-3}
Group Selection	= 1.2 x 10^{-3}
Line Selection	= 0.4 x 10^{-3}
TOTAL	= 1.9 x 10^{-3}
(2) Incoming Call	
Group Selection	= 1.2 x 10^{-3}
Line Selection	= 0.4 x 10^{-3}
TOTAL	= 1.6 x 10^{-3}
(3) Outgoing Call	
Preselection	= 0.3 x 10^{-3}
Group Selection	= 0.01 x 10^{-3}
TOTAL	= 0.31 x 10^{-3}

operates, and a test is made via the available terminal selector verticals to call finder frames having access to a free register. As the terminal selector verticals from each terminal selector frame appear over all call finder frames, a selection of one particular call finder frame is made by the common thousand control relays. The particular register to be selected and the call finder vertical to be connected are controlled by the register finder. When a register has been selected the call finder frame calls the line marker and the selection of a terminal selector and identification of the calling subscriber is made.

When the subscriber has been identified the category allocated to it (that is, duplex service, straight line, temporarily disconnected, variable tariff public telephone, etc.) is fed from the marker to the register via the faisceau connector and coupler in a 2 out of 5 code. If the category allows connection, the subscriber's "la" relay of the line junctor is operated. At this stage the verticals in the call finder and terminal selector are operated and held. Then the line marker is released, as are also the control relays of the call finder and terminal selectors. The subscriber now receives dial tone from the register. The coupler and faisceau connector have very short holding times and release immediately after the register receives the subscriber's category. The time taken is 500 milliseconds.

The subscriber dials and the first two impulse trains are recorded and stored by the register. On the reception of two impulse trains the coupler is again called and connects to the translator via the translator coupler. At the same time, a test is made to the primary selector and a group marker is seized. The two impulse trains are sent from the register to the translator in 2 out of 5 code. Since on a local call two impulse trains are insufficient to direct the routing of the call, the translator sends a signal to the register that 2 additional impulse trains are required and releases. The coupler, primary selector and group marker are also released.

When the register has received a total of 4 impulse trains, the coupler and translator are again called and the coded impulses are fed into the translator. This time the translator converts the coded digits into 1 out of 100, for example, 8,650 becomes 05, and this number is sent from the translator to the group marker to operate the required route relays, so as to allow the group marker to test the outlets in the required direction. When the coupler is seized a test is made of the primary selector to ensure that it is available.

If the primary selector is available the group marker is called, which in turn calls the group faisceau connector. The group faisceau connector receives the routing information from the translator via the coupler, then the marker tests, and connects an outlet in the required route. This time the translator and faisceau connector release but the coupler is held. The marker checks the category of the selected route, recalls the faisceau connector and sends this category to the register.

The register receives the remainder of the impulse trains and when six digits have been stored the coupler is again called and a test is made to the 50 selector vertical to check its availability. On completion of a successful test the line marker is called. The faisceau connector is also called and the line marker receives the last 3 digits in 2 out of 5

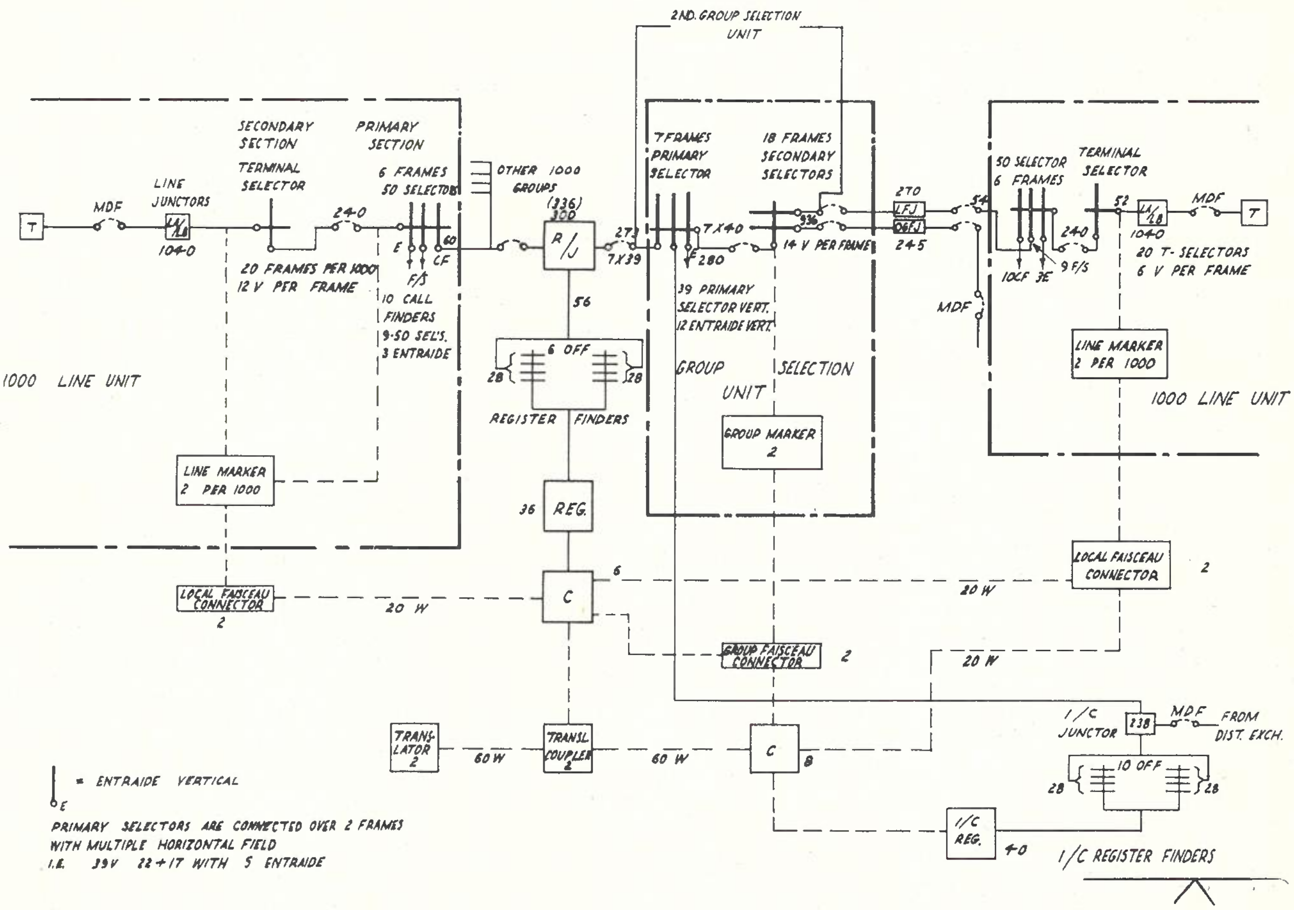

Fig. 5.—Trunking Diagram—Kew Exchange.

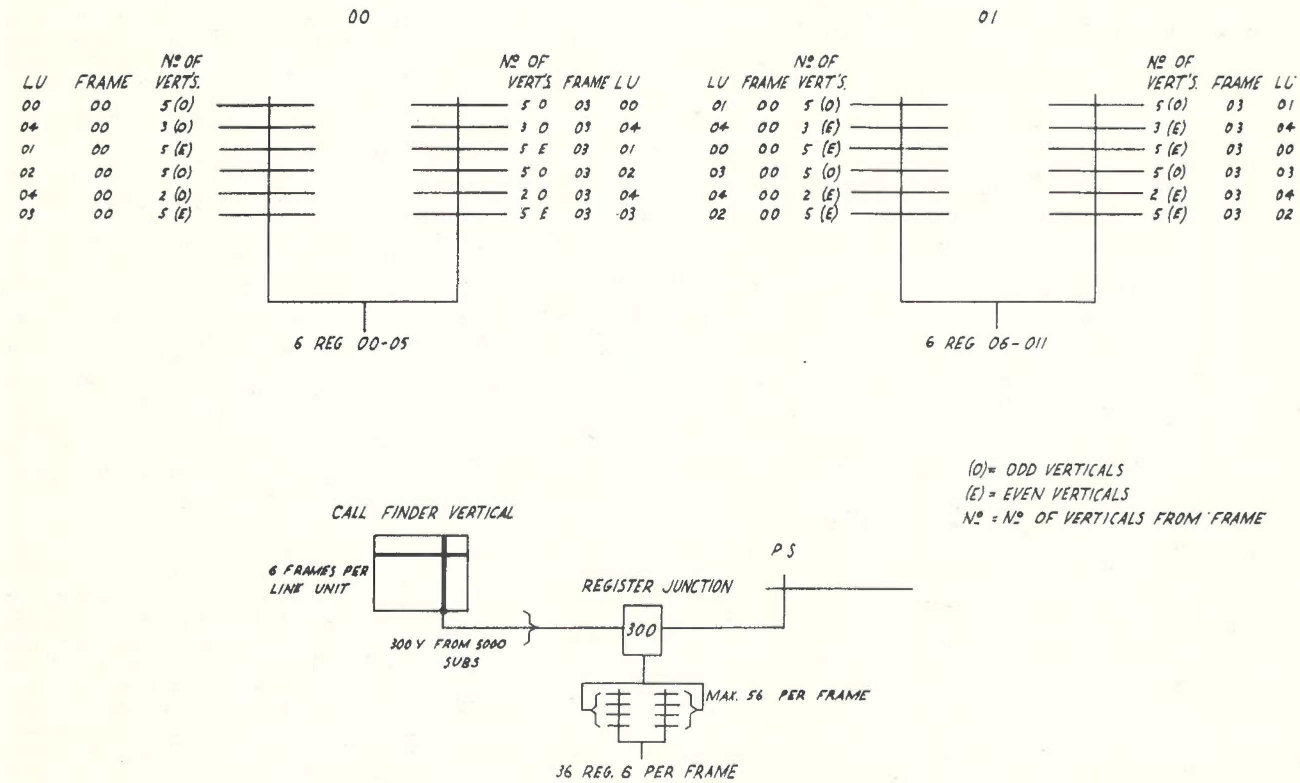

Fig. 6.—Connection of Call Finder Verticals to Register Finders.

code via the coupler. The faisceau connector releases but the coupler holds. On the operation of the terminal selector horizontals, the called subscriber's category is returned to the register. If the category is satisfactory the verticals of the 50 selector and terminal selector are operated and the subscribers are connected.

The local feed junctor which is located between the secondary selector of group selection and the 50 selector of line selection provides tones, ring current, transmission bridge and metering pulses.

Outgoing Call

As in the case of a local call the subscriber lifts his receiver and is connected to a register. After dialling two impulse trains the translator is called in and as 2 digits are usually sufficient for group selection on an outgoing call, the translator forwards this information on to the group marker, which has been called after the coupler has tested the primary selector as in the previous case.

Once again the group marker tests the nominated route and selects a free junction. The category of this junction is checked and the register told of the number of digits to transmit. The outgoing feed junctor now acts as a repeater. For outgoing calls the register re-generates the impulse trains which have been stored in it and sends them out as decimal impulses. In the case where the register catches up to the subscriber's dialling and no more digits are stored or being received by the register, the register releases and connects the subscriber directly to the outgoing feed junctor. The register will not release until one digit has been sent after group selection. The maximum post dialling delay is 7 seconds.

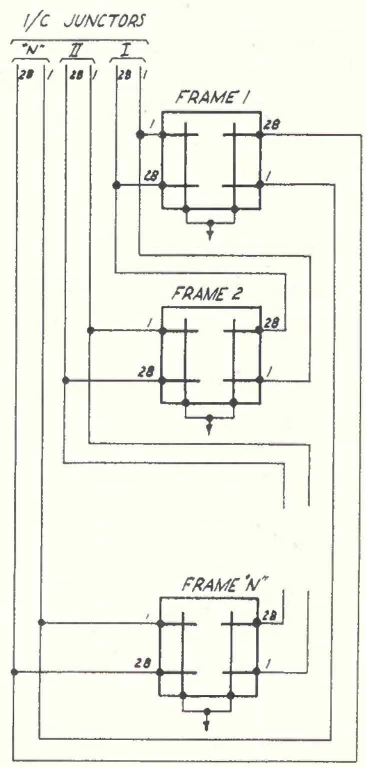

Fig. 7.—Connection of Incoming Junctors to Incoming Register Finders.

Re-routing of Outgoing Calls

If when the routing information is received all outlets on the chosen route are busy the alternate route is automatically tested by the marker after a short delay period. If the alternate route is available the marker signals to the register the category of the route, giving the number of digits to be transmitted. Should there be no outlets available in the alternate route the register is informed, the marker is released and the register circuit restored to recall the translator and resubmit the original coding digits. The register informs the translator that the backbone route is required. Should this last test be unsuccessful, try again tone is given to the calling subscriber and the register is released.

Incoming Call

When an incoming junctor is seized by a calling subscriber the junctor is connected to an incoming register via a register finder. Since this may take a little time, provision is made in the incoming junctor to store the first impulse train. If no register is available by the time the second train arrives, try again tone is transmitted to the calling party from the junctor and the register finder releases.

If, at the end of the first impulse train, a register has been seized, the digit is transmitted to the register. All subsequent digits are fed in 2 out of 5 code to the register.

When an incoming register is seized, the code 86 (Kew) is automatically set up on storage relays as the first

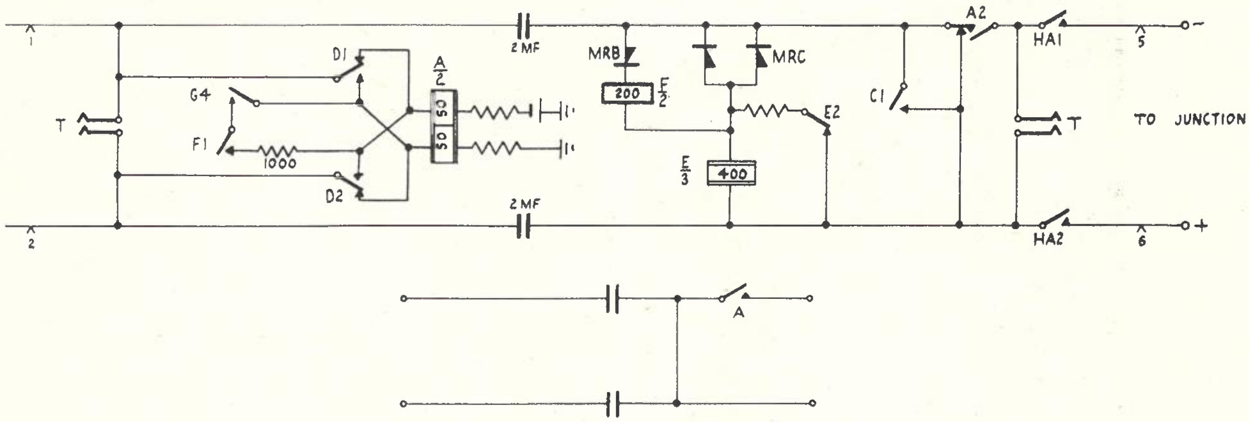

Fig. 8.—Impulsing Circuit, R.S.R.

and second impulse train. On receipt of the fourth impulse train the translator is seized and group selection takes place. When the final digits are received by the register, the last 3 are fed in 2 out of 5 code to the line marker and line selection takes place. As in the local call, at the end of selection, the marker, coupler and register are released, and ring, ring tone, and transmission feed are supplied by the local feed junctor.

CHARACTERISTIC FEATURES

Independence of Subscribers Directory Number and Line Element Appearance

By providing a crossconnecting frame with each marker in line selection it is possible to connect any call number (that is, number listed in the Directory and subsequently coded in the marker) to any line in a 1000 line group. Under normal conditions the first 50 lines in a 1000 line group appear in the first terminal selector frame, but should the traffic generated by these lines exceed the design limits for the number of terminal selectors equipped in the frame, certain lines can be transferred to a 50 selector frame with a lower calling rate. As certain 200 line boards were reserved for P.B.X. subscribers with the original 2000 type exchange, this facility of taking lines out of their

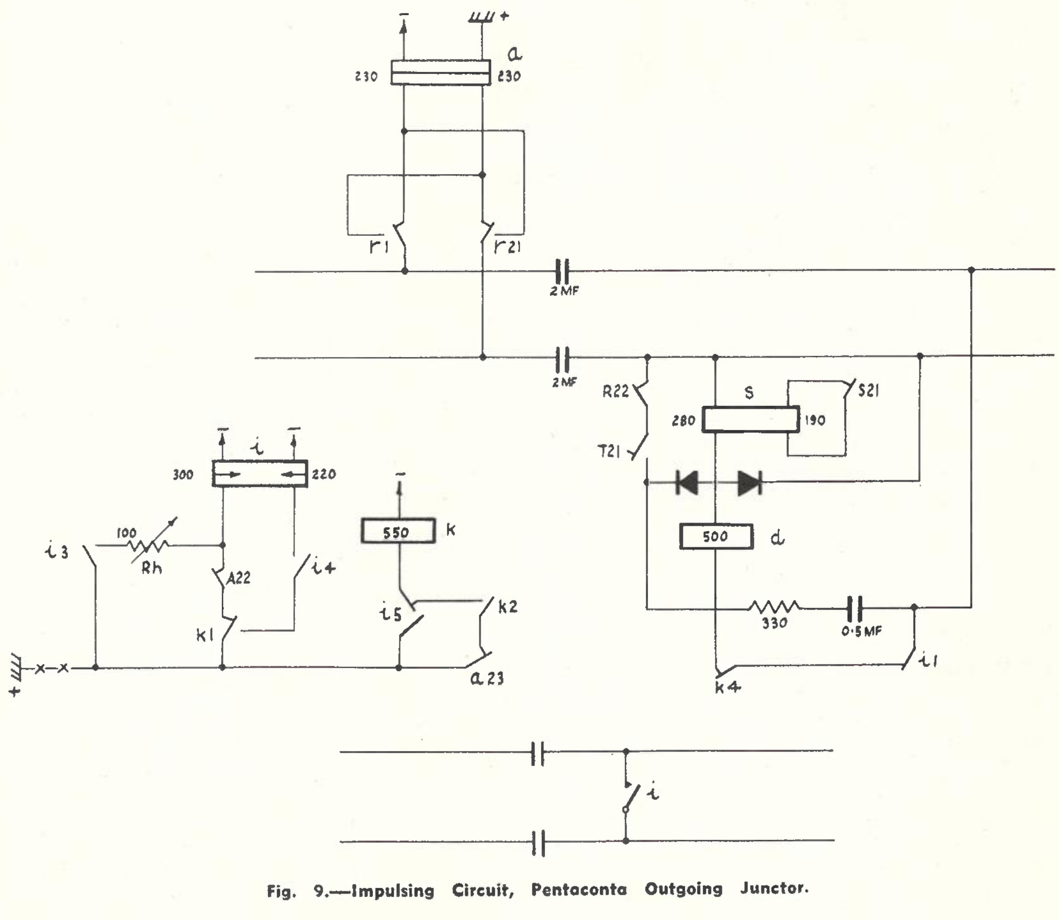

Fig. 9.—Impulsing Circuit, Pentaconta Outgoing Junctor.

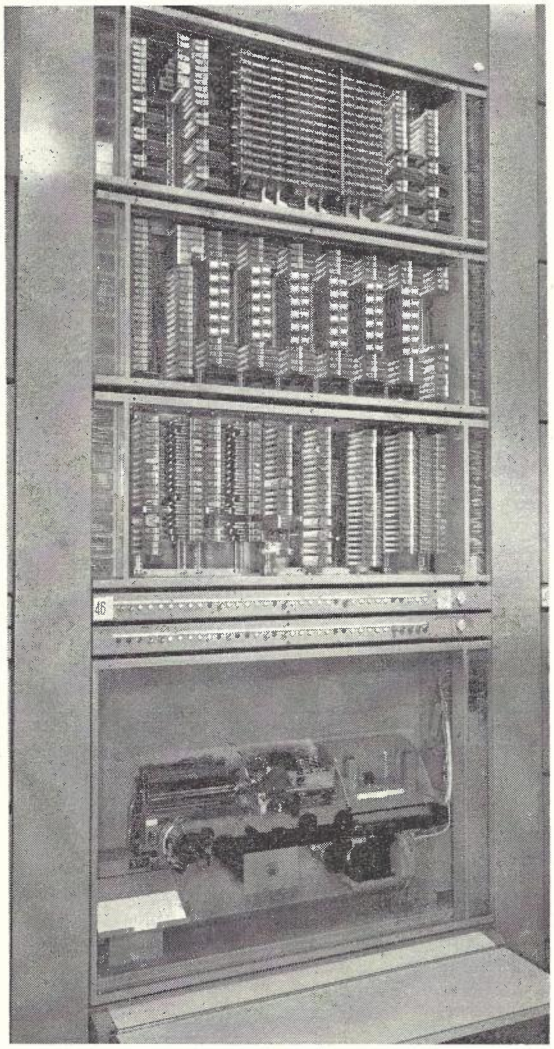

Fig. 10.—The Maintenance Robot. Covers are removed to show the localizer, memory relays, control relays and card punch machine.

normal numerical appearance was used to distribute the traffic evenly over the 1000 line group without a number change to the subscribers. There are, however, certain disadvantages in this practice from a maintenance viewpoint and they are that the M.D.F. is no longer numerical, and for test purposes it is necessary to dial the number associated with the geographical location of the line. Whilst this may not be a difficulty with local staff it means that after-hours testing staff and the centralized complaints centre must be aware of the fact that certain numbers are out of the numbering scheme.

P.B.X. Lines

With the equipment at Kew any line in a 1000 line group may be converted to P.B.X. working, the only limitation being that all lines in any one group must be in the same 1000 line board and not extend over more than 3 terminal selector frames. Any line in the group can be selected as the Directory entry and all lines except the Directory entry can be night-switched. At present the size of any one group is limited to 20 lines, but by using a route out of group selection, or by installing additional relays, the P.B.X. group can be extended to more than 20 lines. Under normal circumstances the order of selection is random but ordered selection can be achieved by arranging that all lines in a particular group are connected to the one pilot relay in the one terminal selector frame (13 lines to one pilot relay), and in this case order of selection is controlled by the position of the horizontal bar in the frame, that is, the first bar in the frame is the bar nearest the battery feed and receives priority.

Release Features

On local and incoming calls the release of the connection is controlled by the calling party. Should the called party fail to restore the receiver after the calling party has cleared the line, the called party is thrown into line lock-out.

In the case of outgoing calls, the release is first party release with a delay of 2 to 4 minutes if the called party restores first. This is a valuable feature as it eliminates C.S.H. conditions caused by Kew subscribers at distant exchanges and ensures that junctions are released and not held up without traffic. It is proposed to extend this feature to the local feed junctors at Kew exchange and thus eliminate the inconvenience caused to subscribers when a line is held by failure of the calling party to clear the line on completion of a call.

Junction Back-busying

All outgoing junctions are equipped with back-busying features which busy out junctions in the event of the junction being faulty or reversed.

Transmission Conditions

The system employs a standard Stone transmission bridge using 220/220 ohm relays without ballast resistors. The attenuation of the bridge is 0.4 db at 800 c/s. The fact that the battery supply to the transmission bridge is filtered separately from the battery used for normal relay operations and that the contacts of the multiselector are never opened or closed whilst alive, contribute to the excellent transmission quality of this system. There are virtually no extraneous clicks or noises in the transmission circuits. It is also the practice in the Pentaconta system to maintain the same D.C. polarity on each side of the transmission condensers in the local feed junctors.

Special Line Categories

At Kew five out of a possible 10 line categories are in use.

Category 1: This is unrestricted and applies to all normal subscriber services.

Category 2: This category is allocated to multi-coin public telephones which are restricted to the local unit fee network and to trunk line access via the special manual positions. The usual practice of identifying multi-coin public telephones by use of a pip tone is not required with this category. Should it be necessary to send a telegram via a multi-coin public telephone, the call is switched to telegrams via the special trunk manual positions. The call notices have been altered to cover this feature. No difficulty has been experienced with leased multi-coin public telephones.

Category 3: Variable tariff public telephones which are restricted to the unit fee area are in category 3, that is, it is impossible to make a trunk call from a variable tariff public telephone.

Category 4: Subscribers who are temporarily disconnected one way, that is, receive incoming calls only, are in category 4.

Category 6: This category is used for duplex services. These require a special category as the registers are designed to reject lines which are grounded. Under normal conditions when a local subscriber calls another local subscriber who is busy, the call is released and the calling party receives busy tone from his local line circuit. Duplex services are routed to a busy tone junctor in group selection.

Impulsing Conditions

The specifications for the Kew exchange indicate that the equipment is designed to operate satisfactorily within a voltage range of 44-56 volts for subscribers lines with the following characteristics:

Maximum Loop (including telephone) —1,500 ohms.

Minimum Leakage Resistance—15,000 ohms.

Dials—Speed 8-14 impulses per second.

—Make Break Ratio 37/63 — 30/70.

Initially the impulses are received in the register by a high speed relay which in turn operates the counting relays. These relays operate satisfactorily under the above conditions, but in the case of an outgoing call the register is designed to release after one digit beyond group selection if no digits are stored or being received by it, which means that the subscriber then impulses directly into the outgoing junctor; thus the characteristics of the outgoing junctor become the limiting factor for the impulsing conditions.

The impulsing circuit conditions for a standard relay set repeater and the Pentaconta outgoing junctor are shown in Figs. 8 and 9 respectively.

In the case of the R.S.R. circuit the impulses are received by a 50/50 ohm A relay and are repeated by a contact of the same relay. This contact is on the outgoing side of the transmission condensers which are short circuited during impulsing. In the case of the Pentaconta outgoing junctor the impulses are received by a 220/220 ohms A relay and transmitted on the outgoing side by two slave relays "i" and "k" which are designed to provide an impulse with a constant break ratio. The adjustment of the break is obtained by the potentiometer "Rh" which controls the timing of the "i" relay. During impulsing the transmission condensers are presented to the junction.

In the initial adjustment of the impulsing circuit it was found that the circuit did not impulse correctly if the input loop was under 300 ohms. In the case of a register impulsing into the outgoing junctors, the input loop is 510 ohms. To overcome this feature all low loop lines were built out to 300 ohms. It was found however, by analysing the subscribers wrong number complaints, that outgoing junctors adjusted to give a ratio of 36/64 at 10 impulses per second gave wrong numbers if the dial speed was fast. The ratio at 12 impulses per second was 25/75 which in terms of milliseconds gives a make of 21 milliseconds and a break of 62.3 milliseconds. Under these conditions it is possible that the "B" relays could release on high digits if they were not in correct adjustment. This fault was overcome by testing the junctors with an impulse of 30% make at 11 impulses per second and adjusting for a satisfactory make period. Since this adjustment was made wrong number complaints have disappeared.

It is apparent from experience at Kew that an impulse correction circuit is satisfactory if the dial speed can be kept within rigid limits. It is of interest to note that these faults were not detected by the traffic route tester as the digits are sent out with a low interdigital pause and would be regenerated and transmitted to the outgoing junctors under ideal conditions of speed and ratio. It is also possible to clip the first break period of an impulse should the subscriber recommence dialling during the release of the register. This is compensated for by the impulse correction circuit. When these points are considered it would be an advantage to have the register designed to release after the total number of impulse trains required for a particular route have been transmitted and thus obtain all the advantages of the register impulsing circuitry. The impulsing conditions are still under investigation and an outgoing junctor, which has been modified by C.G.C.T. to eliminate the above mentioned disadvantages, is under trial. The results to date are satisfactory. From Fig. 9 it will be seen that the pick up loop of the outgoing junctor is approximately 400 ohms.

SPECIAL FACILITIES

The Maintenance Robot

From a maintenance viewpoint the facilities provided by the Pentaconta system for the supervision of plant performance are unique in Australia, and could be considered as the ultimate in maintenance methods. The operation of the complete exchange is permanently supervised by the maintenance robot shown in Figs. 10 and 11. In the event of any incident which results in the switching equipment failing to perform its correct function in a pre-determined time, the maintenance robot is called in by one of the various active units in the

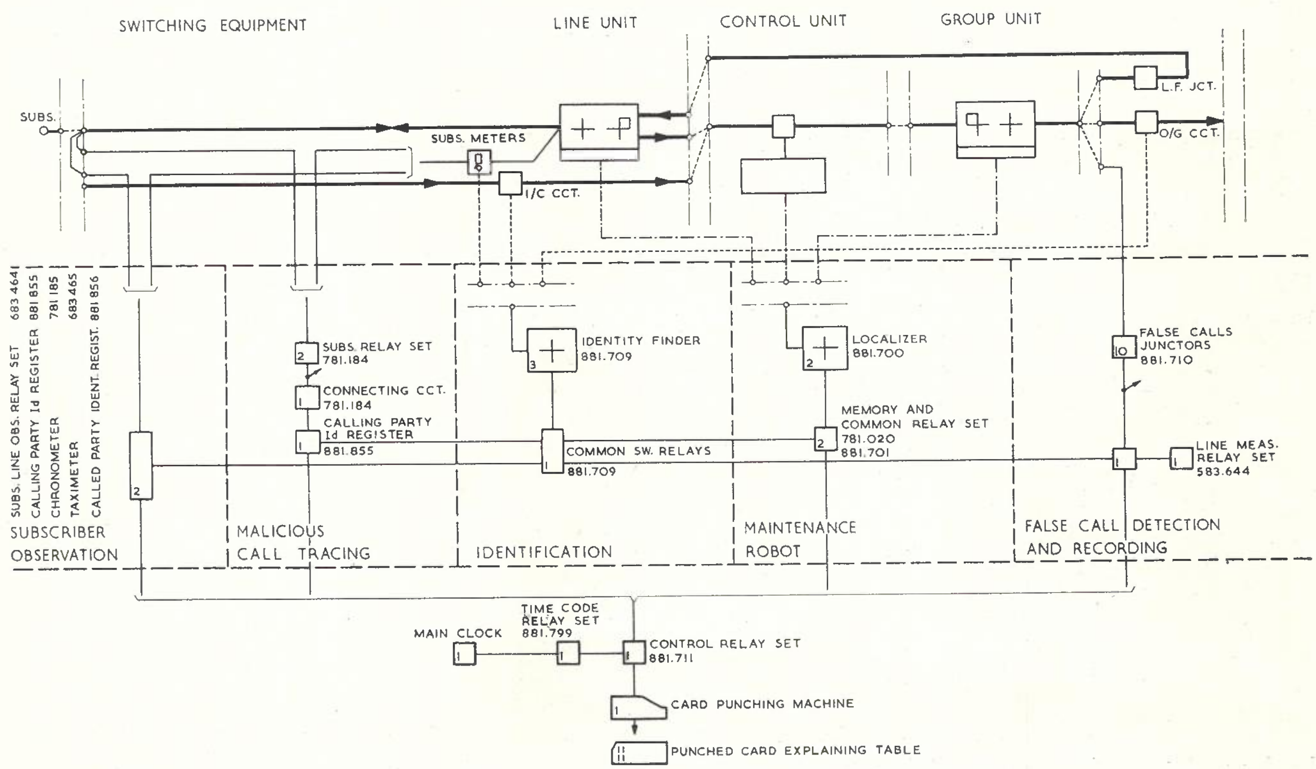

Fig. 11.—Trunking Diagram for the Maintenance Robot.

selection chain. These units, namely the common thousand relays, markers and registers, send a signal to the maintenance robot which causes the identification of all the switching equipment held in the faulty chain, also the stage of operation of the principal function indicating relays in each control unit. This information is initialy recorded by the memory unit and when complete, it is transferred to the perforator associated with the robot. The perforator can be switched on as required, as once the exchange has been in operation for a period, it is only necessary to switch the card punch machine on for an hour a day. The information is then delivered on a punched card. The filing and analysing of these cards is described later under Maintenance Procedures. Provision is also made by means of a button to hold the faulty chain, thus enabling the call to be traced. This facility is used only in times of very light traffic, and under these conditions an audible alarm is provided at the card punch machine when a fault is recorded. All cards issued from the machine are punched to indicate the type of fault (that is, incident, false call, observation, etc.), as well as the date and time of the fault to the nearest 5 seconds.

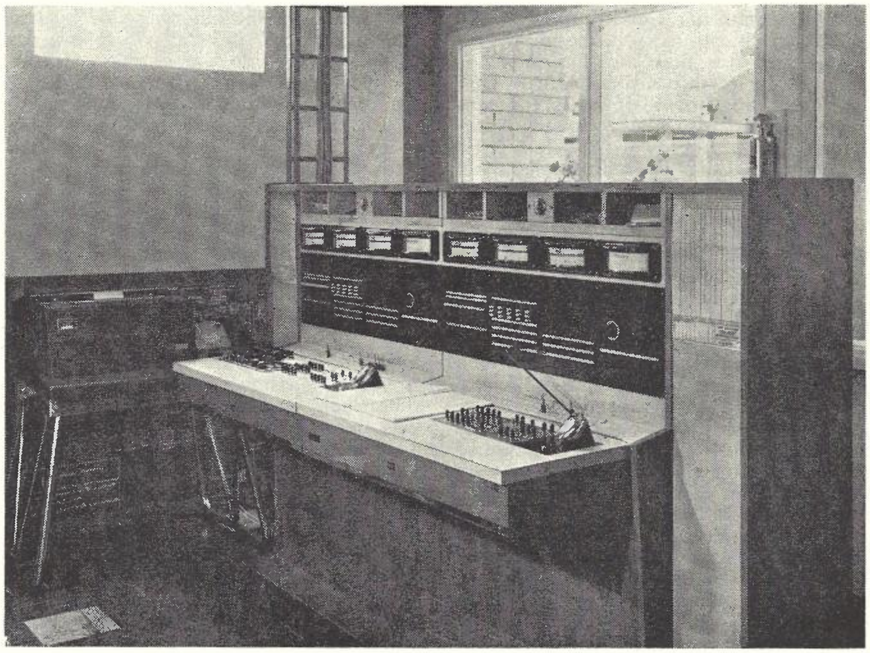

Fig. 13.—A Pentaconta Test Desk. The teleprinter on left-hand side is used for passing complaints from the "00" centre.

False Calls

A false call condition exists when a register is seized but does not receive impulses or the impulses are not sufficient to complete selection. After a delay of 20 to 40 seconds, the register will extend the call to 1 of the 10 false call junctors which returns busy tone to the offending subscriber. The register, of course, is released. If this condition exists for a period of 2 to 4 minutes the maintenance robot is called and a card is issued giving the following indications:

(1) Type of fault (for example, "FC"—false call).
(2) Date and time.
(3) Number of the faulty line.
(4) Condition of the line—
 1, resistance A to B.
 2, resistance A to ground.
 3, resistance B to ground.

The resistance tests are carried out by a bridge associated with the false call junctors, and the resistance values are indicated in the following groups:

1 — 0 - 1000 ohms.
2 — 1000 - 10,000 ohms.
3—over 10,000 ohms.

After the line has been tested it is then thrown into the line lockout condition at its individual line junctor.

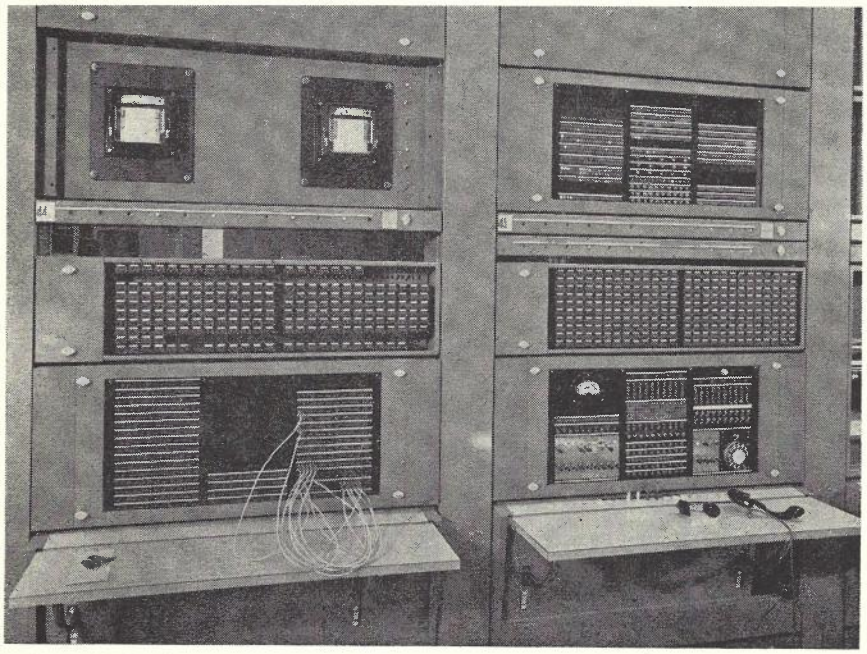

Fig. 12.—Traffic Supervision Equipment. This includes recording ammeters, traffic and congestion meters, and lamp display. Local subscriber observation equipment can be seen on the lower right-hand side.

Malicious Calls

Provision is made to connect any two subscribers to the malicious call recording equipment associated with the card punch machine. The called party dials the digit 1 on receipt of a malicious call and a card is issued giving the date and time of the call, and the number of the calling party if connected to the same exchange or the incoming junction if the call is from a distant exchange. It also indicates the number of the subscriber under observation.

Subscriber Observation Facilities

Facilities are provided to observe eight subscribers at any one time. Two of these circuits are associated with the card punch machine which automatically records on a card the date, time, identity of the junctor used, the number called, the number of meter pulses received, and the duration of the call. In cases of incoming calls to the subscribers under observation, the calling subscribers number is recorded if it is a local call.

The remaining six circuits are manually observed on a lamp display panel. A pilot lamp indicates that one of the six circuits is in use. By depressing a key associated with the particular circuit in use, the lamp display indicates the number called, the number of meter pulses received, and the duration of the call. If the incoming call is made by a local subscriber, the subscriber's identity is recorded. Facilities are provided at the observation panel to speak to the subscriber and conduct simple tests on the subscriber's line.

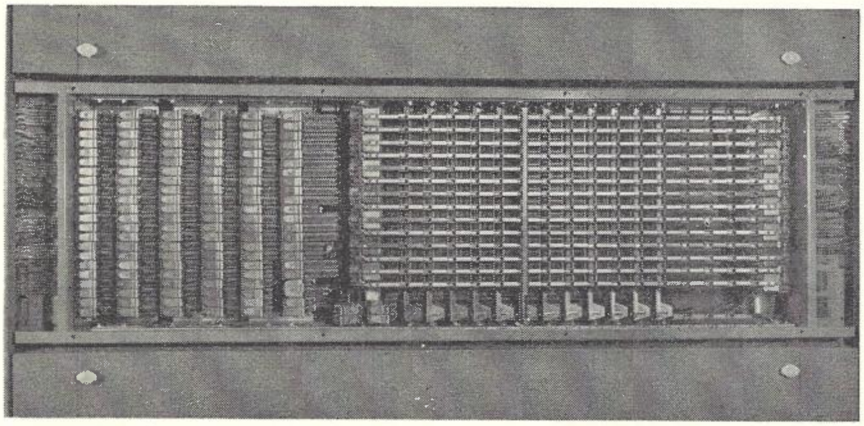

Fig. 14.—Partially Equipped "50" Selector Frame. The line and cut-off relays can be seen on the left.

In order that the test desk operator may supervise lines or public telephones which may be subject to faults of an intermittent nature, the incoming trunks to the test desk and test register access facilities are also extended to this position.

Traffic and Congestion Meters

In the past we have relied mainly on overflow meters to indicate congestion in our trunking schemes. In some instances the underprovision of switching equipment has been detected by inspection or by subscribers' complaints. Recently, however, direct reading traffic meters have been installed in some exchanges but, in the opinion of the author, the equipment provided at the Kew exchange for recording the traffic distribution in all sections of the trunking is far superior to any other equipment in use in this country at the present time. The equipment, Fig. 12, may be divided into three sections:

(1) Lamp display equipment which provides a visual indication of the occupation of all items of common switching equipment in the exchange.

(2) Occupation and congestion meters. The traffic meters record the total number of calls to each route out of group selection, as well as the number of seizures on each register frame (that is, incoming traffic to the group unit). Congestion meters record the total number of calls failing due to (i) internal blocking in the line unit, (ii) internal blocking in the group unit, and (iii) underprovision of junctions in any route. Apart from the meters permanently connected as above, sixty additional meters are provided and can be strapped as required to indicate traffic or congestion in any stage of the switching equipment.

(3) Recording ammeters. Two recording ammeters are provided to allow traffic observation on the following equipment by means of a selective cross-connection on a jack field with appropriate shunts and connecting cords:

Each secondary section of each group unit; each 50 group of each line unit; local and incoming registers; and local, incoming and outgoing junctors, and groups of register junctors.

Special Observation, Centralized Observation and Interception Circuits

These facilities are designed in accordance with the existing requirements. In the case of centralized service observation, which is now first selector observation, the tapping circuits are wired to the register junctors.

Test Desk

A two position test desk (see Fig. 13) has been installed. In addition to the normal testing facilities provided on the A.P.O. standard test desk, this enables the following tests to be made on the lines:

(1) The presence of A.C. voltages.

(2) The value of the ringing current on the line.

(3) The capacity of the line in microfarads.

A sensitive bridge is also built into the first test desk and can be connected to the lines by a special low resistance circuit.

As no provision was made for testing transmission level, the standard 15, 25 and 50 db pads have been provided. The standard service tones are wired to the test desk in order that they may be explained to subscribers where difficulty has been experienced in their recognition. One point about the test desk which is not in line with the other modern practices in the equipment is that the test lines and test circuit are connected by cords and plugs. In connection with the testing of subscribers' lines, the circuitry does not permit the line to be cut through to dial tone whilst held on the test train. All other test facilities such as trunks to the M.D.F., Hospital Circuits, and test and plug up circuits, are in accordance with normal Australian practice.

EQUIPMENT AND PRACTICES

General Construction

The basic construction unit is a metal framework carrying the switching equipment. This may be a multiselector or a group of relay sets. The frames are 3 or 4 feet wide and 15 inches high. A typical one is shown in Fig. 14. The switching equipment is delivered in the form of fully equipped shop-tested frames, complete with cable forms. A group of frames installed on vertical rack members constitutes a rack. The racks are approximately 12 feet high and are usually equipped with 7 frames. At Kew there are 7 racks per suite. The suites face each other as in step-by-step equipment, the spacing being 3 feet 9 inches.

As shown in Fig. 15, all frames carry at each end, connection blocks comprising an insulated box containing square bronze wire tags which extend to the front and rear of the frame. The factory wiring is connected at the rear whilst the installation cables are connected at the front. Cabling between racks and suites is via cable runways over the top of the wiring aisles. Cable runs down the racks are protected by the rack members and a sheet metal cover which is in alignment with the metal covers of the equipment frames, and held in position by magnets. Apart from providing a neat and pleasing finish to the exchange, these covers provide protection for the equipment as well as forming comparatively small dust-proof enclosures which also reduce the risk in case of fire. The covers are shown in Fig. 16.

It is interesting to note that the interconnecting cables are not laced and formed, as is the practice with step-by-step equipment. This, coupled with the advantages of using solderless wrapped

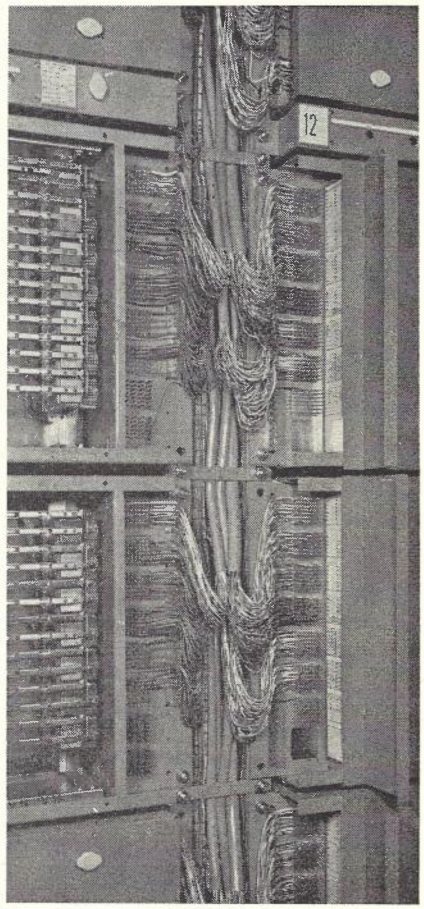

Fig. 15.—Interconnecting Cables Terminated on the Selector Frame.

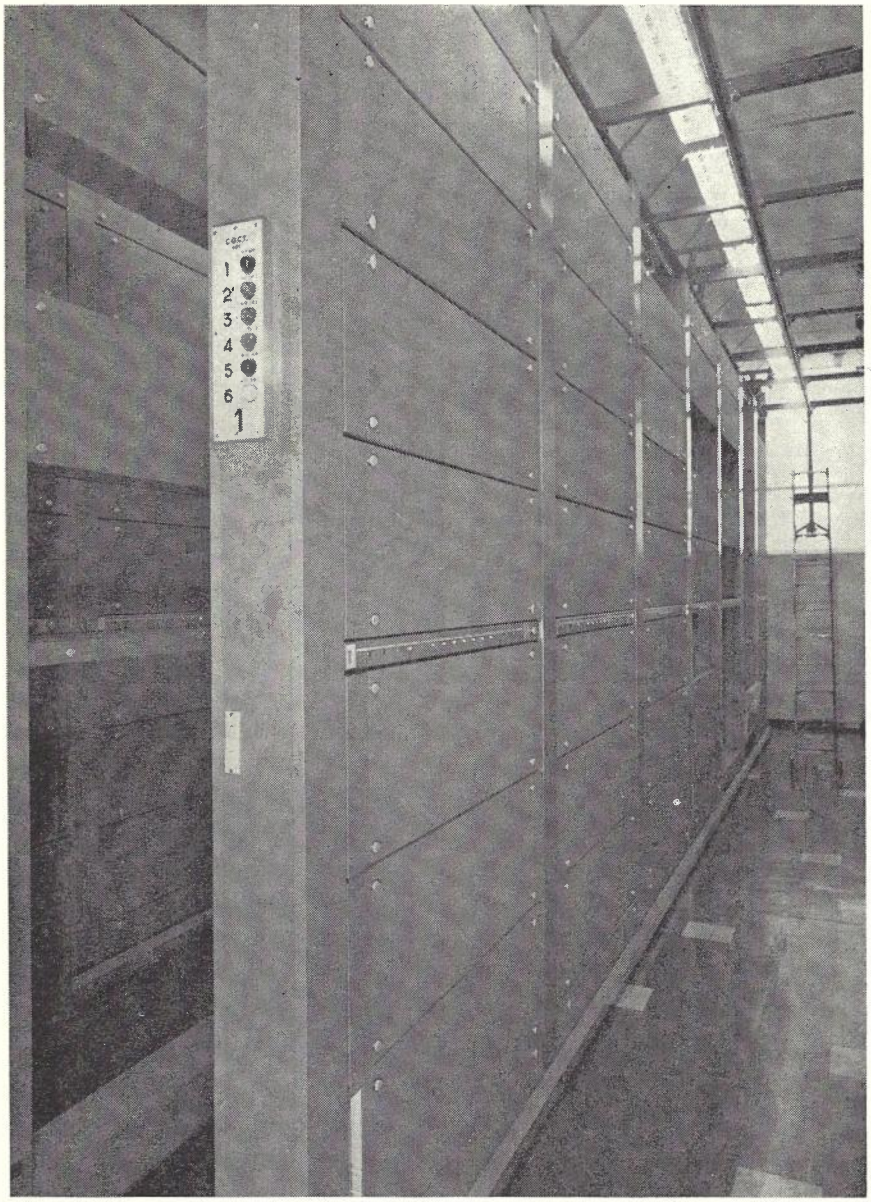

Fig. 16.—Pentaconta Line Unit showing the Rack Layout.

connections, enables the installation time to be reduced.

Solderless Wrapped Connections

Solderless wrapped connections are used at the factory during manufacture, and during the installation of the equipment. Soldered joints are used only in the strapping of the horizontal multiples. The advantages claimed for solderless wrapped connections are:

(1) The elimination of dry joints.
(2) The elimination of solder splashes.
(3) Absence of damage caused by heat.
(4) Absence of damage by gases formed during soldering.
(5) Uniform quality of connection independent of skill.
(6) Economy in time and manpower.

Rack Layout

When a distributing frame is associated with a rack it is mounted at the top of the rack, an example being the jumpering field between the marker leads and line relays of a line unit. The supervision panel is mounted in the centre of the rack whilst the power feed and associated fuses are at the bottom of each rack. (These can be seen in Fig 16.)

Relays

The crossbar system depends mainly on the reliability of the relays to ensure its correct functioning. In the Pentaconta Exchange the following types of relays are used:

(1) Relays with flat coils.
(2) Relays with round coils.
(3) Magnetic counters.
(4) Quintuple relays.
(5) High speed relays.

Flat coil relays shown in Fig. 17 are used for simple go or no-go functions, and control a single spring pile which has up to 33 springs in it. The flat shape of the coil enables a greater number of relays to be mounted in a given space. Where it is required that the relay should control 2 or 3 spring piles, or have other circuit requirements such as high inductance, limited power consumption, or special operate or release timing, a round coil relay is used. The components of the relays are similar except for the coil and the armature. On these relays the fixed and movable springsets are located in independent plastic combs. The comb supporting the movable springs is operated by an arm on the armature. The springs which have twin gold-silver alloy contacts welded to them are mounted straight and without tension, the restoring tension being supplied by an easily adusted auxiliary spring which is mounted over the spring pile. Where X action springs are required they are specially mounted in such a position that the comb containing the moving springs is operated via them. The residual air gap is obtained by welding a non-magnetic plate to the armature. Round coils dissipate 7 watts and flat coils 3.8 watts.

Magnetic counters, shown in Fig. 18, are used to distribute the traffic over the available registers and to provide access to the marker in a cyclic order from various calling frames. The magnetic counter has 10 armatures, each

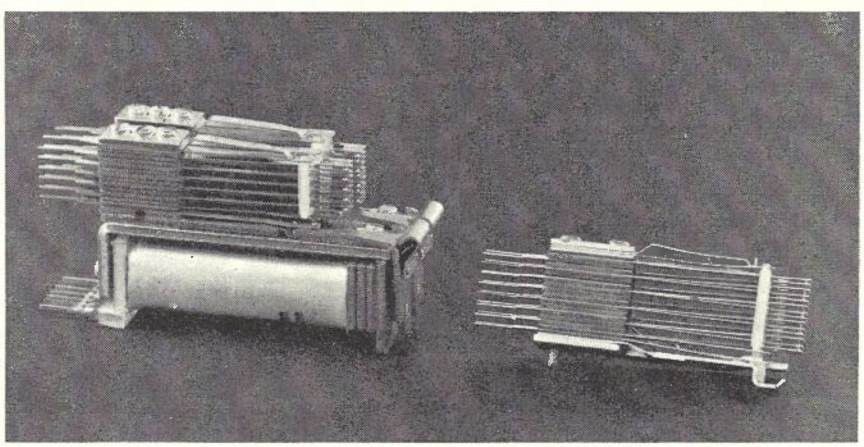

Fig. 17.—General Purpose Pentaconta Relay with Flat Coils and "X"-action Spring Set.

of which can assume one of 3 positions, released, ready and operated. The release position of the first armature is the ready position. On receipt of the first pulse the 1st armature operates and holds. The next armature automatically assumes the ready position and will operate on the next pulse. After all armatures have operated they are simultaneously restored to their rest position by the application of a demagnetizing current. These relays require special static and dynamic adjustment.

Quintuple relays, shown in Fig. 19, are used for simple functions where a single contact is sufficient. The quintuple relay consists of 5 miniature relays mounted on a frame. The space requirement is so small that 2 quintuple relays mount in the same space and on the same base as a round Pentaconta relay. They are used for such functions as digit storing in registers and as memory relays for the test robot. These relays require 110-170 milli-watts to operate, and as they have low inertia, the operate time is about 5 milliseconds and the release time about 2 milliseconds.

The impulses from the subscriber's dial are received by a high speed relay of the type which is also shown in Fig. 19. It has 2 windings of 240 ohms. This relay will respond to a very wide range of impulse conditions but as this system releases the register as soon as possible, the limiting factor is the outgoing junctor which is critical to impulse speed.

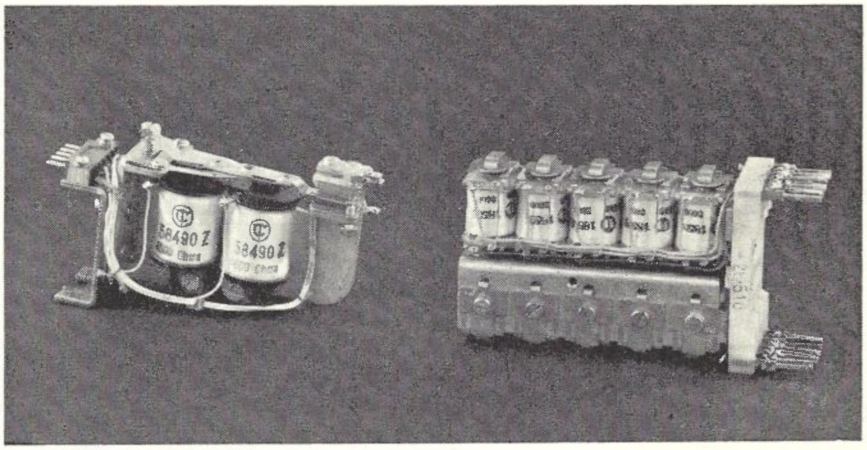

Fig. 19.—High-Speed Relay (left) and Quintuple Relay (right).

Exchange Layout

It will be noticed from the exchange floor plan, Fig. 20, that the switching equipment is installed in a separate room, and the test desk, M.D.F. and maintenance equipment in a second area. By providing such equipment as the maintenance robot, observation equipment and traffic recording equipment in this second area, the operation of the exchange can be fully supervised without undue staff movements in the equipment room. The power equipment and subscribers' meters are also installed in this area.

Power Supply

The equipment is designed to operate satisfactorily within a voltage range of 44-56V. The equipment consumes more power than the step-by-step equipment which it replaced. The maximum discharge for the replaced temporary exchange which was trombone trunked to Hawthorn (main) was 110 amps., whilst readings of 200 amps. have been recorded since cutover with the same number of subscribers. As the exchange would be "off the air" should the power equipment fail, a duplicate D.C. operated emergency supply is installed. Apart from the 52V negative supply, a 48V positive battery supply is also required for test purposes, the current drain being estimated at 2 amps per 10,000 lines. An 80V 50 c/s A.C. supply is required for the discrimination of subscriber and junction categories. From this supply a 13V A.C. feed is rectified to 10V D.C. for use in subscriber identification equipment. Metering is 50V negative battery.

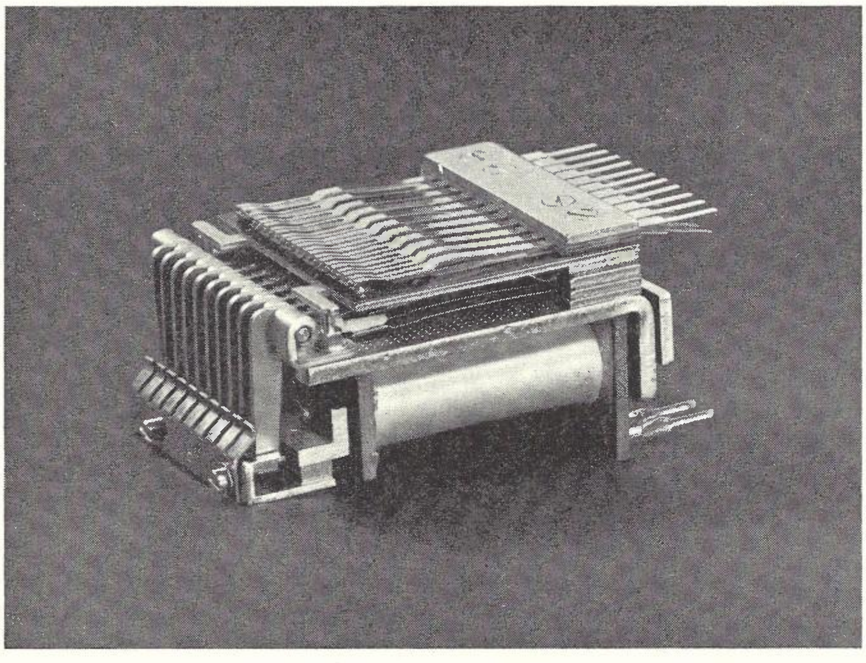

Fig. 18.—Magnetic Counter.

MAINTENANCE PROCEDURES

The Maintenance Robot

The aim of the Pentaconta system is to reduce maintenance costs to an absolute minimum, yet at the same time ensure that the plant is functioning satisfactorily and providing a high and constant grade of service. To achieve this aim the usual system of routine testing, which, from our experience in step-by-step systems, is far from satisfactory, has been abandoned in favour of the maintenance robot which constantly supervises the operation of the plant under service conditions and enables faults to be detected as they occur, with the minimum of staff effort. The robot can be switched on as required.

Whilst the maintenance robot is in operation, any fault condition or incident occurring in the selection will be indicated on a punched card (see Fig. 21) issued from the perforator associated with it. The two types of selection incidents encountered are (i) failure of common equipment which will be indicated by a large number of cards all indicating that the same unit is defective, and (ii) the incident that shows itself by the rare appearance of cards of the same family, which, if repeated over a period of time, will permit detection.

In order to locate intermittent faults the punch cards are filed and the information recorded and analysed on various forms on a monthly and yearly basis. They are filed according to the stage of the call when the incident occurred, and the active unit associated with the calling of the maintenance robot.

Traffic Observation

As the maintenance robot will not indicate the distribution of traffic

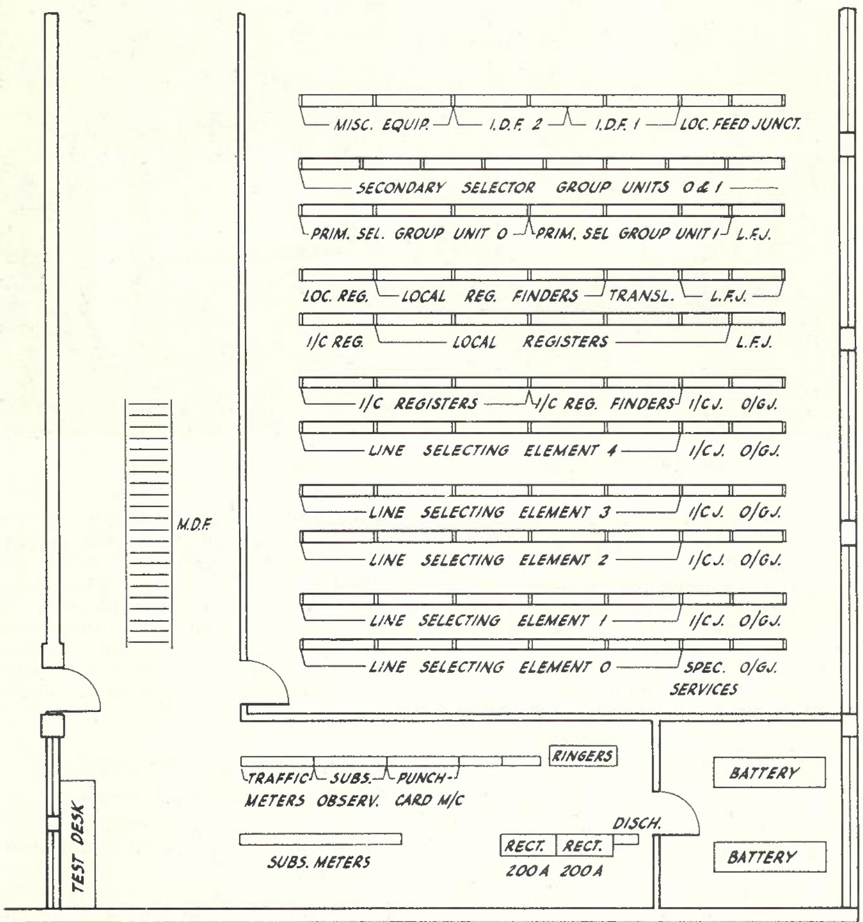

Fig. 20.—Kew Exchange—Layout of Equipment.

within the exchange, ample facilities are provided by means of lamp displays, occupation meters, congestion meters and recording ammeters, to analyse the traffic in any section of the switching equipment. This equipment was shown in Fig. 12.

The lamp display indicates the occupation of all common items of switching equipment in the exchange. The failure of a particular lamp to light in turn could mean that the availability had been removed from that equipment, whilst a lamp glowing for an excessive period of time could also indicate a fault condition. A button is provided to allow the indicating lamps to be switched off when not required.

The traffic and congestion meters are divided into 2 groups as discussed previously under Special Facilities. Recording ammeters are used to balance traffic between terminal selectors in the 1,000 line groups, and to verify readings obtained on the traffic meters. Traffic meters are merely an indication of the number of seizures and not necessarily the amount of traffic carried by the particular equipment.

By recording and analysing the results of the monthly and quarterly readings, it is also possible to detect fault conditions which may not be noticed by the maintenance robot, as well as to control the traffic distribution to cater for changes in subscribers' calling habits.

Service Quality Tests

Call robots, commonly known as traffic route testers (T.R.Ts.), are used to determine the quality of service for a given sample number of calls. These calls are programmed to call through the exchange and also on outgoing junction routes. Special test numbers are allocated in each 1,000 line unit to enable all pilot relays of terminal selectors to be tested. The results of these test calls are recorded and analysed and all faults recorded in the same manner as the results of the maintenance robot. Fig. 22 shows a portable T.R.T.

Faults Reported by Subscribers, and from Distant Exchanges

The fourth main service indicator used to control the maintenance effort in the exchange is the analysing of faults reported from without the exchange, including C.A.R.G.O. (Complaints Analysing, Recording and Graphing Organisation).

Mechanical Inspection — Lubrication and Routine Tests

Another aspect of the maintenance required is the periodical mechanical inspection of the multiselectors and relays. The mechanical inspection of multiswitches should be combined with the lubrication routine. The manufacturer recommends that, after the exchange has been in operation for 3 months, all switches and relays be inspected and relubricated, as deposits usually form under armatures, etc., due to wearing in of the mechanical parts. From then on the inspection is to be performed each year for common control switches and every 2 years for other switches. As far as relays are concerned, they are to be inspected, and contacts cleaned with a small piece of chamois leather on a piece of bakelite, as follows:

Translators and connecting relays — yearly.

Couplers and markers — 2-yearly.

Other circuits — 5-yearly.

As every function of the equipment is not tested by the maintenance robot or T.R.T., further test sets are provided to thoroughly check the local, incoming and outgoing feed junctors. These tests are proposed on a 6-monthly basis. (A test set is built into the translators in order to test their correct operation.) The remaining tests to be performed

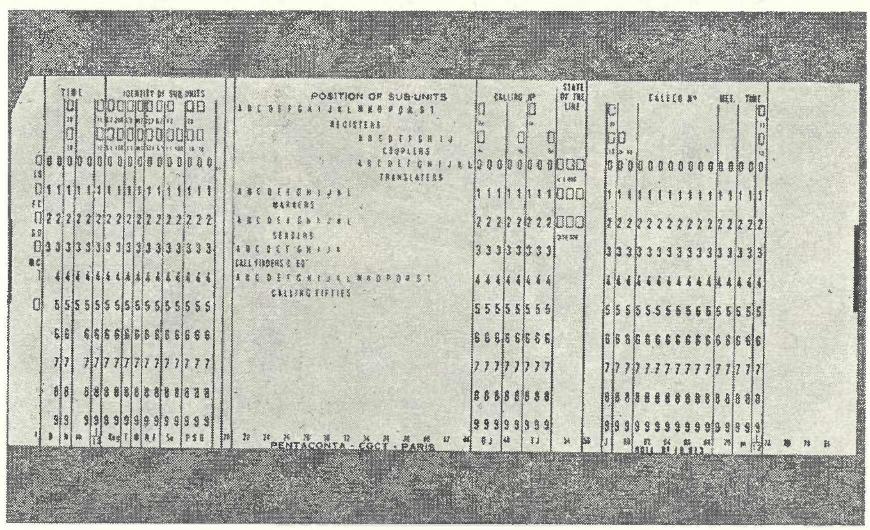

Fig. 21.—Card Used with the Maintenance Robot.

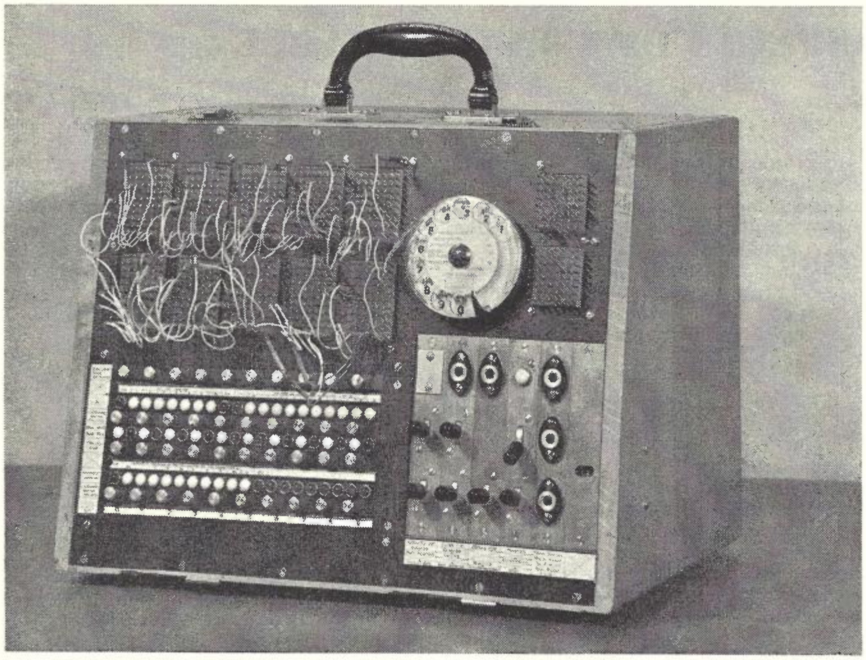

Fig. 22.—The Pentaconta Portable Traffic Route Tester.

are also on a $\frac{1}{2}$-yearly basis and are listed as follows:

(1) Testing of all impulse generators and relays.

(2) Testing the distribution of the cams and cadences and the operation of the automatic changeover in event of a fault.

(3) Testing of the temporizations which call in the maintenance robot.

(4) Testing of all exchange alarms.

It will be noted that special emphasis is placed on recording and analysing the results obtained from all the service indicators and tests carried out, in order that any defect in the equipment design or circuitry may be detected. It will also serve to indicate any need to vary the frequency of the routines required. The routine tests are being performed more frequently in the initial stages of the exchange operation.

ACCEPTANCE TESTING AND CUTOVER

The exchange was formally handed over to the Department's Exchange Installation Section on 18th July, 1962, and the cutover date set for Sunday, the 15th September. During the intervening period, the equipment was subjected to a very thorough examination and test. Whilst it was not possible to check every crosspoint, the program was designed to completely test the trunking and ensure that the common control equipment performed satisfactorily with each item of switching equipment. The registers were tested for impulsing, outgoing junctions adjusted and tested, local feed junctors tested, as well as the alarms and other supervisory equipment. Prior to cutover, each subscriber and each junction had been let in and tested with the new equipment. The cutover of all but a few common choice junctions took place in the early hours of the Sunday morning. The subscribers were then let into the new equipment with no number change. It must be noted, here, that during this 8-week period of testing, very few equipment faults were detected and, in this regard, credit is due to the thorough tests carried out by the installing engineers prior to the exchange being handed over to the Department. In fact, from a maintenance viewpoint, the cutover was very successful. It was decided to staff the exchange until 11 p.m. for the first week until the equipment settled in, but this precaution was found to be unnecessary. The equipment has performed satisfactorily since the cutover, and the initial readings taken on the traffic equipment indicate that the junctions and equipment provided are in accordance with the traffic requirements.

Since cutover, the grade of service has been sampled using the local Pentaconta T.R.T. for calls within the exchange and a standard T.R.T. for calls on junction routes. From the figures to November, 1962, the grade of service on local calls has been 0.1% and from the standard T.R.T. testing over 25 junctions routes, a grade of service of 2.0% has been recorded. A further breakdown of the faults on the junction routes indicates that, as far as Kew Pentaconta equipment is concerned, the grade of service is 0.1% on outgoing calls also.

CONCLUSION

From a service engineer's viewpoint, the facilities provided for the supervision of the switching equipment would be the most advanced yet to be installed in Australia. They are designed to obtain the maximum performance from the switching equipment with the minimum of staff effort. The system itself is very flexible. Any subscriber can be transferred to any 50 line group within a 1,000 line unit. Any line can be used for P.B.X. working, and a change in call sign merely requires a change of strapping in the translators. The principle of "conditional selection" combined with "entraide" provides for full availability in each switching stage. Automatic re-routing and automatic second attempt to complete a call in cases of an incident in selection, combined with the fact that the traffic distributors and changeover circuits would cause any second attempt to make a call to be re-routed via different equipment, all combine to offer a very high grade of service to the public. In this system particular attention has been paid to the quality of transmission. The equipment itself presents a pleasing appearance and the protective covers provide further protection against dust and fire risk. The switching equipment is mounted in a separate room and the maintenance staff have been supplied with special dust coats and slippers to further reduce the dust problem which could detract from the reliability of the switching system. In connection with information on the system full circuit descriptions, cabling data, and relay data have been supplied. The circuits are of the detached contact type which are familiar to our staff. There are, however, two aspects which still require attention, and they are the fusing of feed junctors and the provision of some indication to the main exchange should an item of common equipment fail whilst the exchange is unattended. These matters are in hand.

The staff of the old Kew step-by-step exchange consisted of one Supervising Technician Grade 2, one Senior Technician, and 4 Technicians (including one Substation Maintenance Technician and two Technicians-in-Training). Since cutover this staff has been reduced by 2 Technicians and the substation maintenance duties are rostered on a monthly basis in order to ensure that all members of the staff receive training in the new equipment.

ACKNOWLEDGMENT

In conclusion the author would like to express his thanks for the co-operation of members of the Installation Section whilst the installation was in progress, and to Mr. Paul Pahaud, of C.G.C.T., for advice in the preparation of this article.

EXTERNAL PLANT ASPECTS OF COAXIAL CABLE MAINTENANCE

*L. R. STEPHENS**

INTRODUCTION

Broadband multi-channel telecommunication systems are already well established in Australia and a rapid expansion in their use is taking place. As each installation is completed the very important task of ensuring uninterrupted service on the channels provided falls on the internal and external plant maintenance staffs. This article deals with maintenance of coaxial cables from the external plant aspect and refers particularly to practices used on the Sydney-Melbourne Coaxial Cable (1). It describes the measures adopted to avoid interruptions to cables in the first place, and then covers the methods used to make urgent repairs when a fault has occurred.

PREVENTATIVE MAINTENANCE

General

In the case of underground cables the term preventative maintenance has a different meaning to that which was common in past years for internal plant, where it implied repetition work associated with restoration of standards prior to equipment failures. Since underground cable is passive there is no deterioration due to use and, because of its physical construction and location, deterioration due to aging is insignificant. On the other hand cable can be influenced by external situations which may cause deterioration or unscheduled interruptions, and because of the very large channel capacity of a coaxial cable, it is essential to keep the incidence of failure to a minimum by the implementation of preventative measures. Apart from the prevention of actual damage to the cable, these measures can be taken to include means of detecting deterioration at a stage early enough to prevent interruption to the circuits carried by the cable.

Disturbance of Buried Cable

The four feet cover provided by the cable laying team during installation must be maintained to ensure security from disturbance by man-made causes. Soil erosion (see Fig. 1), which is primarily man-made, is a hazard which requires careful control and constant inspection to ensure cable cover is not reduced. Erosion affects the cable, trench, joint manholes and their surroundings and its control is an integral part of cable maintenance. It is also the concern of the maintenance staff where it is affecting access tracks, leading from roads maintained by other authorities, to the cable trench (see Fig. 2).

The reduction of cover over the cable by the activities of property owners and of statutory authorities who may have a genuine need to excavate soil across the cable trench or from its surrounds, may require either lowering the cable or re-locating a section to obtain adequate security. This work could require the same amount of effort as the original installation in that vicinity. The security of the cable where it is buried through open country is also endangered soon after installation by soil movement of either an improperly back-filled trench or soil erosion attributable to the installation activities. Early action is required to remove these hazards.

Electrolysis

The life of an underground cable can be seriously shortened by electrolysis. The principles involved and the practices adopted to prevent cathodic corrosion have been covered elsewhere (see for example Reference 2), and apply to all high priority cables. The necessary bonds once installed become part of the system of cable safeguards and their maintenance is in effect maintenance of the cable itself.

Gas Pressure Alarm System

A considerable measure of protection by preventing the ingress of moisture through a sheath fault is afforded by maintaining pressure within the sheath greater than that of the outside air. The system used on the Sydney-Melbourne cable (3) is automatic in its electrical operation, but requires attention from the external plant maintenance staff in respect to the replacement of air supply cylinders and maintenance of dry air supply equipment. Where the air supply is from storage cylinders the maintenance staff keeps a weekly graphical record of the supply pressure, and a change in the rate of fall in pressure will indicate an air leak which may be located and removed before the pressure in the cable falls to the value where the automatic alarm system will operate.

Continuity Testing and Insulation Resistance

Spare tubes in a coaxial cable provide a rapid means of restoring service where the type of fault is such that only working tubes are damaged. To ensure that the spare tubes are always available for use, their primary electrical characteristics are regularly checked. Each spare tube is normally connected through at minor repeaters with a coaxial patch cord and a pair of tubes are looped together by a similar cord at the next major repeater. The loop resistance of both inner and outer conductors can then be read with a bridge megger at the testing major repeater station and the results compared daily. Variations in the readings obtained will indicate not only open circuits but high resistance joints anywhere in the major repeater section. Likewise the insulation between inner and outer conductors is tested with 2,000 volts D.C. which will reveal short circuits and will cause high voltage breakdown of the tube if incipient fault conditions are present such as a metal sliver which is almost touching the centre conductor, or dust on the face of a terminating socket at a repeater. This testing is carried out by Technical

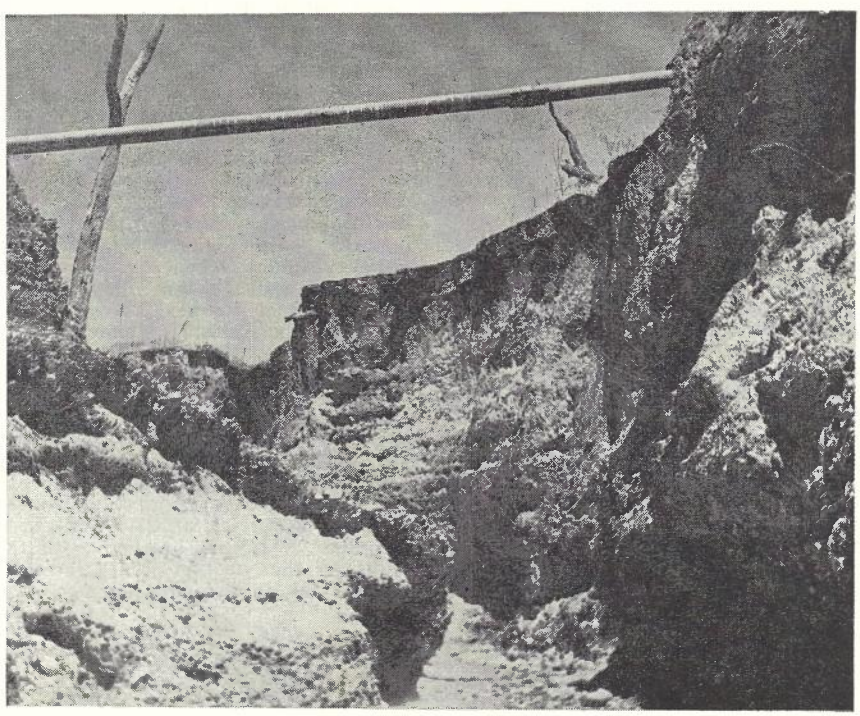

Fig. 1.—Cable Crossing a Soil Erosion Gully in Galvanised Iron Pipe.

* See Page 81

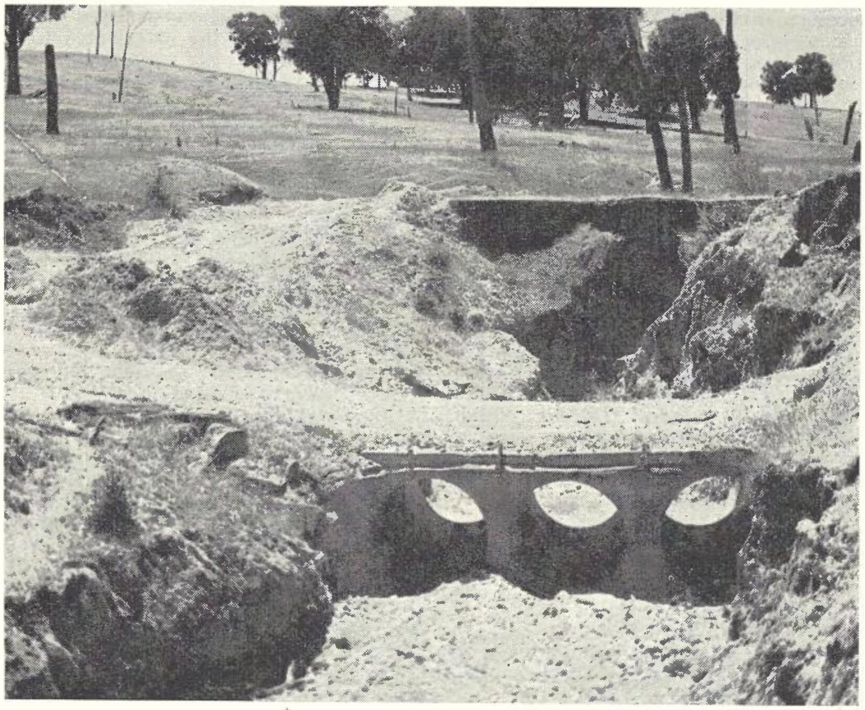

Fig. 2.—Patrol Access Track Crossing Soil Erosion Gully. Cable is buried through this crossing.

staff and any faults detected are attended to by the external plant staff at times of light traffic on the system when power can be removed from the cable.

The occurrence of metal slivers is peculiar to coaxial cables having air dielectric. During the manufacturing process of forming the cylindrical outer conductor from flat strip, thin slivers may lift from the edge of the metal and those enclosed within the cylinder which do not immediately contact the inner conductor may remain undetected by the manufacturers' tests. During subsequent handling of the cable and installation there is always a possibility that a sliver may be disturbed and cause a short circuit. The majority of such faults will become evident by the time final testing of the completed installation is carried out, but even after these have been cleared the possibility of further short circuits from this cause exists for some time. The removal of a metal sliver is accomplished electrically without opening the cable at the location of the fault and is covered subsequently.

MAINTENANCE PATROLS

General

All of the preventative maintenance activities with the exception of the insulation and continuity testing are carried out by Lines staff. In order to ensure the necessary amount of continuous attention, a number of two-man patrols, each with its own transport, operate exclusively on coaxial cable maintenance and are not required to perform other types of line work. Both members of each patrol are required to be skilled coaxial cable jointers who preferably were engaged on the installation of the cable and have the ability to appreciate the various hazards which may endanger the cable. As the patrols have considerable contact with the public and with other authorities, they have a major responsibility to ensure that the presence of the cable is not forgotten nor its importance disregarded. In this respect, experience has shown that the provision of cable markers and warning signs (see Figs. 3 and 4) is not sufficient in itself to prevent damage; although these signs play an important part they must be supplemented by supervision of the route and public relations activity.

On the Sydney-Melbourne route, 11 patrols operate over the 600 mile route, so that each on the average is responsible for about 55 miles of route. In practice, patrols cover from 20 to 40 miles of route on each side of their head stations.

Patrol Duties

Each patrol operates continuously during normal working hours, five days per week, and is recalled to duty for emergencies at other times. It moves continuously along its allotted section of the route and the sections are of such length that they can be covered twice each week, thus enabling all changes in condition of the cable trench and its surroundings to be observed very soon after they occur. Additional inspections of duct routes in built-up areas are made by Area Line Foreman and Line Inspectors during their normal movements on other work. A close liaison is maintained with local authorities and private property owners along the route by frequent visits, and where these bodies are proposing to carry out any activity in the vicinity of the cable, the patrol enters into discussions with respect to the safety of the cable and where necessary makes arrangements to be present when work is carried out. In addition a constant lookout is kept for tradesmen building or excavating in the vicinity of the cable, as often such workmen are strangers in an area and are not aware of the cable's location. By such personal contact many proposed works are revealed in the earliest of planning stages and ample time is then available for discussions to take place between the Department's Engineers and Engineers or Architects of the other body. The situations which could lead to damage in the immediate future are usually obvious, for example such things as earth excavation, active soil erosion and reconstruction of manholes and ducts, but it is activities which initially do not concern the cable but have far-reaching consequences which require early recognition and appraisal of the ultimate conclusion. In this category come land subdivisions for both rural and housing settlements, with accompanying development of new roads or deviations.

The regular traversing of the route enables cable marker posts, identifying signs, access gates and tracks to be kept in good order and remedial action to be taken before the value of the particular item is lost. The aim at all times is to detect deterioration at an early stage when the two-man patrol can effect repairs rather than allow the extent of the repair work to grow to such a size that a larger line party is required to restore the original conditions. This applies particularly to erosion of access tracks which can, by frequent minor attention, be kept in serviceable condition in preference to being allowed to deteriorate to an impassable state when several days' work would be required by a large party with mechanical aids to replace surfaces washed away.

Much of the effort put into the preparation of accurate route locality plans will be lost if these are not kept up to date. The patrol advises the changes made in the field in order that the plans will be amended as necessary. Locally

Fig. 3.—Typical Cable Marker Post Erected in Cross-country Section.

Fig. 4. — Warning Sign on Access Gateway. Buried cable passes through such gates erected on property boundaries.

held copies of plans are marked by the patrol with all potential hazards such as water mains crossing the cable and electric light poles and rural fence posts close alongside the route so that when the patrol observes a tradesman working on such items, it will be in a position to advise with confidence when extreme caution is necessary and erect temporary warning markers defining the limits to which a tradesman may work without supervision of the patrol. These temporary warning signs are most valuable when the patrol can see that work already commenced may endanger the cable but there are no workmen actually on the job at the time. The warning signs are then erected and the patrol seeks out the persons concerned, knowing that if the workmen should resume before they can be contacted, they will not be able to disregard the presence of the cable.

Whilst on the patrol of the route regular contact has to be made with a nominated major repeater station at least every two hours, so that in the event of an emergency elsewhere the patrol can be directed to the trouble spot. Thus from each minor repeater the patrol reports its presence by use of the field order wire which is terminated on a magneto telephone in the entrance lobby of the building. As all the field order wire telephones share one line, they are not left across the line as signalling and transmission would be deteriorated by the parallel connections. They are wired through a switch operated by the opening of the outer door of the building so that the patrol having opened this door can call or be called by the major repeater. The inner door fitted with a "door open" alarm extended to the major repeater does not have to be opened for the patrol to report its presence, but the minor repeaters on the Sydney-Melbourne coaxial cable have the gas pressure alarm equipment in the main room of the building and to check air flows or cylinder air pressures the patrol must enter this section. A modification to this building design is being made on later routes to separate the internal and external apparatus so that the cable patrol would not enter the equipment room but have all the apparatus it maintains in the entrance foyer.

The patrol records weekly on a graph at each minor repeater station the air pressure in the cylinder supply of the gas pressure alarm system. This record indicates when a fresh cylinder is required and also when the amount of air flowing through the cable varies from normal. When the air flow increases in a minor repeater section the patrol proceeds to localise the leak and carry out the necessary repairs. Apart from major leaks caused by physical damage of the cable which may cause loss of air pressure and subsequent operation of the gas alarm supervisory equipment, minor leaks will be detected initially by the increase of air usage from the supply cylinder.

Annually the patrol assists a Technical officer in checking the bond currents and voltages of the cathodic protection installation, and at all other times keeps a visual check on the condition of the bonds and their connection to the cable or sacrificial anodes.

Equipment

The transport provided for each patrol must be capable of conveying it to any point on the cable route in all weather conditions, and must be fully equipped with the necessary tools to enable it to carry out all major repairs without having to return to the depot.

Patrols operating in the metropolitan areas are able to traverse the cable route in standard types of vehicles whilst some country patrols require 4-wheel drive vehicles to cover major portions of the route. Typical of country patrol vehicles are 6-cylinder 4-wheel drive panel vans equipped with a front mounted diaphragm sludge pump and the van interiors fitted with compartments to house tools, maintenance parts, spare dry air cylinder and a work bench (Fig. 5). Such a vehicle can be instantly diverted from anywhere in the patrol area to a fault location and all requirements for restoration will be on hand. The exceptions to this will occur in times of flood when the patrol may have to return to a depot for a flood boat, or after temporary repairs have been completed to proceed to the nearest Line Depot holding a spare 500 yard drum of cable if the cable damage is of such extent that a new length of cable is required. Flood boats and spare drums of cable are held at strategic points on the coaxial route and may as the occasion arises be utilised by adjoining patrols.

A hand-operated spotlight on the vehicle enables cross-country travel to be undertaken at night with safety and also provides initial light at a worksite whilst floodlights are being set up. The sludge pump, operated from the front power take off, enables manholes or buried joint holes to be quickly drained in wet weather whilst the fitted van interior enables all tools to be kept secure and in good condition as well as providing clean dry storage for jointing components. Other patrol equipment includes the normal jointing kit and essential tools used by other line staff engaged on cable work.

REMEDIAL MAINTENANCE

General

This section deals with faults which cause interruption to one or more systems working on coaxial tubes within the cable. Such faults may be either confined to one particular point of the cable or spread over a length of cable and may or may not be visible, depending on the extent of the damage and its location.

Fig. 5.—Typical Country Patrol Vehicle with Front Mounted Sludge Pump.

Power Cut-off Procedure

It cannot be too strongly stressed that, before any work is commenced on a faulty cable, the power fed on the cable to minor repeaters must be removed and the safety of staff working on the fault ensured against accidental re-connection of power. When power is being disconnected prior to fault attention being undertaken by external plant staff, the patrol leader must witness the operation and ensure that the cable safe lamp (4) is alight for the section he is about to work in. This lamp will only light when the inner conductors of all working coaxial tubes in the section have been earthed by operation of a switch in the power feed equipment bay. The patrol leader will then check that the doors of this bay are locked and place the key in the specially provided security box which he must then lock with his own padlock and carry its key with him personally until all work on the fault is completed and all external plant staff are clear of the cable. He may then return to the repeater where the cable was rendered safe and unlock his padlock, allowing the power feed bay to be re-opened and power restored to the cable.

Fault Location

The primary fault location will be advised by the Supervising Technician at the major repeater station having the alarm supervisory set for the section. This equipment indicates which section between minor repeaters has failed to pass the pilot signal associated with each working system on the cable. A further location may be available to the technical staff by calculation of the power being drawn by minor repeaters which will be above normal for short circuit faults and below for open circuits.

Having initially determined the faulty section, the Supervising Technician will test the spare coaxial tubes in the cable for continuity and insulation resistance. Should these prove satisfactory, two Technicians are sent, one to each minor repeater on either side of the faulty section, where they will first check whether the fault is in the internal equipment or due to cable failure. If the fault is proved in the cable they will request the major repeater station to disconnect power from the faulty tubes and patch the spare tubes into the section between minor repeaters. When this is done the power may be restored and the system returned to traffic. Wherever possible patching between minor repeaters should be the first step of fault restoration as systems will be restored to traffic by this means more quickly than by any other means.

Whilst the Technicians are travelling to the minor repeaters, the nearest patrol is contacted and is instructed to proceed to the minor repeater nearest to the major repeater station which feeds power for the section and stand by. If a patch has been made by the Technicians the cable will still be carrying power for working systems and therefore not safe for the patrol to commence work.

After the systems have been restored by patching, a closer indication of the position of the fault than given by the primary indicator can be obtained with a pulse echo tester used either from the major repeater station if the faulty section is adjacent, or from a minor repeater at one end of the faulty section if it is remote. This instrument will give sufficient accuracy for the patrol to carry out a visual inspection of the locality, looking for signs of ground disturbance if the cable is buried or disturbance of the cable itself where it is in a manhole or building and is exposed. Where the fault is due to mechanical damage the chances of the patrol locating the exact spot are good, especially if the patrol has regularly inspected the locality prior to the fault and is observant of physical changes since the last inspection. However, before the patrol does any work at the site of the damage, the cable must be made safe.

Where visual inspection fails to indicate the location, further electrical testing is necessary and may be carried out, either by a more accurate pulse echo tester than is normally held at each major repeater station, or with a Wheatstone Bridge using either one or a combination of the 3 wire, Varley Loop or Murray Tests. The pulse echo test may be carried out using only the faulty tube or tubes, but bridge testing requires at least one good wire through the faulty section in the case of Varley and Murray tests and two good wires in the case of the 3 wire test.

If all tubes and paper pairs in the cable are faulty and no good wire exists, the damage is most likely to have been severe and caused by an external source, hence its location will most likely be obtained in the patrol's visual inspection, whilst if only one tube is affected the cause could be a metal sliver which may possibly be removed without having to locate its position. Slivers are removed by use of a Sliver Burner which applies a high voltage, high current condensor discharge between inner and outer conductors of the faulty tube. The heat generated in the sliver by the high current passing fuses the fine sliver of metal to a small globule and the tube is once more serviceable.

Where a single tube fault cannot be cleared by this means the other good wires of the cable are available for whichever bridge test is required to make an accurate location of the fault. Having obtained an accurate location of a fault in a cable length which is still carrying systems either by patches onto spare tubes or in a length where a spare tube is faulty, that section of the cable must be rendered safe before field work is commenced. To achieve this whilst still retaining the systems, the power feed to the minor repeaters must be stopped at the minor repeater on the power feeding side of the faulty section, and fed again from the minor repeater on the distant side of the fault. A dummy load equal to the load of the repeaters divorced from the main station power feed is connected at the former repeater and a mobile remote power feeding diesel alternator set connected at the latter repeater so that it will feed power to all minor repeaters beyond the fault (5).

Under these conditions the patrol is required to observe the cable safe lamps at both minor repeaters and lock the power feed bay keys at each repeater in the security boxes provided. This is necessary to prevent accidental power feeding on the section from the one end by re-connecting the main power feed or from the other by back feeding the remote power which can be done by switch operation for power synchronising when required.

Fault Clearance

When the cable section has been made safe the patrol can move to the locality of the fault and establish communication with the nearest major repeater station and the two adjacent minor repeaters. This is facilitated by provision of a specially allocated Field Order Wire pair in the cable and a portable magneto telephone. Access to this cable pair is provided at contactor joints so that it may be used without having to open the cable, and from the nearest of such points it can be extended by a temporary line to the work site. If such an access point is remote from the fault site, connection of the field order wire will not be made until the cable is exposed and the sheath opened to connect the portable telephone directly to the cable pair.

If there are signs of ground disturbance in the vicinity of the electrical location of the fault the cable is exposed at that point by removal of the covering soil or duct and, depending on the circumstances, assistance of a Line Party may be required for this work. However, where no disturbance is to be seen and the electrical location is the only indication of the position of the fault the cable should be exposed either side of the probable location. After opening at these points and installing temporary interruption cable to bridge the gap in cases where all tubes have failed, further location tests can be made. Due to the shorter length being tested a more accurate location will then be obtained. For ease of working and speedy restoration, these openings are preferably made at an adjacent joint as access to the tubes in a cable having outer paper pairs is difficult when a sheath opening only is made.

A fault which is caused by mechanical damage will generally be located by soil disturbance and the subsequent repair of the cable will depend on the extent of the damage. Restoration may be possible by opening the sheath and reforming the affected tubes with a reforming mandrel and clamp. The outer conductor is opened at the seam for sufficient length to insert the mandrel and then pressed back to its original cylindrical shape by the clamp. It is then re-opened carefully to extract the mandrel and finally reformed around the inner conductor spacers.

Where the damage extends over a few inches of the cable, a pieced joint is used and for these the patrol carry twelve-inch sections of tube which have had their ends prepared previously in the manner of a normal joint. These are jointed into the cable itself and enclosed in a standard joint sleeve and protection box.

In more severe cases where between one and four feet of cable is faulty a new section of cable four feet long will be cut in and both ends of this section will require a standard joint and protection box. Again this section of normal cable has prepared ends and is carried by the patrol for speedy insertion as required.

Damage which extends beyond four feet will have either been caused by a mechanical excavator travelling along the line of the cable, which is a hazard the patrol will be constantly keeping a look out for, or perhaps by lightning strike or other electrical discharge. In either case a number of faults could have occurred along a section and fault locations made from either side of the damage will indicate this fact and the section of cable would be considered for complete replacement.

Under these circumstances a temporary repair with interruption cable will be far more expeditious than jointing in short lengths as in the case of "spot" faults. Each patrol carries 500-foot lengths of single tube interruption cable with male and female connectors attached to either end. A pair of these would be used to bridge either a section such as would span an electrical location as mentioned earlier, or one including a long length of damaged or suspected damaged cable. By interconnecting 500-foot lengths which are carried on special drums, one patrol can cover a manhole length with two tubes, allowing for restoration of one system, and by calling on adjacent patrols for their interruption cable, further systems may be restored. In order to terminate either end of the interruption cable into the parent cable, a short length of one foot fitted with a male connector at either end is carried by the patrol. To protect the joint of the parent cable to the interruption cables it is enclosed in a single fold of self-adhering rubber sheet.

When the systems have been restored by this means further fault location can proceed followed by excavation and repair of "spot" damage, or in the extreme case the replacement of the entire length which has been bridged out by a new section of cable. Spare drums of cable for such needs are held at strategic points along the cable route and comply to rigid electrical specifications so that they may be inserted as a replacement length without causing impedance mismatching. These drums are kept in weatherproof storage sheds and the drums themselves treated to preserve the timber. The cable on the drums is kept under air pressure similar to the working cable, and every care must be taken to ensure that the cable will be fit for use and the drums fit for transportation to a fault even though they may have been held at a depot for some years.

CONCLUSION

Experience in dealing with faults in coaxial cable can only be obtained in two ways, firstly, in the field as the opportunity arises, or secondly, by simulating fault conditions on spare unfit lengths of cable which have been left over from installation projects. When a fault develops on a working cable the restoration must proceed in accordance with a predetermined sequence in order to achieve the minimum "out of service" time of communications and/or television channels. The patrols must carry out practice jointing of cable and insertion of interruption cable into parent cable at their depots to ensure maximum efficiency in all phases of their work at all times. Technical officers called upon to carry out fault locations in the field must likewise have regular practice with their testing equipment to ensure accurate fault locations and speedy operations. These officers also must make use of spare cable lengths and when spare tubes exist in working cables, artificial faults such as short and open circuits can be inserted at minor repeaters to be "located" by each of the various location methods available and so build up the confidence of the testing officer in his instruments and methods.

The staff organisation for fault attention extends from Divisional Engineer level for overall control, through the Engineer Class 2 controlling all field activity, the Engineer Class 1 controlling fault locations, tube patching and power feeding, to the Supervising Technician at the major repeater station, Senior Technicians at minor repeaters and Patrol leader and patrolman working on the cable itself. Additional labour in the field may also be required and involve an Area Line Foreman and his staff. With this number of officers involved, communication between work locations and supervisory levels is most important so that those concerned know at all times what is being done. The Field Order Wire between work site and repeaters, the Short Haul Order Wire between minor and major repeaters together with the Long Haul Order Wire between major repeater stations and the Line Control terminal are used to provide the necessary network.

A summary of the faults which have occurred in the New South Wales section of the Sydney-Melbourne Cable since it was placed in service is given in Table I.

REFERENCES

1. "The Sydney-Melbourne Cable Project"; Telecommunication Journal of Australia, Vol. 13, No. 3.
2. W. Dejko, "Principles and Practice of Cathodic Protection of Underground Cables"; P.M.G. Engineering Bulletin No. 33, External Plant.
3. Reference 1, page 205.
4. Reference 1, page 243.
5. Reference 1, page 265.

TABLE 1. Faults Located in Sydney-Melbourne Cable, N.S.W. Section, 1/11/61 to 10/12/62.

TYPE OF FAULT	ORIGINAL INDICATION	LOCATION METHOD	LOCATION	REPAIR ACTION
Sheath Damage 8	Gas Pressure Alarm 5	Inspection by Patrol 11	Buried cable 11	Sheath and/or sleeve 6
Cable Damage 5	D.C. Tests by Technicians 11	Pulse Echo Test 5	Minor repeater termination 9	Tubes reformed 7
Open circuit, short circuit and earthed tubes 9	Power feed Voltage and Current 3	D.C. Bridge Test 2	Field manhole 4	Joint remade 7
Faulty Manufactured Cable 2	Patrol report 5	Percussion Test 1		Additional Joint 1
		Patrol's initial report 5		Paper pairs pieced 1
				Minor repeater terminal socket 1
				No fault found 1

NEXT ISSUE

The next issue of the Journal (October 1963) will be a special issue which will appear at the same time as the meetings of C.C.I.T.T. Study Groups are being held in Melbourne. Because of its interest to overseas delegates as well as to Australian readers, the issue will be devoted to a general review of developments and practices in Australia in all fields of telecommunications. MAKE SURE YOU RECEIVE YOUR COPY.

TAREE TRANSIT EXCHANGE

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INTRODUCTION

This article describes some of the unusual features of the true four-wire transit exchange provided recently at Taree, the geographical and commercial centre of a wealthy dairying, agricultural and timber district on the central North Coast of New South Wales. It handles a comparatively large volume of through traffic which is increasing, and the provision of additional switching equipment to enable this traffic to be handled automatically and relieve the manual trunk switchboard was justified economically. As there was a very wide range of different types of signalling equipment in existence at Taree, standard transit techniques could not be used. A new design was therefore required to provide unrestricted interswitching of all types of signalling. The design work was undertaken by the New South Wales Country Installation Section, which also carried out the installation. The transit equipment uses Siemens Henley motor uniselector switches and provides all four-wire and pad switching facilities necessary to give the optimum transmission performance of the switched trunk circuits.

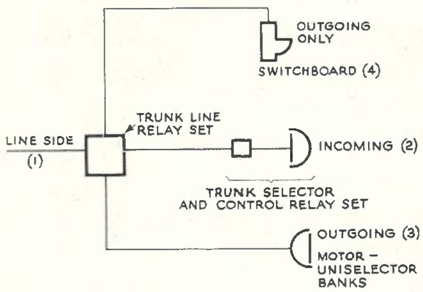

Fig. 1.—The Fundamental Accesses.

GENERAL FACILITIES PROVIDED

The transit equipment provides the following general facilities:

(a) "True four-wire" connection of switched four-wire circuits, including 2VF to 2VF circuits, with retention of the through transit facilities normally provided by Siemens Henley equipment.

(b) Free unrestricted interswitching of trunks with the following types of signalling:
- (i) Siemens 1VF.
- (ii) Siemens 2VF.
- (iii) "E and M" type signalling, including both "in-band" and "out-of-band" systems used on carrier and radio circuits.
- (iv) Simple D.C. "loop dial" over physical circuits.
- (v) Cailho "loop dial" over four-wire VF amplified junctions.

(c) Complete pad switching facilities when connections are made between four-wire trunks and two-wire trunks.

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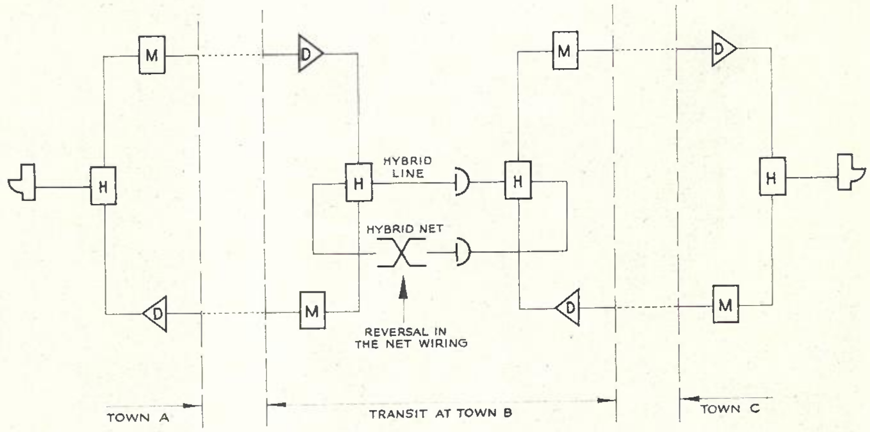

Fig. 2.—Tail Eating Connection.

TRUNK LINE RELAY SETS

In a transit scheme every trunk line has a trunk line relay set. This trunk line relay set can be considered to have a maximum of four fundamental "accesses", which are shown in Fig. 1. They are:

(1) The line side access to the "trunk" (physical, carrier channel or VF amplified pair).
(2) Incoming access to the transit through the associated "trunk selector" (selector and control relay set).
(3) Outgoing access from the transit through the banks of the trunk selectors.
(4) Manual access from the switchboards for outgoing calls.

Besides catering for the basic accesses, the trunk line relay set converts the type of signalling used on its trunk into a common form of signalling required for the transit equipment. As explained later, D.C. "loop disconnect" signalling with reversal supervision is the common form used at Taree.

TRUE FOUR-WIRE SWITCHING

The most interesting feature of Taree transit is the true four-wire switching using Siemens motor uniselectors as the switching device. So far in Australia, most transit switching schemes have used the "tail eating" method (for example the standard Siemens 2VF method), where the "hybrid lines" and "hybrid nets" are connected together. (See Fig. 2).

This method has two disadvantages:

(a) If the hybrid line and net path impedances are not equal, for example, because relay equipment connected across each path is not identical, or because different types and lengths of cabling are used in each path, there will be transmission from one four-wire path to the other, which can lead to instability of the switched circuit, or echo (see Reference 1).

(b) If the nets are not "poled" correctly (that is the reversal is not inserted), or if there is another accidental reversal in either the line or net path, there will be a very high loss through the connection.

In true four-wire switching, a direct connection is made between the respective modulator inputs (mods.) and demodulator amplifier outputs (demods.). Fig. 3 shows a connection between two trunks. It will be seen that with this type of switching, the stability of the

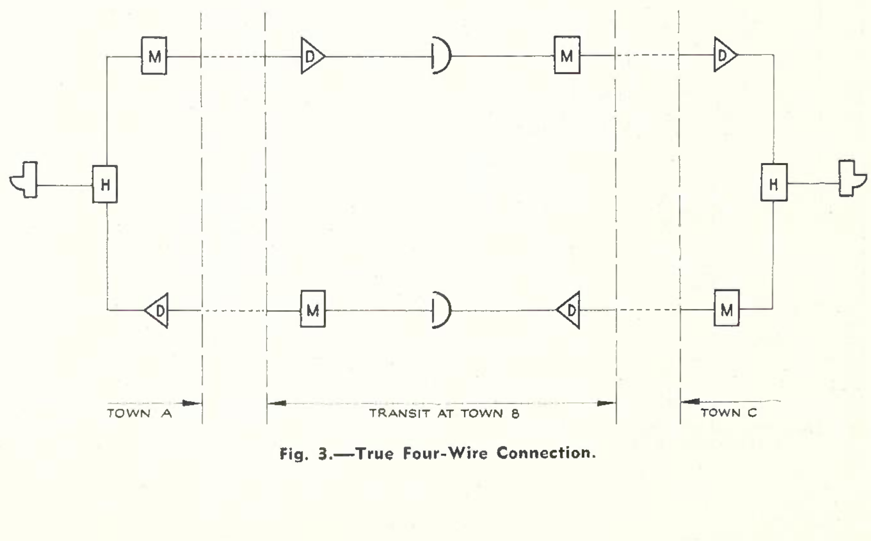

Fig. 3.—True Four-Wire Connection.

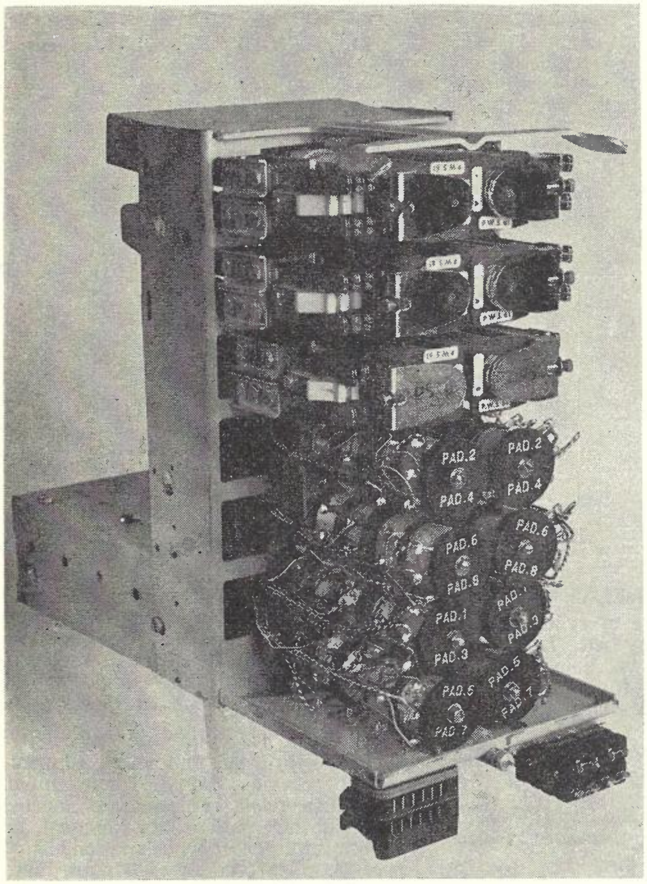

Fig 4 (a)—The Hybrid Switching Relay Set.

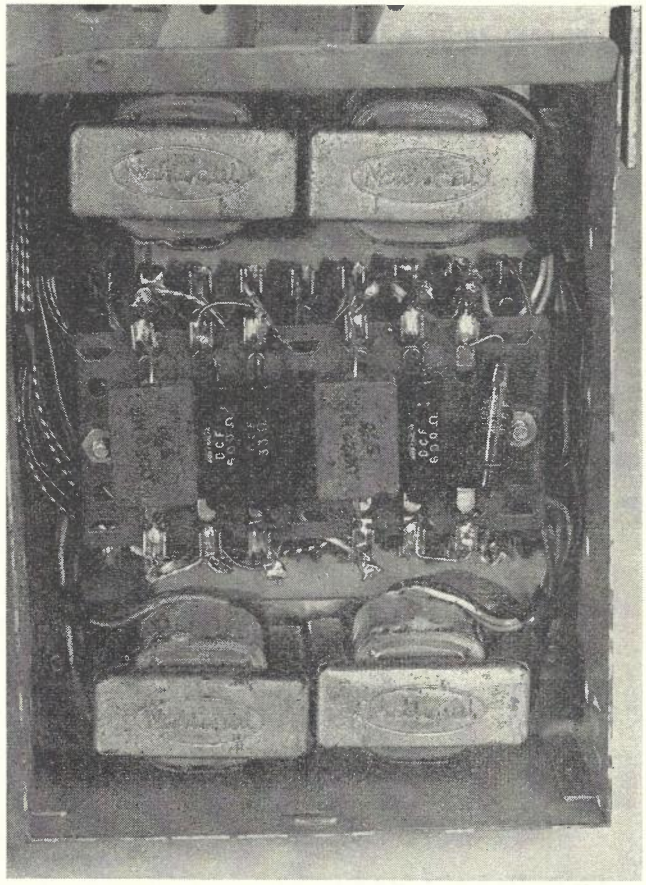

Fig. 4 (b)—Hybrid Transformers Mounted in Condenser Can.

overall circuit depends only on the hybrids at each end of the connection.

In a true four-wire transit scheme, four-wire trunks have to be capable of being switched to two-wire circuits as well as other four-wire circuits. Although there are several ways of achieving this requirement, it is done at Taree by providing every four-wire trunk with a hybrid switching unit which is "functionally" between the carrier system and the trunk line relay set.

The hybrid switching unit performs several major functions:

(1) In the idle state it provides a two-wire termination for the four-wire circuit.
(2) When connections are made to a two-wire trunk it provides the hybrid and associated pads.
(3) When connections are made to a high loss two-wire trunk it removes the 3 db switching pad.
(4) When connections are made to other four-wire trunks, it removes the hybrid from the circuit and connects the mod. and demod. to the appropriate pair for either the incoming or outgoing condition.

In practice the hybrid switching unit is mounted in a relay set base. There are two circuits per base and each unit is wired for both way working. Monitoring access to the "hybrid line" point is provided by means of a set of links mounted on the right-hand side of the relay set plate. These can be seen in the photograph, Fig. 4 (a).

In the two-wire idle state the hybrid line is terminated by 600 ohms in the trunk line relay set. The hybrid net is not extended at any stage and its termination is provided in the hybrid switching relay set (see Fig. 5).

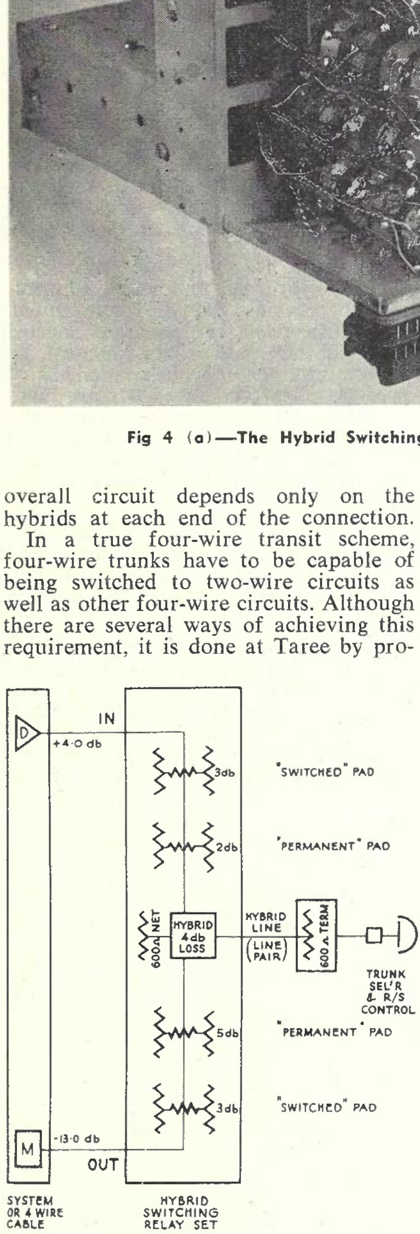

Fig. 5.—Hybrid Switching Unit—Two-wire Condition.

Because the switching scheme is somewhat unusual in that the same wires are used for connections on either a two-wire or a four-wire basis, it was necessary to introduce a new set of designations for the connecting wires. These are illustrated in Fig. 6.

The fundamental speech and signalling pair has been called the "line pair". All relay sets are in the line pair because of the D.C. signalling between them. In the two-wire condition the line pair joins the hybrid lines whilst in the four-wire condition it joins the incoming demod. to the outgoing mod.

The "auxiliary pair" completes the four-wire connection. It joins the incoming mod. to the outgoing demod. Also in two cases it carries special D.C. control signals. The legs of the auxiliary pair were designated N— and N+ to maintain the original Siemens trunk selector designations. Several of the illustrations in this article show a reversal in the auxiliary pair as it passes through the trunk selector. This is because the selectors were originally built for use in "tail eating" transits. As there was no advantage in altering the selector circuits, the reversal was left in its internal wiring.

Fig. 7 shows the connection of two four-wire trunks. The "FW" lead is the means of changing a hybrid switching unit from the two-wire to the four-wire

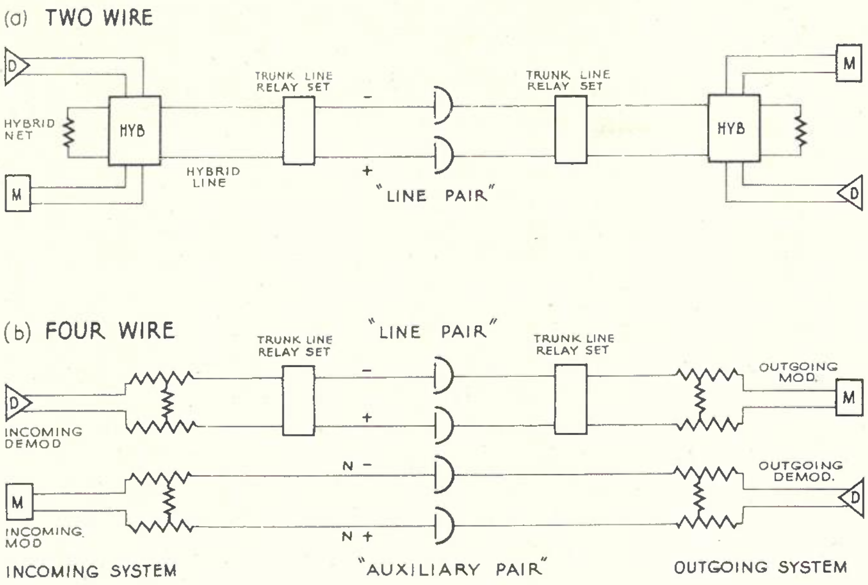

Fig. 6.—The Line and Auxiliary Pairs

condition. It will be seen that the earthed incoming FW lead is connected to battery on the outgoing FW lead. This allows the IC and OG relays to operate and switch the hybrids out of the connection. It is possibly of academic interest to note that conversion to the true four-wire condition does not take place until after the switched connection has been set up, so that the term true four-wire "switching" may not be strictly correct. However, as the arrangement used gives a true four-wire connection while transmission is taking place and is indistinguishable from four-wire switching for all practical purposes, it has been referred to as such in this article.

Fig. 7 also shows the signal levels and pad values. The standard mod. and demod. levels of —13 db and +4 db were used for all four-wire circuits. The design of the hybrid switching unit was simplified by the use of separate pads for the two- and four-wire connections. The equipment in the line and auxiliary pairs has an equal loss of about 1 db, the auxiliary pair having retards, etc., across it to pick off cailho signals as required in many cases as discussed later.

Fig. 8 shows the complete drawing of a hybrid switching relay set.

SIGNALLING

The second major feature of the Taree transit is the free, unrestricted inter-switching of 1VF, 2VF, E and M, and loop dial types of signalling.

As no one type of signalling was in the majority it was decided to convert all the signalling to the same common denominator. The type adopted was "loop disconnect" with reversal supervision, as shown in Fig. 9. This had two main advantages which simplified the design of the new relay sets:

(1) There were well tried circuits for converting the various types of signalling into loop dial.
(2) Loop dialling was required for the trunk selectors.

Despite the simplification, eleven new relay sets had to be designed. These used the standard relay techniques and incorporated special features to accommodate the 500 ohm battery private search conditions for the motor uniselectors, the 600 ohm terminations and ring tone feed arrangements for the line and auxiliary pairs of the true four-wire connections, and the cabling for true four-wire working. In cases where there was subsequent dialling after going through the transit, impulse repetitions were required. This applied especially to the 2VF and R.A.X. lines. Special arrangements were made for the 2VF to 2VF calls which are described later.

All trunk line relay sets have to provide the following basic facilities:

In the Idle Condition:

(a) Be in the incoming condition.
(b) Be capable of being picked up "outgoing" by having the 500 ohm battery on the private.
(c) Provide a termination for the hybrid line.

In the Incoming Condition:

(a) Set up trunk selector by a "loop" on the "line pair" and ground forward on the private.
(b) Provide a hybrid line termination before and during dialling, and until the selector has found the required outlet.
(c) Provide a short circuit dialling loop with a spark quench across the impulsing springs.
(d) During the duration of the incoming call, including the selector release time, guard the circuit from outgoing seizure.
(e) Accept the reversal supervision signal from the outgoing relay set and send this back to the originating end.

In the Outgoing Condition:

(a) Be capable of being picked up by having the 500 ohm battery on the private. If an outgoing "trunk", light the switchboard busy lamp on transit seizure.
(b) On seizure and subsequent dialling convert these to the appropriate method of signalling 2VF, 1VF, E and M, etc.
(c) Provide a 600 ohm termination across the line pair until the called subscriber answer signal is received.
(d) In the case of junctions send back ring tone to the calling end.
(e) Stop the ring tone when the called telephonist answers.
(f) Send back reversal supervision to the incoming circuit when the "called" subscriber answers or the "called" telephonist meters the call.
(g) Provide a guard against "follow on calls" during the condition when the calling party has cleared before the called party.
(h) Revert to the incoming condition when the trunk selector releases the relay set.

TRUE FOUR-WIRE SWITCHING OF 2VF CIRCUITS

The third unusual feature of Taree transit is the true four-wire switching of 2VF circuits. Siemens designed their 2VF system for two-wire or tail eating connections in which the receiver is always across the hybrid line and the tones are sent on the hybrid line (or on

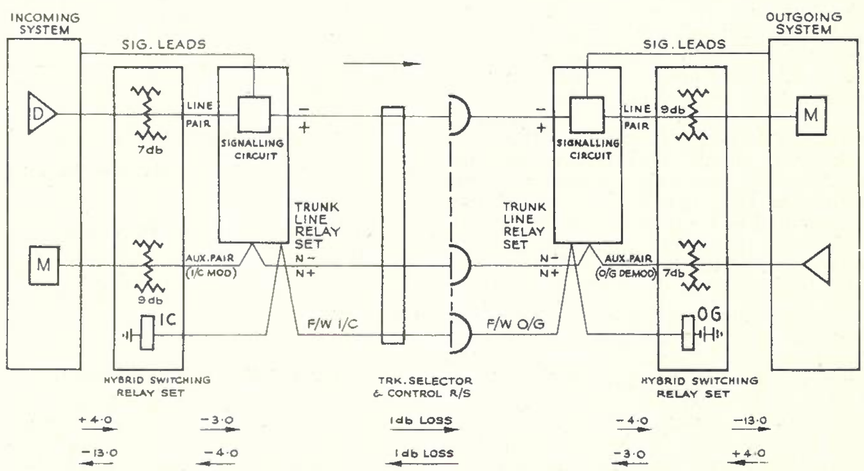

Fig. 7.—Four-Wire Connection Through the Trunk Selector.

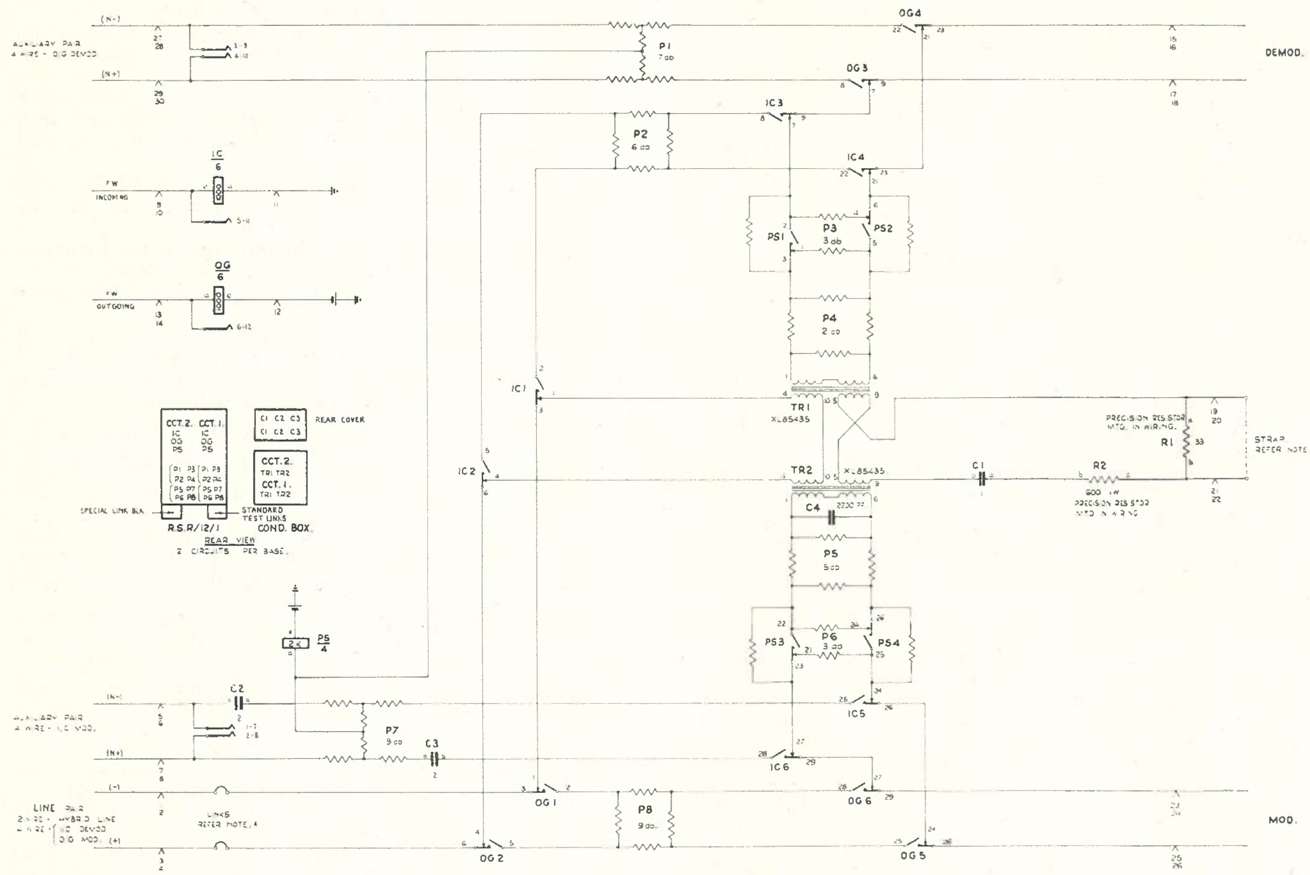

Fig. 8.—The Hybrid Switching Unit—Complete Drawing.

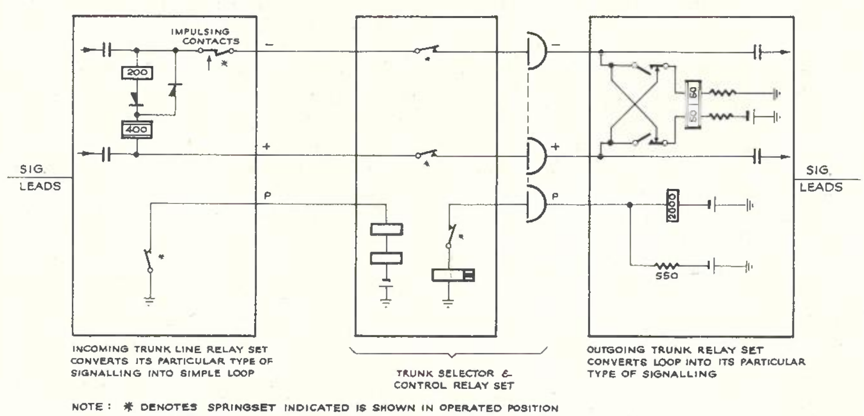

Fig. 9.—The Basic Method of Signalling.

both hybrid line and net if required). At Taree two-wire operation of 2VF was straightforward as the 2VF relay set, being in the line pair, was connected to the hybrid line. The problem at Taree was ensuring that the 2VF receiver and sender circuit elements were always in the right place for incoming and outgoing four-wire operation.

Fig. 11 shows a 2VF bothway circuit in the four-wire incoming condition. Because of the hybrid switching action the line pair is now connected to the incoming demod. In order that the sender can send tones back to the originating end and at the same time to ensure that the demod. is not coupled to the mod. through the tone sending circuit (to avoid instability), the T.S. relay was fitted. This opens the tone feed to the line pair for an incoming four-wire call and is attached to the incoming FW lead, as shown in Fig. 11. Note also that due to the normal splitting action of the SP relay, the tones are sent back only to the "calling" end.

In the outgoing four-wire condition, because of the hybrid switching action, the line pair is now connected to the outgoing mod. Therefore the receiver has to be switched over to the auxiliary pair outgoing demod. Fig. 12 shows how this was achieved by providing an RS relay which switches over the receiver for an outgoing four-wire call.

The addition of TS and RS relays and the modifications to the 2VF relay sets were relatively easy to make as it was possible to remove two existing relays (PC and FW), which were no longer required.

LOOP TO 2VF CONVERSION

Another design problem was the conversion of loop impulses into 2VF tone. At Taree all outgoing circuits had to be capable of accepting loop impulses when picked up on transit. As 2VF was in the minority, it was decided to put the loop/2VF conversion auxiliary relay sets between the selector banks and every 2VF outgoing or bothway relay set.

The 2VF relay set was picked up by seizure of its outgoing private which was extended straight through the auxiliary relay set to the selector banks. The auxiliary relay set simply converted all loop impulses into 750 c/s tone impulses. All answer acknowledgments and supervision functions were done in the usual way by the 2VF relay set.

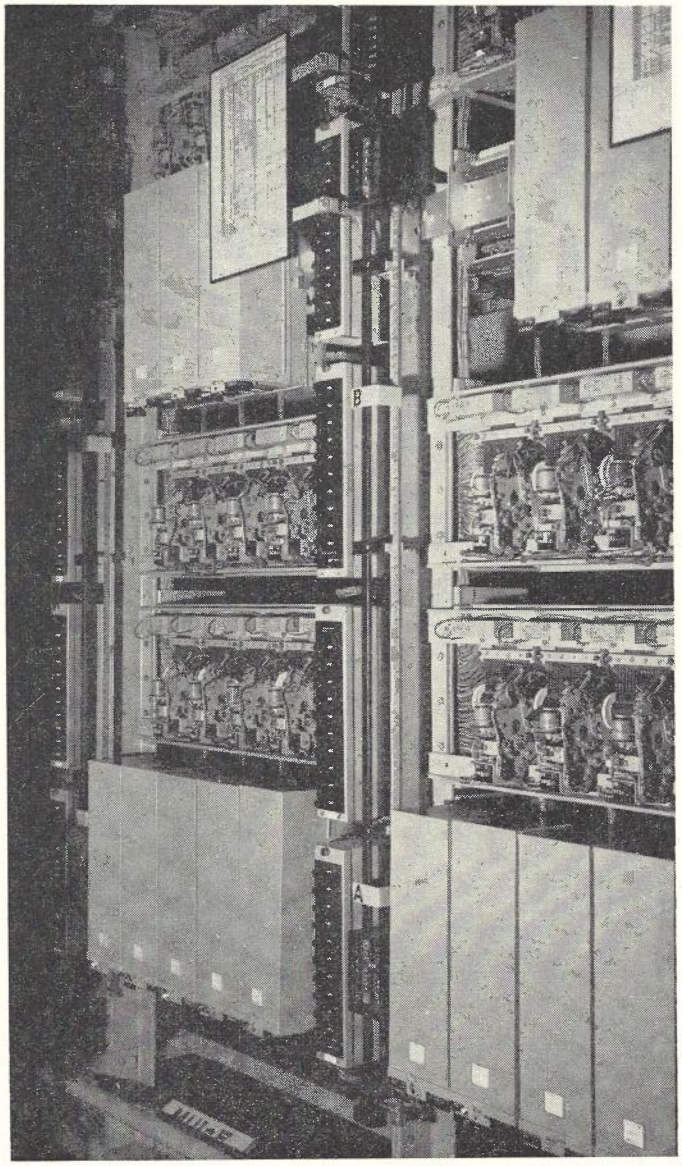

Fig. 10.—Siemens Motor Uniselectors and Control Relay Sets.

At first there were considerable difficulties with "clipping" of the first break impulse due to relay operate times. However, an improved design using a shunt transformer to feed the signalling tones to line greatly reduced the clipping. During conversion the transformer had an open circuit secondary and just became a high impedance shunt inductance across the line.

SPECIAL CONDITION—2VF TO 2VF

The auxiliary outgoing 2VF relay set enabled trunks with 1VF, E and M, etc., types of signalling to be connected to the 2VF trunks.

However, a special problem arose when a 2VF trunk made a transit call to another 2VF trunk. Because of the auxiliary 2VF conversion relay set the incoming 2VF signals would have been converted to loop, then back into 2VF again, which was undesirable because it introduced another impulse repetition and other troubles. Siemens had intended in their original design that when a 2VF trunk called another 2VF trunk via transit, the subsequent 750 c/s dialling impulse tones would pass through both relay sets without any conversion. They did this by providing a T.T. lead from the incoming circuit through the selectors to the outgoing circuit. This T.T. lead (transit trunk) operated T.T. relays in the incoming and outgoing relay sets which prevented false operations of receivers.

To ensure satisfactory operation of the transit it was highly desirable to retain this feature. However, this was not easy as the seven wires through the selectors were already used for the line pair, auxiliary pair, private, F.W. and B.M. leads. This was achieved by extending the T.T. lead from an incoming 2VF relay set over one leg of the auxiliary pair as shown in Fig. 13. In the 2VF auxiliary relay set this leg was picked off and made to operate a T.S. relay. The T.S. relay removed the loop/750 c/s. conversion circuit from the line pair and also sent a signal onto the T.T. relay in the outgoing 2VF relay set.

This arrangement works well and 2VF to 2VF calls are made in the manner originally intended by Siemens.

THE B.M. AND C.B. LEADS

Between every four-wire trunk line relay set and its associated first trunk selector there were eight wires:

The line pair	2 wires
The auxiliary pair	2 wires
The private	1 wire
The incoming F.W. lead	1 wire
The B.M. lead	1 wire
The C.B. circuit busy lead	1 wire

The functions of all the wires except the B.M. and C.B. have been described previously.

The C.B. (circuit busy) lead is used to send back a busy signal to the trunk line relay set if the selector does not return to normal after releasing.

The B.M. (branch magneto) lead was originally intended by Siemens to send an earth signal back to the incoming 2VF relay set from the selector indicating that the selector had stopped on a branch magneto trunk group. However at Taree the B.M. lead has two other functions. Firstly, for all non-2VF trunk line relay sets, the B.M. lead earth signal was used to remove the hybrid line termination provided by the incoming trunk line relay set. Once the selector had stopped, and switched, the hybrid line termination for the incoming circuit was provided by the relay set to which it had been switched.

The second function of the B.M. lead was to provide a safeguard for all 2VF circuits. When calls are made to the junctions (magneto exchanges with pushbutton metering), there will be conversation between telephonists before the metering. Incoming 2VF circuits regard metering as the same as "called subscribers answering". Therefore for the 2VF circuits there will be many cases of conversations taking place in the unanswered condition. Previous experience had shown that in this condition there are false operations of the X tone receiver to voice. It was known that if the incoming 2VF circuit received a signal on B.M. lead it became immune to this trouble. Therefore all selectors for 2VF trunks were strapped to give a signal on the B.M. lead for trunk groups with pushbutton metering.

Also, the B.M. lead facility was used for when 2VF trunks called the 0 level trunk assistance. It enabled the calling telephonist to ring forward and attract the attention of the assisting "through" telephonist at Taree.

PAD SWITCHING

Another feature of Taree transit was that full pad switching facilities were provided to work in conjunction with the true four-wire switching. The aim of pad switching is to improve the return loss values at the hybrid lines when con-

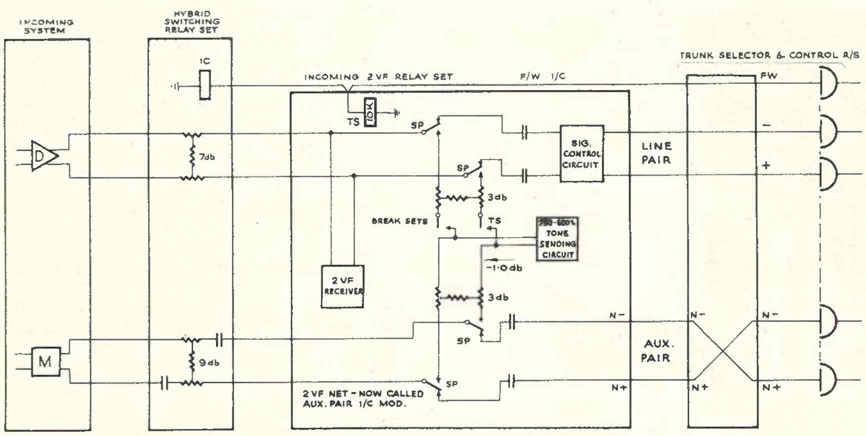

Fig. 11.—2VF in Incoming Four-Wire Condition—Schematic.

nected to low loss physical circuits and thus assist stable operation and improve echo performance (see Reference 1). The basic technique of pad switching is to insert an extra 3 db pad when connection is made from a four-wire circuit to a low loss two-wire trunk or directly to a subscriber's line.

In designing a pad switching scheme there are two principal problems:

(a) Where to put the pads.
(b) How to switch them in and out as required.

A close study was made of all the possible connections of two-wire and four-wire trunks via transit and by the switchboard. It was decided to associate the 3 db pads with the four-wire trunk line relay sets because, during the design study, it was found that if the pads were in the two-wire relay sets there were several types of connection with unavoidable 3 db and even 6 db losses. Also, fixed pads were not used in any of the trunking. In actual practice the pad switching action was carried out in the hybrid switching relay set because it was easier to derive the pad switching control circuitry, and it simplified the design as the functions of pad switching and four-wire switching were together in one relay set, thus leaving the trunk line relay set free to deal with only signalling. Fig. 5 shows the locations of the switched pads. At Taree all "open wire" physical circuits were regarded as high loss and all Taree subscribers and switchboard levels (levels 5, 0, 01) were regarded as low loss trunks.

The 3 db pads are normally inserted and the pad switching function occurs when:

(a) a four-wire circuit selects a two-wire high loss circuit,
(b) a two-wire high loss circuit selects a four-wire circuit.

Therefore a high loss two-wire circuit has to have some means of identifying itself when it calls or is called by a four-wire circuit. This requires a controlling signal wire to be extended through the transit selectors, and one "side" of the auxiliary pair remained available for the purpose.

To assist in understanding the operation of the pad switching the following facts are required:

(a) Every trunk selector input has been cabled to the transit T.C.F. with eight wires to work "four-wire".
(b) Every trunk selector outlet has been cabled to the transit T.D.F. with seven wires to work "four-wire".

Firstly, consider what happens when a high loss two-wire trunk calls a four-wire trunk. When the connection has been made the line and auxiliary pairs are extended from the input of the first trunk selector at the T.C.F. to the hybrid switching relay set of the four-wire trunk. As this is a two-wire to a four-wire connection, the hybrid switching relay set will NOT switch and so the auxiliary pair will not be carrying any speech currents. At the trunk selector input on the T.C.F. one leg of the auxiliary was permanently connected to earth. This earth is extended right through to the hybrid switching relay set where it operates the P.S. relay. This P.S. relay removes the 3 db pads. Fig. 14 shows the arrangement.

Similarly, when a four-wire trunk makes a transit call to a high loss two-wire trunk, the hybrid remains in the circuit and the auxiliary pair, although extended, is not used for speech. In this case the auxiliary pair is extended from the hybrid switching unit to the T.D.F. At the T.D.F. one leg of the auxiliary pair of the two-wire trunk selector outlet is permanently connected to earth. This

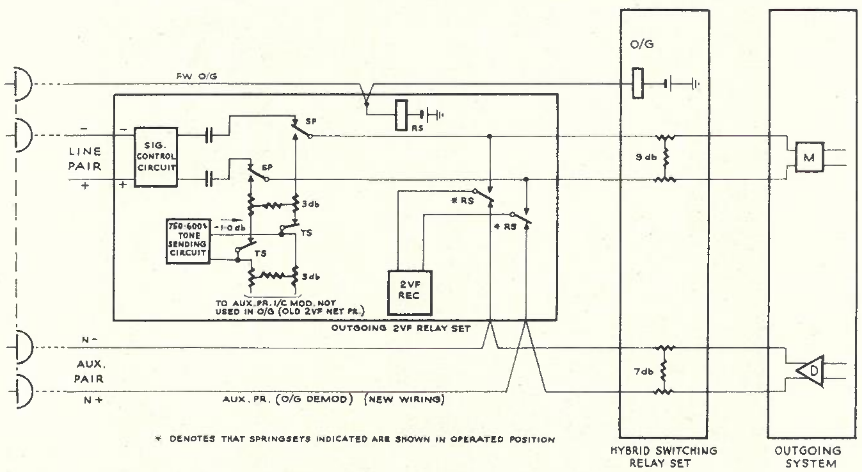

Fig. 12.—2VF in Outgoing Four-Wire Condition—Schematic.

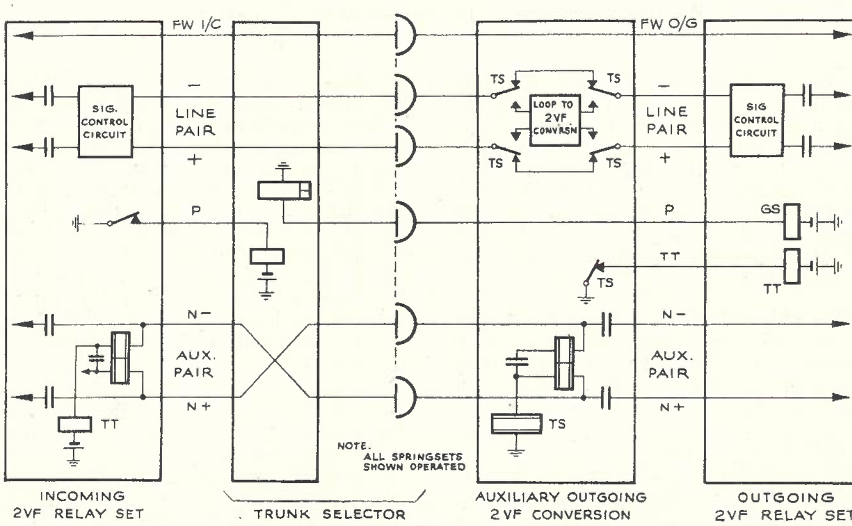

Fig. 13.—2VF to 2VF Through Auxiliary Outgoing 2VF Relay Set.

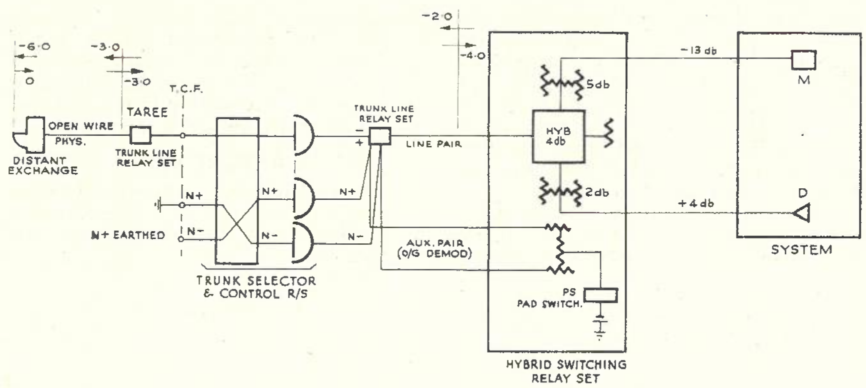

Fig. 14.—Pad Switching, Two-Wire to Four-Wire.

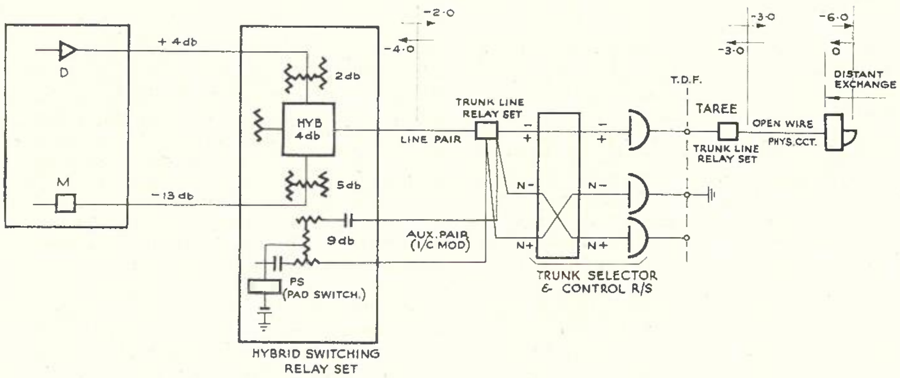

Fig. 15.—Pad Switching, Four-Wire to Two-Wire.

is shown in Fig. 15. As before, this earth is picked off the auxiliary pair in the hybrid switching relay set and operates the P.S. relay.

Fig. 8 shows the complete drawing of a hybrid switching relay set. The condensers in the pad in the auxiliary pair (incoming mod.) were necessary to isolate the pad switching battery and 2VF T.T. lead battery which are on the legs of the auxiliary pair.

TESTING

The testing of Taree was divided into two classes:

(a) The testing of the installation cable and jumpering.
(b) The functional testing of the whole scheme.

The testing of the installation cabling involved much more than just buzzing of the cables. Due to the seemingly complex cabling and jumpering some simple method was required to test the whole installation. To do this, a pair of special test relay sets were made, one incoming and one outgoing. The incoming unit was put in a trunk line relay set's position and test calls were made to the other unit which was moved around the R.S.R.'s to the positions of all the trunks obtainable on transit to the trunk under test.

The incoming unit was fitted with a dial, set up keys and eight supervisory lamps. The outgoing unit had three supervisory lamps and the battery feeds for the lamps in the incoming unit.

These tests checked:

(a) The correct polarity of the battery from the selector.
(b) Out of balance of the A relay in the selector.
(c) Correct operation of the selector.
(d) Continuity of the wiring right through the transit.
(e) Reversals or "split pairs" in the wiring.
(f) Correct provision of the earth on one leg of the auxiliary pair for the pad switching.

Although these tests were long and laborious, they proved that every trunk line relay set could call every other trunk line relay set.

The functional testing was divided into two parts. The aim of the first part was to check the design of each type of trunk line relay set for correct operation. The method of testing was to make calls from one type of relay set to each of the seven other types in turn. This is shown diagrammatically in Fig. 16. The testing was done from the patchboards which had been rejumpered to provide access to mod. and demod. points. Also the patchboard circuits had been modified to enable the Technician to signal into the transit or the systems with any of the four basic types of signalling.

The aim of the second part of the functional testing was to check the performance of every trunk line relay set. The tests made were:

(a) a check of the hybrid balance when in the idle state; and
(b) a check of the correct functioning and transmission losses when a call was set up to or from a four-wire trunk and high loss two-wire trunk.

CUTOVER

As there were 138 trunks and junctions to 31 centres in an area of approximately 2,000 square miles, the introduction of the transit was a gradual process spread over 16 days. The junctions to the small magneto offices were done first and the trunks to Newcastle and Sydney were done last. A cutover schedule was produced which had the aim of providing a handbook of important information for all personnel associated with the introduction of the transit.

The schedule contained:

(a) A general outline of the cutover.
(b) A timetable of events.
(c) Lists of transit codes.

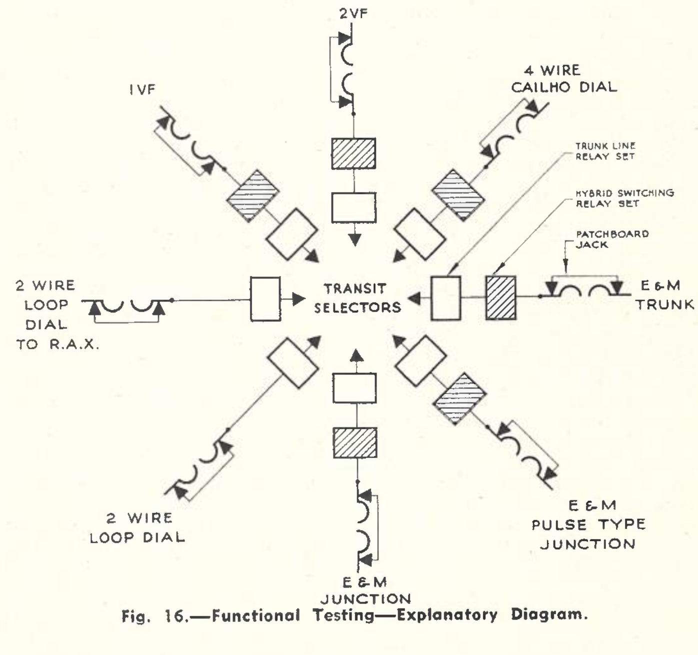

Fig. 16.—Functional Testing—Explanatory Diagram.

(d) Cutover Schematic Drawing.
(e) Complete information on every trunk line involved in the cutover, namely, its existing designation and type of signalling, its "bearer" circuit, and its proposed designation and type of signalling.

CONCLUSION

Taree transit exchange has now been in operation for over a year and has proved itself technically and functionally. The Maintenance Staff report that they have not had any "design" troubles and that apart from an occasional release alarm it is behaving very well. The Traffic Staff are also pleased with its operation. Their "through assistance" traffic is now very small and they are able to handle anticipated increases of traffic into their A positions.

It is felt therefore that Taree represents a practical solution to the problem of providing true four-wire transit switching at a centre with a wide range of signalling equipment. It is hoped that the example of Taree may be of some assistance in solving the "interface" problems that are arising in the planning of future trunk switching networks.

REFERENCE

1. R. G. Kitchenn, "Stability and Echo in the Trunk Network"; Telecommunication Journal of Australia, Vol. 13, No. 1, page 49.

TECHNICAL NEWS ITEM

SIXPENNY LOCAL CALL PUBLIC TELEPHONES

The Postmaster-General announced recently that it is proposed to raise the charge for local calls from public telephones to sixpence and to round off public telephone trunk charges to sixpenny multiples. To give effect to this decision all public telephones will soon be modified to operate on silver coins only. The variable tariff unit fee type will operate on a single sixpenny piece and all multi-coin type instruments will accept a single 6d., 1/- or 2/- coin for a local call. As the rounding off of trunk charges to sixpenny multiples will mean that the pennies will no longer be required for public telephone calls, the opportunity will be taken to change the penny slot in the multi-coin instruments to accept a 2/- piece for the convenience of users making high rate trunk line calls.

The decision to increase the public telephone local call charge to sixpence is a logical one, since public telephone users do not pay rental and the service costs on public telephones are very many times higher than the service costs on private telephones. If the private subscriber drops and breaks his telephone instrument he has to pay for a replacement, but vandalism alone on public telephones adds £100 per annum to the service charges on each public telephone in some city areas.

The public telephone local call fee would probably have been raised to sixpence much earlier had a suitable method of converting the variable tariff public telephone to sixpenny operation been developed. The cost of completely replacing all the variable tariff instruments by a new sixpenny type would have offset the revenue gained by the increase in charges. The sixpenny modification of the variable tariff type instrument was developed a short time ago for installation as a leased coin attachment and this instrument will now be used for public telephone service.

A few years ago a Mk 2 multi-coin attachment was introduced, which was fitted with a sixpenny and shilling balance-arm, to permit users to make local calls in an emergency with these coins. The same principle of operation will be used now to convert all multi-coin attachments to operate on sixpence instead of four pennies.

Two different kits of parts will be issued to field staff for the conversion programme. One will convert variable tariff public telephones to sixpenny type and the other will convert all types of multi-coin public telephones to operation on sixpence, shilling and two shilling pieces.

To convert the variable tariff type, the existing coin head, coin chute, coin counting racks and escapement adjusting cam are removed and replaced by modified parts designed specially for the sixpenny coin. The new rack will have only one operating tooth on the left hand side instead of the series of teeth which were required to count the four pennies. It is realised that the complicated rack and escapement which is part of the variable tariff public telephone is not necessary for the single sixpenny coin, but as all these public telephones will probably have to be scrapped when decimal coinage is introduced, it was decided to adopt the simplest type of modification which would work, instead of embarking on a major redesign. The other important factor in favour of using the modified variable tariff design is the desire to have the conversion completed by the end of this year. This would not have been possible had the whole mechanism been redesigned.

The kit for the conversion of multi-coin type public telephones will, like the variable tariff kit, contain a number of components which will replace those in the existing public telephones. There are three types of multi-coin mechanisms in use, representing different stages of development of this particular type of public telephone. The original type is fitted with a single balance arm which was originally designed to operate with two pennies. An additional counter-balance weight made the instrument operate on three pennies, but when it was necessary to increase the public telephone charge to fourpence the new type of balance arm mechanism had to be fitted. This type of mechanism is now generally known as the Mk 1 type and is distinguished by the fact that it uses a latched balance arm instead of the plain balance arm. The latest model known as Mk 2 is similar to Mk 1 but an additional balance arm has been fitted so that local calls can be obtained with either a sixpence or shilling piece.

The multi-coin conversion kit will convert all these types to a single, common type. The kit contains a spring controlled latch on a bracket, a modified balance arm, a new coin gauging plate to exclude pennies and accept two shilling pieces, a modified gauging plate for the existing penny coin chute, and a new label plate to designate the coin slots on the top of the instrument. It is hoped that when converted, the multi-coin public telephones will be suitable for operation on the new decimal coinage.

Both the variable tariff and the multi-coin conversion kits have been designed for installation in the field as it is felt that this method of conversion will produce the quickest results. Workshop or Depot modification of the multi-coin type instrument has advantages, but this type of operation necessitates a good supply of converted mechanisms at the outset in order to carry out the work quickly, and sufficient stocks may not be available in time from current contracts.

The Melbourne Workshops have already tooled up for the conversion kits for the variable tariff type public telephone and it is hoped that the first supplies of these kits will be available early in September. The Sydney Workshops will make the multi-coin type kit and although the tools have not yet been made for the parts, it is hoped that because the kit is very much simpler, Sydney Workshops will be able to deliver kits at about the same time and rate as the Melbourne Workshops.

The present target is to start production of both kits by 6th September, commence field operations on 16th September, and have the installation work completed by 20th December. This means that between September and December of this year between 15,000 and 20,000 multi-coin public telephones and about 15,000 variable tariff public telephones must be converted to sixpenny operation.

SYDNEY-MELBOURNE COAXIAL TELEVISION TRANSMISSION—PART I

*P. G. KRASTEV, Dipl.Ing., A.M.I.E.E.**

INTRODUCTION

The Sydney-Melbourne coaxial transmission system is capable of transmitting two television programmes (one in each direction) conforming with the high quality requirements of the Australian Television Standards. The Canberra-Melbourne section of this television system was completed early in February, 1963 and was used for topical telecasts during the Royal Visit.

This article describes some of the general features of television transmission on coaxial cables and the television terminal equipment used on this route. A second part in a later issue of this Journal will describe in some detail the technical aspects and the performance of the complete television transmission system.

FEATURES OF THE TELEVISION TRANSMISSION

The transmission of television on cables presents a number of design problems from band utilization and shaping, modulation degree, control of the transmitted wave form (that is phase and amplitude equalization of the line within narrow limits), to the special synchronous demodulation requirements in the receiving terminal. These features are described briefly in the following paragraphs.

Television Transmission Band

The television modulation system (which is coded Philips type STR.120) is designed for transmission of a video signal with a bandwidth of 25 c/s - 5 Mc/s, that is 625 lines per picture and 25 pictures per second, according to the Australian Post Office specification, and it complies with the most recent C.C.I.T.T. and C.C.I.R. recommendations (C.C.I.T.T. Red Book, Volume III and C.C.I.R. recommendation No. 267, Los Angeles, 1959).

* See Page 83

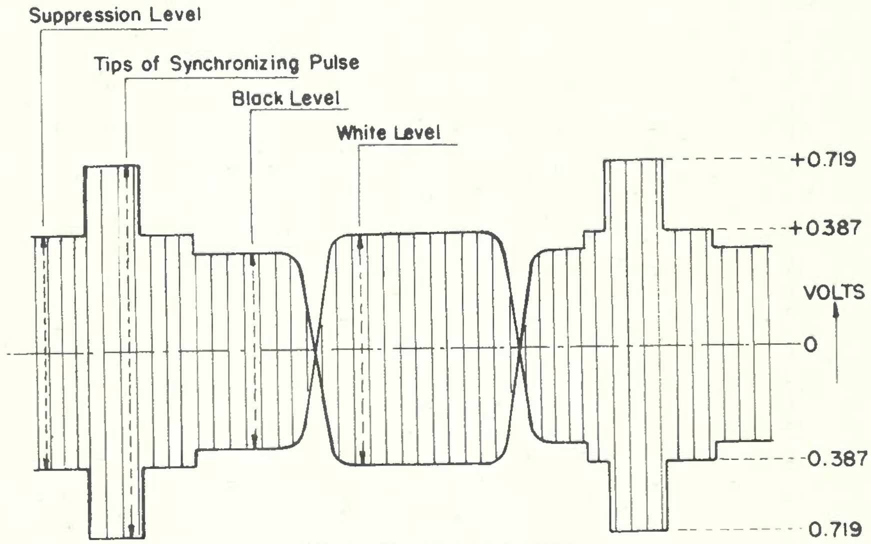

Fig. 2.—TV Modulated Signal.

Because of the large relative bandwidth of the video signal (200,000:1), and the problem of low-frequency interference (1), direct video transmission on coaxial cables is limited to local television distribution over distances usually not exceeding about 20 miles. The STR.120 system translates the video band into the range 556 kc/s-6,056 kc/s. The allocation of this band is an optimum from the transmission point of view. Although the lower frequency range of the coaxial system is not utilized, any shift below 500 kc/s will increase the relative bandwidth of the television band and it will create more severe phase equalization requirements. The television transmission mode could be described as a vestigial single sideband transmission with a semi-suppressed carrier.

Modulation Process

The translation of the video band into the carrier frequency range is performed in two steps. The modulation diagram, Fig. 1, shows the modulation process. The first step is a modulation with a carrier of 12,672 kc/s, the 12th harmonic of the line carrier 1,056 kc/s. The upper sideband is suppressed and no attempt is made to shape accurately the vestigial sideband. For the second modulation the carrier 13,728 kc/s modulates the intermediate frequency band of 7,672-12,672 kc/s and translates it to its proper position in the carrier band, 556-6,056 kc/s.

The signal is then shaped partly by the transmitting vestigial sideband filter which contains its own phase equalizer in order to compensate for the phase deviation introduced by the shaping process.

The demodulation of the carrier frequency signal is also achieved in two stages. On arrival at the terminal the line signal is finally shaped by the receiving vestigial sideband filter and then demodulated by the crystal controlled carrier, 13,728 kc/s. The upper sideband is suppressed. The second demodulator completes the demodulation process by sensing the phase of the demodulated

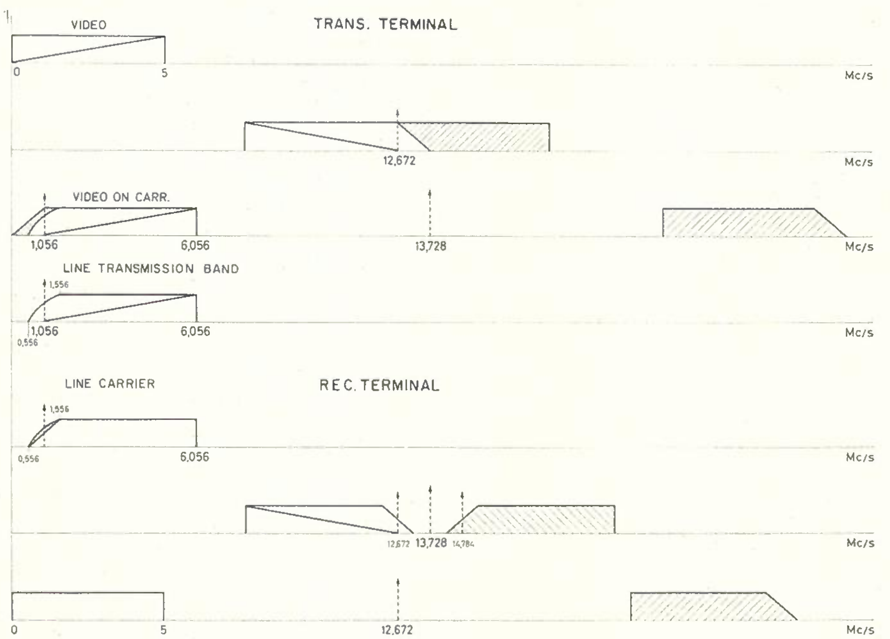

Fig. 1.—Modulation Diagram.

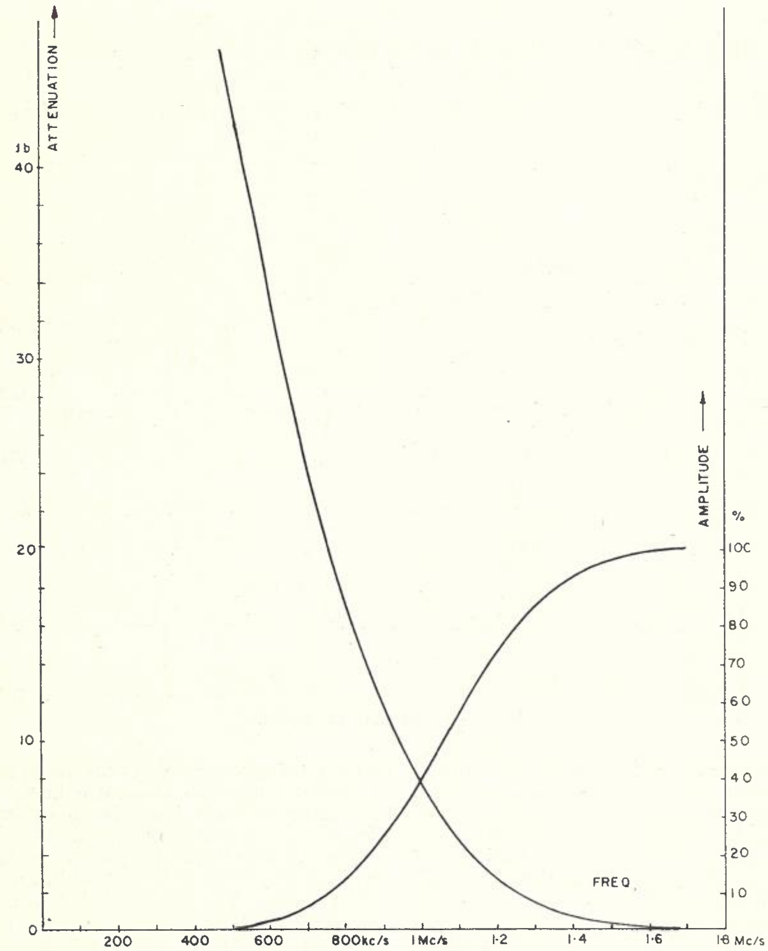

Fig. 3.—TV Vestigial Shaping Attenuation and Response.

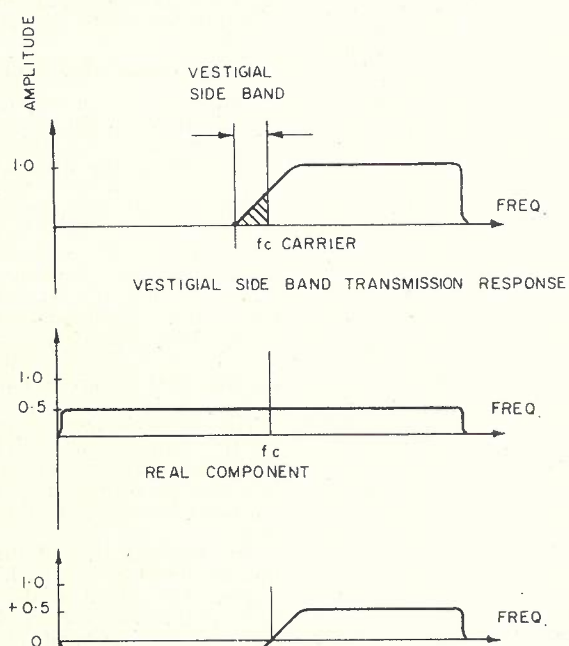

Fig. 4.—Vestigial Sideband Transmission System.

carrier so that the locally generated carrier, after a regulation and comparison process, is automatically and rigidly synchronized with it.

The synchronous demodulation of the system is unique because it does not require any great stability of the transmitted carrier and a tolerance of ± 10 c/s is permissible. However, the 1,056 kc/s carrier is kept within ± 0.5 c/s in order to comply with the international recommendations. The translation processes will be described later in more detail in conjunction with the relevant modulating equipment.

Degree of Modulation

The television system uses an amplitude modulation and a degree of modulation in excess of 100%. This produces a waveform which contains a maximum ratio of picture information to peak carrier signal, which feature is particularly advantageous in improving the signal to noise ratio.

The modulated signal is shown in Fig. 2. It should be noted that, when the carrier is modulated with a signal at suppression level, the amplitude is set to be equal to the carrier modulated at the white level. The nominal white, or suppression level, is 0.387V. peak. A sinusoidal voltage with the same peak value will dissipate 1mW in a 75 ohm resistor. The peak value of the synchronising pulses is 0.719V., that is the peak voltage of the sinusoidal signal dissipates 3.45mW in a 75 ohm resistor.

The detection of the modulated signal cannot be achieved by an ordinary demodulation process as the transmitted carrier is contained only in the synchronizing pulses. The line synchronizing pulses are selected and the phase of the carrier sensed in order to synchronize the local carrier which is used for the final synchronous demodulation process.

Vestigial Sideband Shaping

The television transmission on the coaxial cable uses a vestigial sideband in order to restore the low frequency components of the television signal in their proper phase relation at the receiving end, with a minimum of technical effort. From an equalization and filter design point of view it is not economical to provide the television transmission with a narrow vestigial sideband. Thus a 500 kc/s wide vestigial sideband has been allocated to the system. All frequencies below 500 kc/s are suppressed and the shaping is extended to the other side of the carrier up to 1,500 kc/s.

The ideal curve for the vestigial sideband is shown in Fig. 3, which is according to the C.C.I.T.T. recommendations (Red Book, Vol. III, 1960). The vestigial sideband is shaped to the required response function in the transmitting as well as in the receiving terminal, thus simplifying the design requirements of the shaping networks. On the other hand the shaping produces a phase error around the carrier which must be corrected by separate phase equalizers incorporated in both terminals.

Inevitably the vestigial shaping introduces a quadrature distortion into the system. This unwanted distortion term

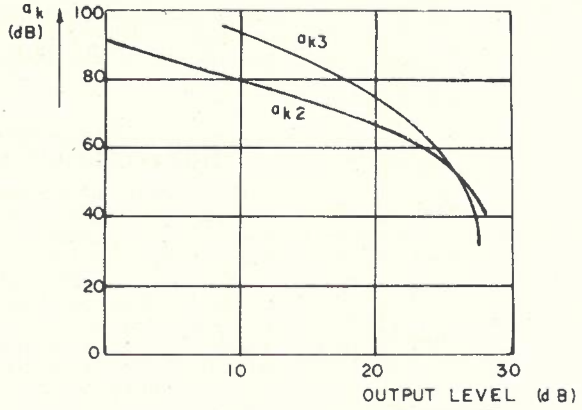

Fig. 5.—Line Amplifier TF750.9—Harmonic Distortion of 1 Mc/s Signal.

is later eliminated in the process of the synchronous demodulation. The presence of the quadrature component of a vestigial sideband (V.S.B.) response function is shown in Fig. 4.

The V.S.B. function can be considered as the sum of two components:

(i) A real component which is in phase with the carrier. This component may be drawn as a double sideband function having only half the amplitude of the V.S.B. function.

(ii) A quadrature or imaginary component which is shifted by 90° relative to the carrier. The quadrature component is in odd symmetry about the carrier and it has only half the amplitude of the V.S.B. function.

It may be considered further that the real component is produced by the ordinary process of modulation where the signal is in phase with the carrier. The quadrature term would then be produced when a video signal is modulated by a carrier which is shifted by 90° in relation to the signal. This consideration makes it possible to understand how the quadrature distortion can be suppressed in the process of the demodulation.

Consider the vestigial sideband signal as shown in Fig. 4, explicitly represented by the following equation:

$$V(t) = A(t) \cos wt + B(t) \sin wt. \quad (1)$$

where

V(t) is the vestigial sideband signal,

A(t) is the real or in phase component of V(t),

B(t) is the quadrature component of V(t),

f_c is the carrier frequency, and

$w = 2\pi f_c$.

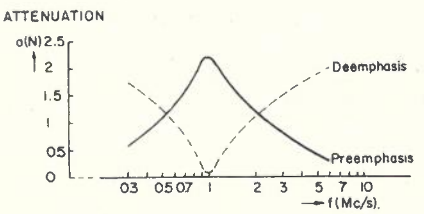

Fig. 6.—Television Pre-emphasis and De-emphasis.

If we assume a demodulator which is an idealized multiplier of the signal and carrier, then the modulation process may be expressed by the product:

$$V_o(t) = C(t) \times V(t) \quad (2)$$

where

$V_o(t)$ is the demodulated signal, and

C(t) is the carrier of the demodulator.

$$C(t) = \cos (wt - \varphi). \quad (3)$$

The angle φ is the phase angle by which the demodulator carrier deviates from the carrier of the real component of V(t).

Substituting equations (1) and (3) in equation (2) results in the following expression:

$$V_o(t) = \tfrac{1}{2} [P(t) \cos (2w - \varphi) + Q(t) \sin (2w - \varphi) + P(t) \cos \varphi + Q(t) \sin \varphi].$$

By neglecting the high frequency terms which are suppressed by the low pass filter of the system and the factor $\tfrac{1}{2}$, we may write:

$$V_o(t) = P(t) \cos \varphi + Q(t) \sin \varphi.$$

This equation shows that both components of the vestigial sideband function appear after the demodulator, but by providing a carrier with a very small difference angle φ the quadrature component may be suppressed completely, that is when $\phi \longrightarrow 0$,

$$V_o(t) \longrightarrow P(t). \quad (4)$$

It has been found by experiment that by maintaining a phase difference of 3° or less the quadrature component may be suppressed beyond any disturbing threshold value.

Harmonic Distortion Considerations

The harmonic distortion caused by the non-linear elements of the bearer could have considerable effect on the television transmission quality. The non-linearity, in general, produces changes in brightness and an interference signal at the harmonics of the carrier. A generation of a power spectrum around the second harmonic of the carrier could be most disturbing. Therefore, special care is taken to design the line amplifiers for an optimum suppression of the second harmonic. Fig. 5 shows the curves of the second and third harmonic attenuation of a 1 Mc/s signal. It may be seen that the second harmonic attenuation is well below –80 db for a signal output of up to 10 dbm.

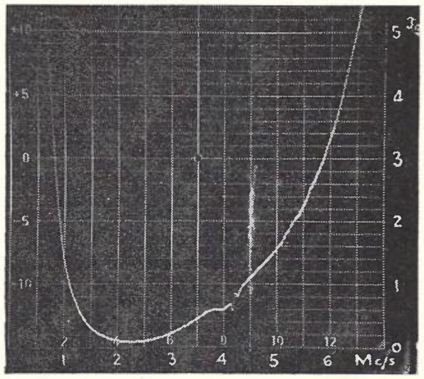

Fig. 7.—Time Delay of the Canberra to Melbourne Bearer.

A further consideration concerns the spectral energy distribution of the television signal. It has been found that the energy is mainly concentrated in the lower frequency range, that is in the proximity of the carrier in the transmission band.

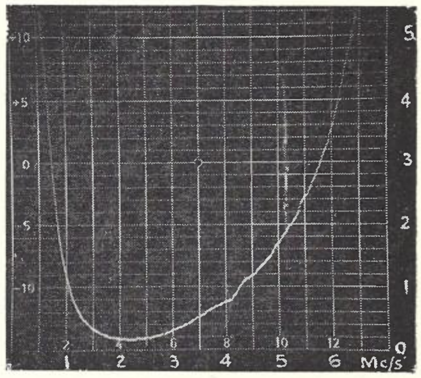

Fig. 8.—Time Delay of the Melbourne to Canberra Bearer.

In order to avoid large dynamic regulations and thus to prevent harmonic distortion, the transmitted signal is pre-emphasized as shown in Fig. 6. The carrier is attenuated and the high frequencies are emphasized. The signal to noise ratio is also improved by the appli-

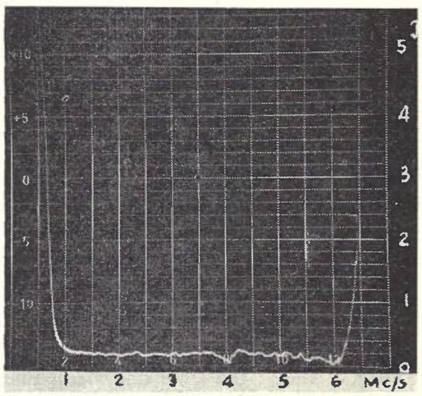

Fig. 9.—Time Delay of the Equalised TV Bearer—Melbourne to Canberra.

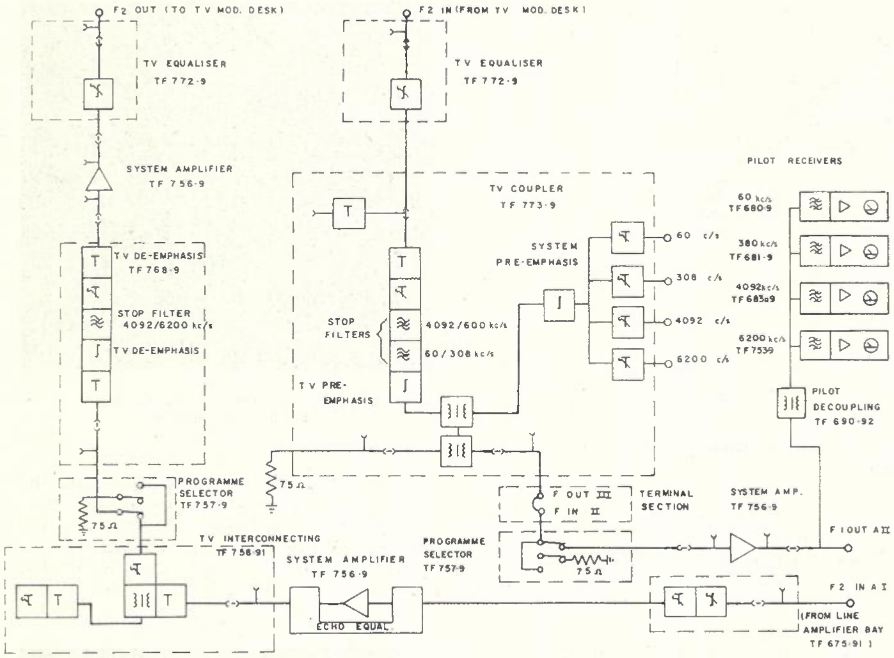

Fig. 10.—TV Terminal Rack Block Schematic.

cation of the pre- and de-emphasis because the basic noise and inter-modulation products falling in the higher frequency range of the band are attenuated at the receiving terminal by the de-emphasis.

Television Line Equalization

The television line transmission sets different requirements for the line equalization than apply for telephone transmission, because any performance of the bearer which deviates from that of a linear system would affect adversely the transient response of the television signal. The tolerable limits for the television transmission are determined by subjective experiments and form the basis of the television transmission standards. The television requirements for the HF line are usually expressed in terms of steady-state amplitude and time delay frequency responses.

The objectives for the television line are an amplitude response of ± 0.5 db and a group time delay not exceeding 0.1 μsec. (100 nano-seconds). Figs. 7 and 8 show the large time delay deviation between Canberra and Melbourne for the normal telephone bearer. The delay error exceeds 5 μsec., and, considering the objectives, it should be reduced to 2% of its maximum value. In other words, a phase error of 30 periods should be reduced to a deviation of few degrees. This is a formidable task which has been solved by a special computor programme based on the successive approximation technique. The phase equalizer consists of thirty phase equalising sections, five amplitude correcting sections, nine separating pads and one phase correcting section for the pilot stop filter in the receiving terminal.

Fig. 9 shows the time delay response of the Melbourne-Canberra bearer after equalisation. Further improvement of the amplitude response of the television bearer is achieved by a manual mop-up equalizer (echo equalizer). The echo equalizer uses the television signal in order to produce the equalizing echoes. The latter are properly located and adjusted to the required amplitude and polarity. The echoes are then inserted in the transmission path where they cancel the unwanted distortion shapes. The echo equalizer will be described in some detail in a later article covering the equalization of the Sydney-Melbourne bearer.

TECHNICAL SPECIFICATIONS OF THE TELEVISION SYSTEM

The objective of the system design is to meet the C.C.I.T.T. recommendations for a reference circuit of 1,600 miles which includes two intermediate demodulations to the video band, so that the circuit is effectively divided into three separate video-to-video links. Further details of the objectives may be obtained from the C.C.I.T.T. Red Book, Vol. III, page 285, but the essential characteristics are summarised in the following paragraphs.

General Design

Video Signal: The polarity of the video signal should be positive. The equipment should accept a video band of 5 Mc/s with the standard 1V. p.p. signal. The input and output impedance should be 75 ohm unbalanced and the return loss better than 24 db.

Transmission Signal: The carrier signal of the system should be 1,056 Mc/s ± 5 c/s. Amplitude modulation is used and the signal is transmitted as a vestigial single sideband. The vestigial sideband is divided equally between the modulating and demodulating equipment. The modulation degree is larger than 100%, or expressed in excess carrier ratio, ECR = 0.65. The output level of the modulation waveform is 1.44 V. p.p.

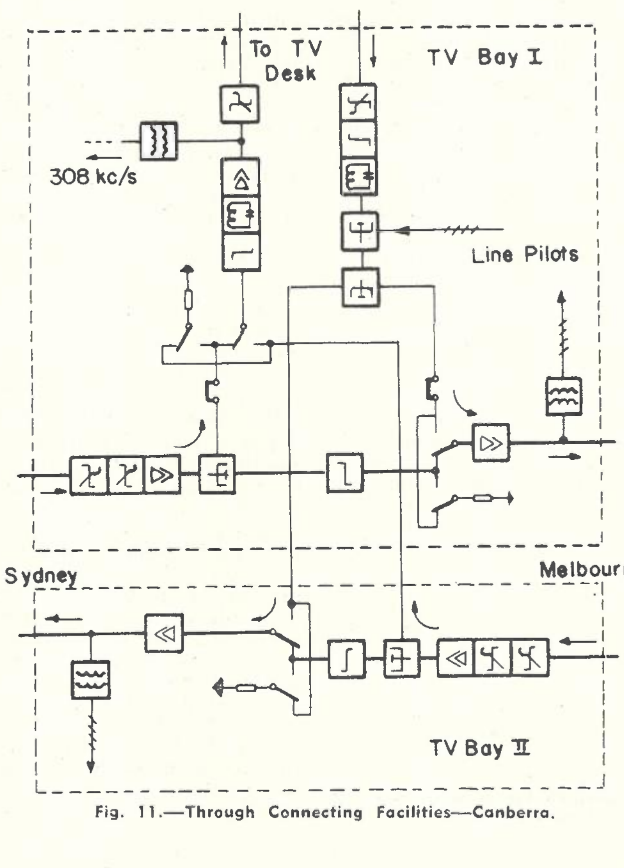

Fig. 11.—Through Connecting Facilities—Canberra.

Transmission Specification

The following overall performance requirements refer to the hypothetical reference circuit of 1,600 miles.

Transmission Equivalent: The transmission equivalent should be 0 db ± 1.0 db.

Noise: The requirements for the different types of noise are:

—Continuous random noise, S/N ⩾ 52 db.

—Single frequency noise, in the range:
1 kc/s-1 Mc/s, S/N ⩾ 50 db.
1 Mc/s-6 Mc/s, decreasing linearly to 30 db.

—Impulsive noise S/N ⩾ 25 db.

Non-Linear Distortion: The line time non-linear distortion ratio m/M should be greater than 0.8. The compression of the line synchronising pulses, S_a/S_b, should be within the range 0.64-1.57.

Waveform Distortion: The field time distortion should be within a 10% tolerance when measured in a manner specified in the recommendations. The line time distortion should be less than 5% and the transient response less than 140 nano-seconds (0.14 μs).

The requirements for the individual sections of the Sydney-Melbourne route are naturally more severe than for the overall 1,600 mile reference circuit. Some of the requirements, for example noise, depend largely on the length of the section of route, while others such as some types of distortion depend largely on the number of video terminal units in a section. It is possible to calculate approximate limits for each individual requirement for a section from a knowledge of the behaviour of the requirement as a function of route length and the number of video terminals, etc. The present system installed in the Canberra-Melbourne section was provided on a provisional basis initially due to its urgency, and some of the noise requirements will not be met completely until final units arrive in Australia. As mentioned previously full details of the performance of the individual sections and the overall system will be given in the second part of this article.

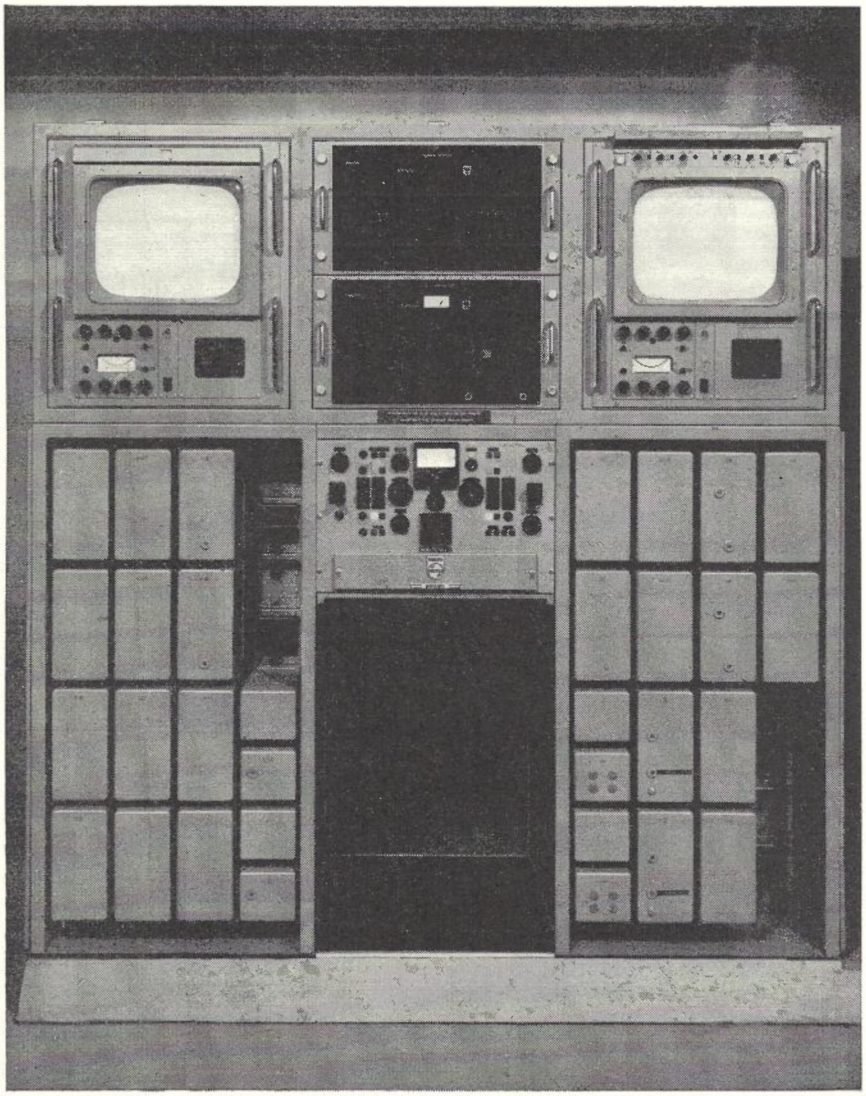

Fig. 12.—TV Modulation Desk.

TERMINAL EQUIPMENT

The terminal equipment consists of the television line amplifier racks and the television modulation desk.

Line Amplifier Racks

Because of the local accommodation and maintenance requirements, the television terminal line amplifier racks are installed some distance from the television modulation desk. They compensate for the losses of the line and associated terminal equipment and provide all the equalization, pilot coupling, pilot decoupling, regulation and switching facilities. Fig. 10 shows a block schematic of a television terminal rack. The equipment is generally similar in function and construction to the terminal line amplifier equipment for the telephone systems (2), and is generally located adjacent to that equipment in the station layouts.

The losses of the incoming and outgoing exchange cables (from the television desk) are equalized by the television equalizer which is manually adjusted. In the following coupling unit the television signal is pre-emphasised in order to improve the signal to noise ratio as well as the harmonic distortion performance. The frequencies in the proximity of the line pilots, 60 kc/s, 308 kc/s, 4,092 kc/s and 6,200 kc/s are then suppressed by crystal stop filters.

The send pilots are injected after the stop filters via the system pre-emphasis for telephony. In this fashion the pilots on the television and telephony bearer have the same levels. The television signal is then finally amplified by a system (flat) amplifier and transmitted to the line. The send pilots are decoupled at the amplifier output and are supervised by the pilot receivers which would give a "Pilot Failure" alarm at any pilot level deviation exceeding ± 1.0 db.

In the receiving direction the television signal is treated firstly as a "telephony" signal and it is amplified and equalised in a line amplifier rack as used in the intermediate attended stations. In this rack the line pilots are decoupled and they control electronically the automatic auxiliary equalizer. The time delay error of the bearer is then equalized in the phase equalizer which is followed by the echo equalizer. The latter serves as a mop-up equalizer in order to compensate for any small amplitude or phase deviations.

The equalizers are followed by the television de-emphasis unit which contains a pilot stop filter for 4.092 and 6.2 Mc/s line pilots. The 308 kc/s and 60 kc/s pilots are not suppressed because they fall outside the television band and the de-emphasis provides some degree of suppression. The pilot receiver for 308 kc/s is provided only for the supervision of the receiving equipment.

Branching Facilities

Television branching facilities are provided in Canberra as shown in Fig. 11. For this purpose two television terminal racks are used and the TV programmes may be selected or connected through at carrier frequency level. In each instance, Canberra terminal may transmit a local programme to Sydney and Melbourne, or receive and connect through a TV

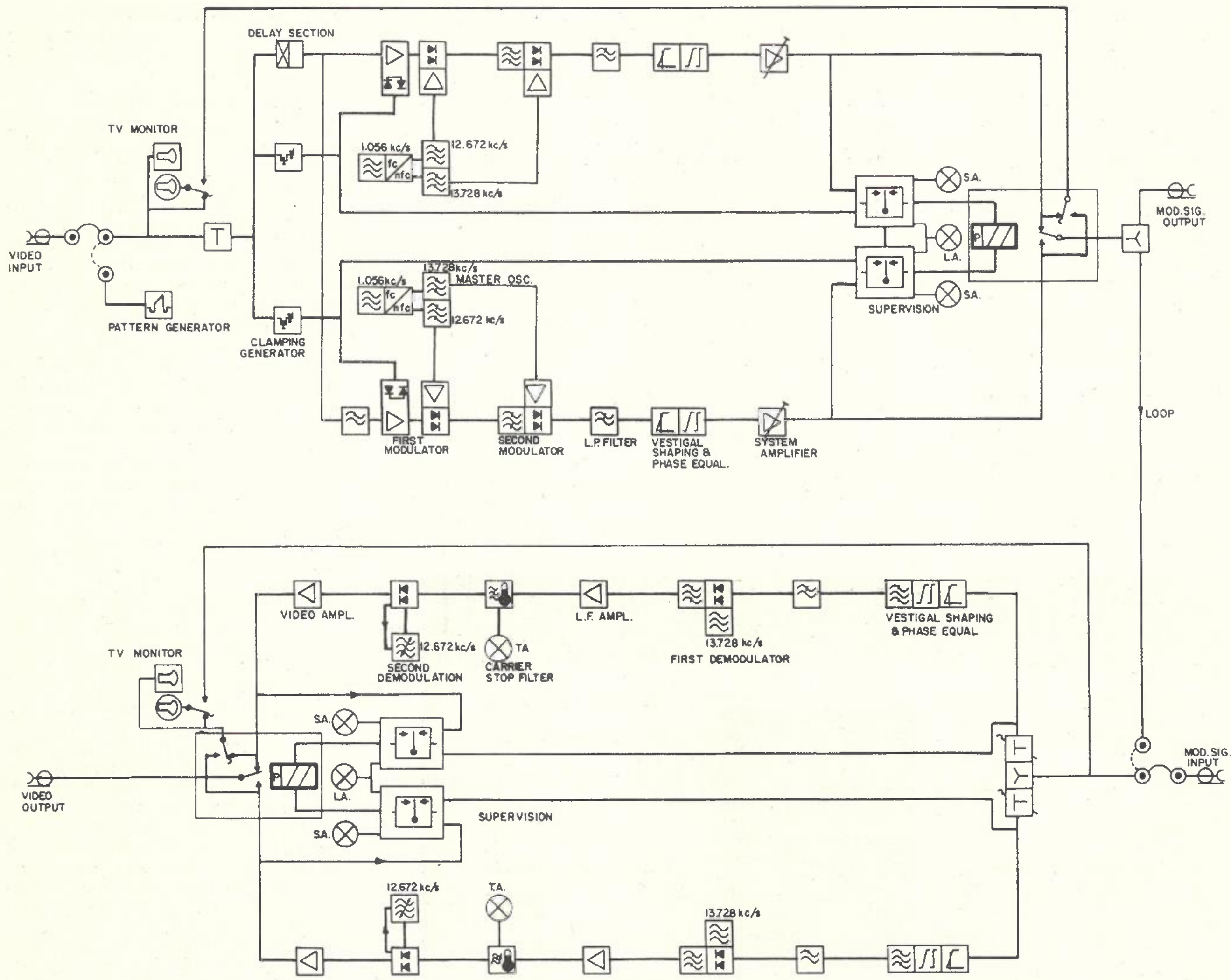

Fig. 13.—Block Schematic of Modulation Desk.

programme originating in Sydney or Melbourne.

TV Modulation Desk

The TV modulation desk is shown in Fig. 12. It contains the modulating equipment in conclave construction mounted in four rows below the video monitors. The TV pattern generator is above the control and the supervision panel. The transmitting equipment is located on the left-hand side, and the receiving (demodulating) equipment is on the right.

Fig. 13 shows the block schematic diagram of the TV desk. It may be seen that there is complete duplication of units. One of the channels in parallel serves as an immediate standby, according to the selection by the operator. The change-over from working to standby channel would be effected automatically in case of failure or at a certain deviation of the transmitted or video signal.

In the transmitting direction the incoming video signal level is set by the input attenuator prior to the modulation process. The first modulator unit contains in addition a video amplifier and a clamping circuit. The introduction of the D.C. component may be effected by D.C. restoration, clamping to the top or clamping to the back porch level of the line synchronizing pulses. The latter is the standard operational mode. The clamping pulses may be derived from the signal or from the clamping pulse generator. The delay line before the first modulator serves to synchronize the signal with the clamping pulses. Both channels are connected in parallel after the delay line and the low-pass filter between both modulators prevents any mutual interference.

In the second modulator unit, the upper sideband is suppressed by a band-pass filter prior to the ring modulator. The following low-pass filter selects the transmitted sideband which is partly shaped and phase equalized in the vestigial sideband filter unit. The signal is then transmitted via the system (flat) amplifier to the terminal line amplifier rack. At the output of the system amplifier the supervision unit checks the proper output level and effects a change-over, if required. The carriers for the modulation process are the 12th and the 13th harmonic of the 1,056 kc/s carrier and they are produced by the crystal controlled master oscillator unit.

At the receiving terminal the incoming signal level is adjusted by a variable attenuator. The vestigial sideband filter and phase equaliser unit complete the shaping of the modulated signal. The low-pass filter, after the shaping unit, prevents any interaction between the receiving channels.

The first demodulator contains its own carrier frequency oscillator. After the translation process, a band-pass filter selects the lower sideband. The signal is then amplified and a very sharp carrier stop filter eliminates any residue of the 13,728 kc/s carrier.

The second demodulator also provides its own carrier which is synchronized with the signal in order to complete the demodulation process. The video signal is further amplified and supervised at the output of the video amplifier. The receiving channel selection is performed by means of relay contacts.

The TV monitors and the TV pattern generator make, together with the TV desk, a completely self-contained unit which may be tested and lined-up for normal operation without any further testing instruments.

CONCLUSION

The main design features of the Sydney-Melbourne TV coaxial system have been described briefly.

The TV transmission requires high standards for the line equalization and stability, so that the line supervision and maintenance require more attention by specialized staff than is the case for a telephone system. The TV terminal equipment is complex from design point of view. However, the complete duplication of the units and the supervision methods enhance its reliability.

Special design aspects such as the signal clamping, the Nyquist shaping filter, the synchronous demodulation, the echo equalization and the supervisory facilities, will be covered in the concluding article in this Journal.

ACKNOWLEDGEMENTS

The author wishes to acknowledge with thanks the information contained in this article and supplied by the manufacturers, Messrs. N. V. Philips' Telecommunicatie Industrie and Felten & Guilleaume Fernmeldeanlagen G.m.b.H. The permission by the management of Telecommunication Company of Australia Pty. Limited to publish this paper is also gratefully acknowledged.

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TECHNICAL NEWS ITEMS

BROADBAND RADIO-TELEPHONE SYSTEM, BRISBANE-CAIRNS

Tenders have been invited by the Australian Post Office for the supply of equipment for the establishment of a broadband microwave radio relay system between Brisbane and Cairns, Queensland. The route distance of this system will be approximately 960 miles, and it will be the longest single system in Australia. The telephony bearer of this system will form part of the inland connection between the landing point at Cairns of the South-East Asia Commonwealth cable (SEACOM) and the landing point at Sydney of the Commonwealth Pacific cable (COMPAC). The telephony bearer will carry one supergroup of 80—3 kc/s channels devoted exclusively to the SEACOM circuits in addition to several supergroups each of 60—4 kc/s channels for internal trunk circuits. The radio system will include a one-way Brisbane to Cairns television bearer which will serve the Maryborough, Rockhampton, Mackay, Townsville and Cairns areas.

PERTH-BUNBURY COAXIAL CABLE

A coaxial cable is being installed between Perth and Bunbury in Western Australia to replace the existing pole route, which is incapable of catering for the additional trunk channels that are needed. A four-tube coaxial cable has been chosen in preference to radio as there are a number of relatively small intermediate exchanges that cannot economically be served by carrier channels on a broadband bearer, and which therefore require voice-frequency cable pairs. Such pairs are readily provided at the same time as the main coaxial cable, either within the sheath of the coaxial cable or in separate cables in the same trench.

The cable will carry a broadband trunk telephone system between Perth, Pinjarra and Bunbury, together with television programme transmission from the A.B.C. studios at Perth to the regional television transmitter at Mt. Lennard which will serve the Bunbury coastal area of Western Australia. (Both-way television facilities could be provided in the future if required). The route distance is 118 miles and, as mentioned, voice-frequency conductors within the coaxial cable sheath will serve the trunk telephone needs of all the smaller communities along the route. In the vicinity of Armadale some 13 miles of voice-frequency trunk telephone cables will be laid concurrently with the coaxial cable to meet the heavy demands originating in the rural communities to the north and to the south of Armadale. The route has been laid out to allow Harvey to become a dropout station when telephone traffic density increases.

The cable is being laid at a depth of 4 ft. throughout the route in open trench cut by bucket wheel ditching machines. At this depth, damage to the cable by earth-moving machines, etc., is minimised. In addition, a continuous-flow gas pressure alarm system is fitted; this gives rapid warning in the event of damage to the cable sheath, and helps to keep water out in that event. Moreover, the lead sheath of the cable is isolated from ground throughout the whole distance by means of an 0.1 inch jacket of P.V.C. to protect the lead from electrolytic corrosion.

Twenty unattended repeater stations are being provided along the cable at intervals of approximately 5½ miles, at which spacing the coaxial tubes will be capable of carrying a bandwidth of 6 Mc/s. Power for the intermediate repeaters is fed over the cable from Pinjarra, situated about half-way along the route. The design of the cable is such that, in future years, the number of minor repeater stations can be doubled with a corresponding increase of useful bandwidth to 12 Mc/s, which would effectively double the telephone channel capacity of the cable.

The whole of the cable is Australian made. Outdoor installation commenced during September, 1962, and is due for completion by May, 1964. The outdoor construction is spread over two laying seasons of approximately nine months each with a planned stop-work period during the winter of 1963. By the beginning of April 1963, some 70 miles of coaxial cable and 13 miles of minor trunk cable had been laid, and the cable jointing operations were well advanced.

The broadband telephone and television transmission terminal and repeater equipment is due for delivery late in 1963 and installation is planned for completion by October 1964. Initial telephone channel provision will meet immediate needs and the equipment has been designed to allow future channels (to a total maximum of 1,260 with the present repeater spacing) to be added as required. Facilities will be available for the provision of broadcast programme channels (10 Kc/s width) and multichannel telegraph systems.

CROSS COUNTRY CABLE CONSTRUCTION—INSTALLATION PROGRAMMING BASED ON PREDICTABLE CLIMATIC CONDITIONS

*F. J. HARDING, A.M.I.E.E.**

INTRODUCTION

The largest cross country trenching operation ever undertaken in Australia formed part of the installation work on the Sydney-Melbourne 6-tube coaxial cable (Reference 1). The total length of the cable is 604 miles and 519 miles of trench was cut to a depth of four feet. Work performance data was compiled and analysed while the project was in progress but was necessarily not concluded until about a year after outdoor construction was completed. This analysis was not concerned merely with the efficiency of methods and practices, but examined the whole field of management for similar large projects and reached well substantiated conclusions on the importance of installation programming and its influence on the final installation cost pattern for projects of this type. This article is concerned only with the correlation which has been demonstrated between unit installation costs and climatic conditions, and a new method which has been developed for predicting optimum periods of the year (in any locality) for least cost outdoor construction on cross country cable installations.

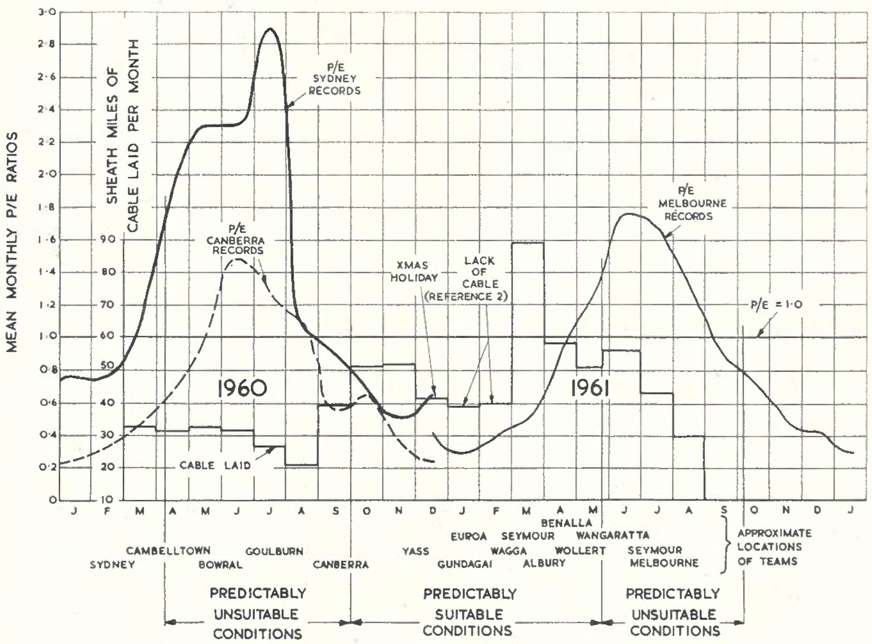

Fig. 2.—Sydney-Melbourne Coaxial Cable. Cable laid per month versus precipitation/evaporation (P/E) ratio.

THE NATURE OF THE WORK

The Sydney-Melbourne project was divided into 14 major geographical sections and, when final costs were available, there was a very wide variation in the installation costs per unit of work done over the 14 sections. Records kept during the progress of the project enabled the following variables to be examined in terms of their influence on unit installation costs:

(a) The soil conditions varied from one major section to another, for example, in some sections extensive deposits of hard rock had to be trenched, whereas in others there was little or no hard ground.

(b) The amount of auxiliary voice frequency cables laid concurrently with the coaxial cable varied from place to place.

(c) The efficiency of the installation teams improved progressively, and in a parabolic manner, as experience was gained.

(d) Temporary shortages of material caused hold-ups from time to time.

(e) There was a wide variation in weather conditions encountered throughout the project.

With reference to factor (e), this particular project had to be completed to a very rigid and stringent time-table which made outdoor construction necessary through two winters and one summer—time did not permit suspension of work during unsuitable weather conditions. These circumstances therefore gave an opportunity to examine carefully the effects of climate on installation cost.

The influences of factors (a) to (d) could be evaluated from the available data and corrections applied to the unit installation costs for the various sections, certain other minor variables being neglected because of their small influence. The corrected unit costs are shown in histogram form in Fig. 1 (shaded columns). It is seen that considerable variation remains and, because there were no major variables other than the weather, it was concluded that these variations were due to the differing prevailing weather conditions. The assumed magnitude of the effect of climatic conditions on costs is shown in the black columns of Fig. 1.

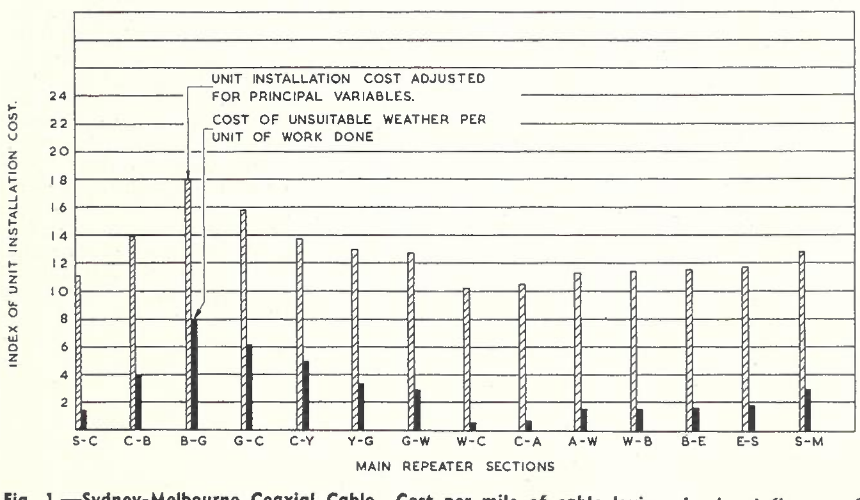

Fig. 1.—Sydney-Melbourne Coaxial Cable. Cost per mile of cable laying showing influence of weather on total cost.

* See Vol. 13, No. 3, Page 269.

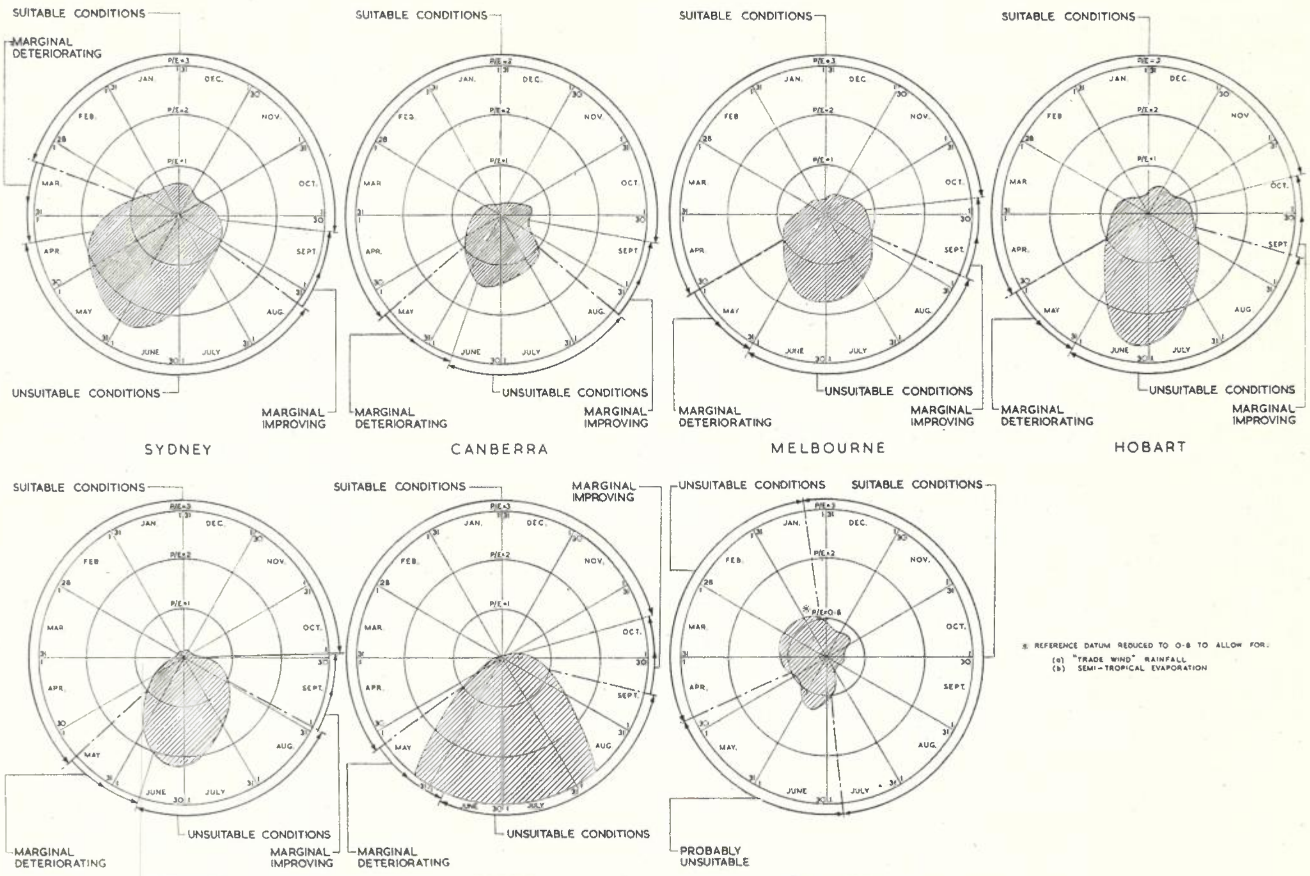

Fig. 3.—Polar Diagrams of Precipitation/Evaporation Ratio for Principal Cities in Australia.

CORRELATION BETWEEN COST VARIATIONS AND CLIMATIC CONDITIONS

Early attempts to correlate the adjusted cost pattern with recorded weather conditions were made on two bases:—

(i) By equating cost variations with the number of wet days for a given period.

(ii) By equating costs with the cumulative rainfall over a given period.

Both these attempts failed to provide a satisfactory correlation, and the nature and effects of rainfall were examined in more detail in consultation with the Bureau of Meteorology, Melbourne.

It became apparent quickly that evaporation rates had to be taken into account in conjunction with rainfall. This is because higher evaporation rates in the summer months nullify, to a certain extent, the impediment of surface water accumulation to cable installation teams.

Mean monthly evaporation rates and precipitation rates were obtained for the principal climatic regions through which the project was installed, these means covering, in nearly all cases, a 30-year period. The ratio of precipitation to evaporation (P/E) was then plotted for the annual cycle. Fig. 2 shows the P/E annual cycles for Sydney, Canberra and Melbourne plotted over the monthly work performance histogram for the project.

The histogram is uncorrected for the variables (a) to (d) but appropriate notes have been included. Fig. 2 shows a satisfactory inverse correlation between P/E ratios and work performance, and the P/E ratios of Fig. 2 show a remarkably direct correlation with the unit installation cost pattern of Fig. 1. This correlation becomes nearly exact when the scale of Fig. 1 is adjusted to take into account different rates of working in the earlier and later sections of the project.

THE APPLICATION OF P/E RATIOS TO INSTALLATION PROGRAMMING

Because of the annual cycle pattern of climatic variations, P/E ratios were plotted for the capital cities in polar form, Fig. 3. $P/E = 1$ was first taken as the reference datum above which conditions were regarded as unsuitable, and below which they were suitable. However further investigation of field observations of soil wetness indicated that a period of about one month should be allowed at the end of the predicted wet season (that is when P/E is greater than 1) for the ground to dry out, and a similar period allowed at the end of the dry season for the ground to become saturated. These marginal periods are shown on the polar diagrams in Fig. 3 together with the predictably suitable and unsuitable periods.

The predictions made on this basis have been shown, on the average, to be valid for many temperate locations where work has subsequently been done. However, for semi-tropical and tropical regions, allowance has to be made for more uniformly high evaporation rates and hence greater weight has to be given to the effect of rainfall. This has been done with apparent validity for the Brisbane area by reducing the reference datum to $P/E = 0.8$ in lieu of 1—see Fig. 3.

The first application of climatic prediction to construction programming has been to the Perth-Bunbury coaxial cable project in Western Australia, based on the P/E polar diagram for Perth given in Fig. 3. The project involves the installation of about 120 miles of 4-tube coaxial cable including an outer layer of 10 lb. per mile voice frequency quads, together with some 13 miles of auxiliary VF cables. The required completion date for the outdoor construction is 1st May, 1964, and the whole of the programme to achieve this target was created primarily around the predictions for suitable climatic conditions. Thus surveying, contracts for material supplies, provision of mechanical plant, staff training, cable manufacture, etc., were timed for a start on outdoor construction to be made at the beginning of the predictably suitable period of 1962/63. The installation rate was programmed to cover two laying seasons, proceeding at a moderate rate, in order to reduce the field staff employed and hence field supervision difficulties, and to cause the minimum disturbance to other more normal construction activities in the State. The overall objective at all times was to achieve maximum productivity and minimum installation cost, at the same time systematically bringing into service those sections of the installed plant where the traffic demand was the highest.

Fig. 4 shows the installation programme for the Perth-Bunbury project which comprises rate charts for cable supply, cable laying, initial jointing, loading and balancing, overall testing and cable protection works—the principal functions of a coaxial cable outdoor installation.

One further example is given in Fig. 5 of the current installation programme for the forthcoming Wagga-Griffith coaxial cable project in New South Wales. This figure shows the form in which basic programming is evaluated. A table of P and E values and P/E ratios is drawn up for the principal climatic areas on the route and a composite polar diagram of P/E ratios constructed. From this it is possible, if the climatic conditions are different, to nominate at which end of the route construction shall commence. In this case it will be commencing at Griffith to take advantage of the somewhat longer predictable period of suitable climate. (Auxiliary advantages also came to light during this study which showed that minimum disturbance would be caused to standing crops by starting at Griffith).

From this basic data the cable manufacturing and delivery programme and the field installation programme was drawn up. It will be seen that the project is to be constructed in one laying season only, so that larger forces will have to be employed to achieve a faster programmed rate than for the Perth-Bunbury project. It is also evident that some risk has to be taken with climatic conditions towards the end of the construction period. In the foreknowledge that this risk exists it is possible to plan in advance to increase the size of the installation teams if the programmed rates seem unlikely to be achieved.

AUXILIARY BENEFITS

The auxiliary benefits of this type of systematic programming are far-reaching. Four of the more important results, in addition to the obvious improvements in field productivity, are:

(a) It is possible to draw up a reliable programme for cable manufacture over a 3 to 4 year period, thus giving uniform loading to cable manufacturing plants and an opportunity to improve productivity in cable manufacturing.

(b) It is possible to plan the deployment of outdoor construction staff so that a higher percentage of city work is done in wetter weather. Thus by judicious local planning, uniform staff loading can be achieved even though the majority of cross country work is confined to about one half of the year.

(c) Reliable programmes can be drawn up to permit adequate time for the important functions of surveying, site selection for unattended buildings and land acquisition.

(d) Financial appropriations can be made with confidence and accuracy when the variables which can upset estimating accuracy are reduced to the minimum.

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1. Barry, D. and Hosking, C. H., "Installation of the Sydney-Melbourne Cable"; Telecommunication Journal of Australia, Vol. 13, No. 3, page 187.

2. Vermont, G. J. B., "Manufacture of the Sydney-Melbourne Cable"; Telecommunication Journal of Australia, Vol. 13, No. 3, page 184.

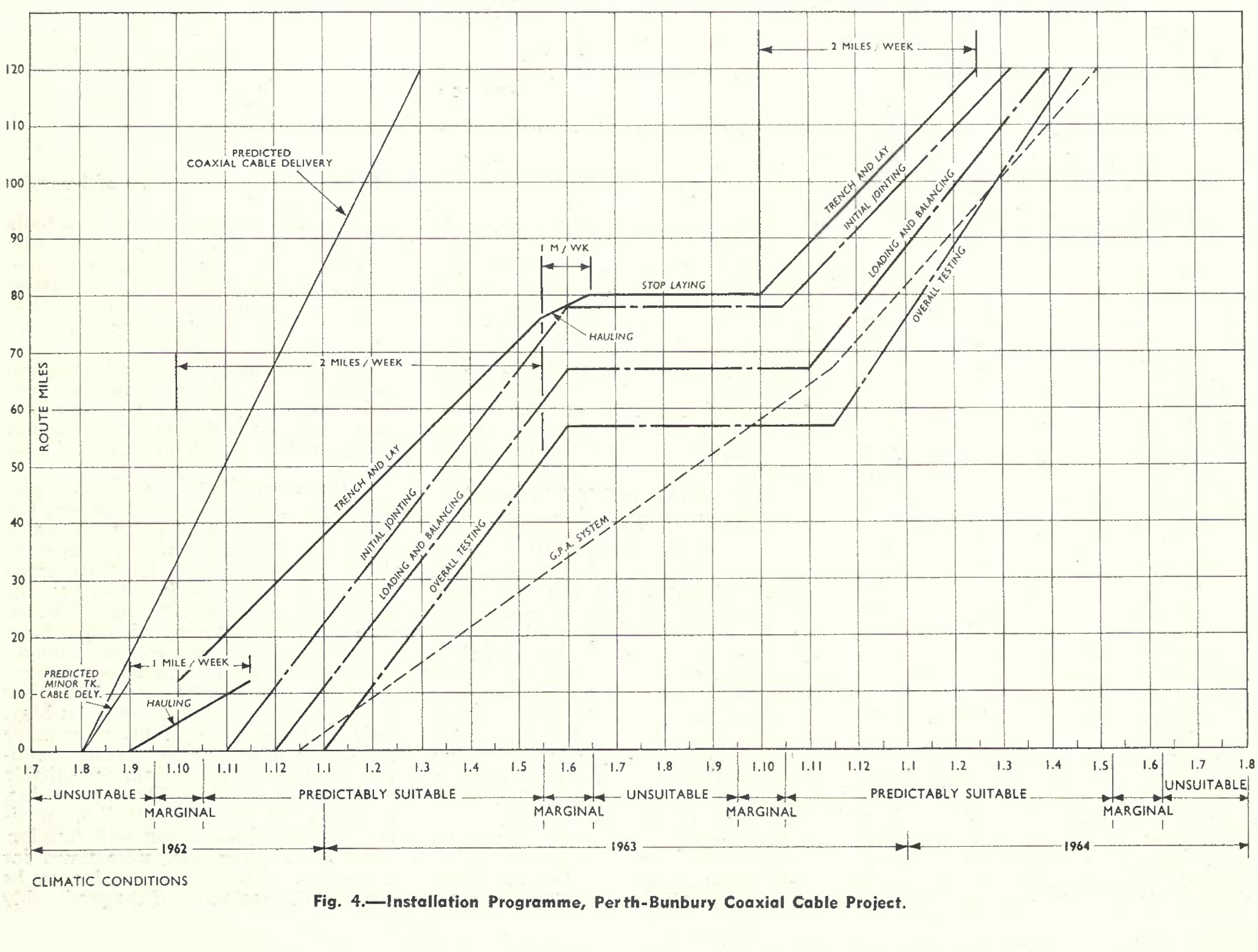
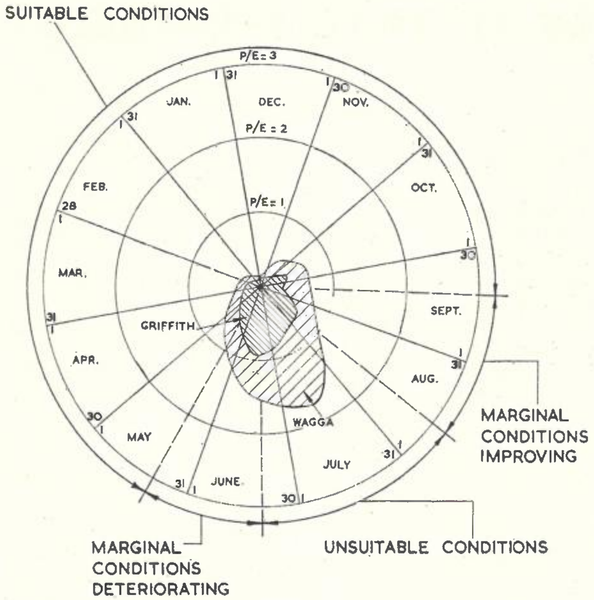
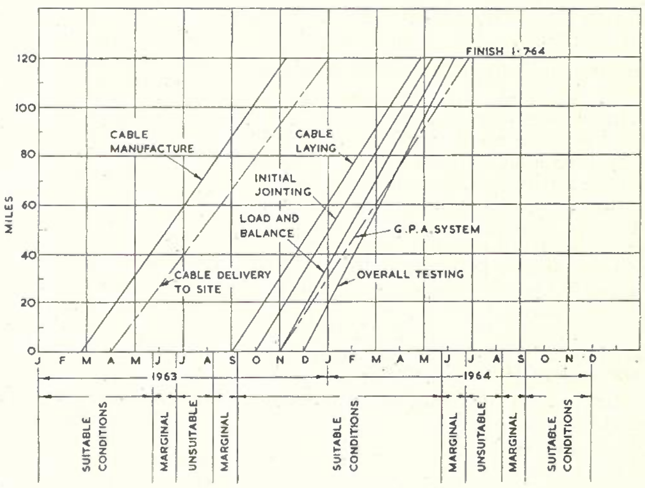


Fig. 4.—Installation Programme, Perth-Bunbury Coaxial Cable Project.





WAGGA	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
P	1·51	1·76	2·03	1·68	1·88	1·95	2·30	1·72	1·94	2·78	1·94	1·39
E	9·44	6·94	6·29	3·8	2·17	1·31	1·31	1·83	2·79	4·21	5·93	8·47
P/E	·16	·254	·323	·442	·867	1·49	1·75	·94	·695	·66	·329	·164
GRIFFITH												
P	1·05	1·13	1·39	1·24	1·36	1·63	1·28	1·56	1·17	1·71	1·18	1·30
E	10·46	7·58	6·26	4·05	2·57	1·75	1·78	2·52	4·0	5·57	7·44	9·50
P/E	·1005	·15	·222	·307	·53	·933	·72	·62	·292	·37	·159	·137

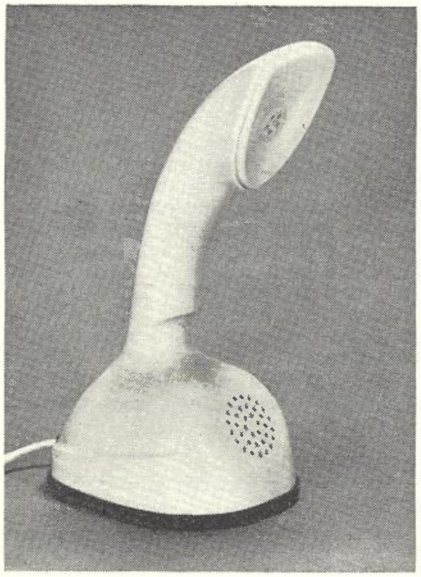
Fig. 5.—Installation Programme, Wagga-Griffith Coaxial Cable Project.

TECHNICAL NEWS ITEM

A NEW TELEPHONE FOR AUSTRALIA—THE ERICOFON

In response to the growing subscriber demand for modern telephone facilities, the Australian Post Office recently decided to extend its range of telephone instruments by introducing the unconventional Ericofon. As will be seen from the photograph, the Ericofon is a single piece automatic telephone of unique design. It has achieved wide public acclaim in several overseas countries, especially for office and bedroom locations, as a conspicuous telephone that requires little table surface area. Colours being purchased by the A.P.O. are ivory, silver grey, carnival red, surf green, and mushroom.

Ericofons are being offered to subscribers as additional instruments on direct exchange line services or as P.B.X. extension instruments insofar as they are technically compatible with other conventional instruments. This means that on a direct exchange line service, an Ericofon may be connected as a second portable instrument, or a second or third parallel instrument, or through a change-over key, provided that one instrument on the service is of the 300, 400, or 801 type.



On a P.M.B.X. or P.A.B.X. extension line Ericofons may be connected alone, in pairs, or together with any other standard instrument, to offer portable or parallel facilities. Press button recall is not a feature of this telephone.

On an exchange service, if the Ericofon is fixed and the other telephone is of the 801 type, the Ericofon internal A.C. buzzer is connected to operate to incoming ring signals. The buzzer is also connected when the Ericofon is a P.B.X. extension unless it is combined with a telephone other than an 801 type. In all cases additional standard alarm equipment may also be connected.

A 6-connection flat plug and socket has been standardised by the A.P.O. for all new telephone instruments and for new portable services. This combination will therefore be used with the Ericofon to achieve ease of interchangeability. A 3-conductor semi-retractable ivory coloured line cord interconnects the plug and Ericofon.

For maintenance purposes the Ericofon is to be subdivided into units comprising plug and cord, the base chassis with dial, the case with receiver, and the transmitter. This is in line with the revised A.P.O. field maintenance techniques, under which all instruments are being divided into functionally separate sub-assemblies or units which may be replaced independently if faulty.

TELECOMMUNICATION SOCIETY OF AUSTRALIA—COUNCIL OF CONTROL

REPORT FOR TWO YEARS ENDING 30th APRIL, 1963

The last annual report of the Council of Control was for the year ending 30th April, 1961. The present report covers two years' activities of the Council.

Telecommunication Journal of Australia

The demand for the Journal has declined over the past two years from about 6,500 to about 5,500 with the February 1963 issue. Not all of this reduction may be attributed to a falling-off in subscribers; some is due to more cautious estimates of requirements by State Committees and the Council with a view to reducing stocks to a minimum. Nevertheless, the reduction is serious enough to merit another special effort by State Committees similar to that which produced the spectacular increases from 2,600 in late 1959 to 6,500 in early 1961.

The current distribution is approximately as follows:—

New South Wales	1,500
Victoria	1,800
Queensland	620
South Australia	450
Western Australia	350
Tasmania	300
Australian Post Office (for official distribution to firms and institutions in Australia and abroad)	83
Overseas (to 34 countries)	252
	5,355
Central stocks (for advertising agencies, authors, late orders, etc.)	145
	5,500

With the exception of the special (Sydney-Melbourne coaxial cable) issue of February, 1962, the size and net unit cost of the Journal have continued at about 92 pages and about 5/4d. respectively; the avoidance of a cost increase is attributable to continued and increased support by advertisers. The Journal is listed in A.A.R.D.S. (Australian Advertising Rate and Data Service) and in I.M.G. (International Media Guide).

Since the June 1961 issue, the Journal has been produced with sewn sections and a square spine, an improvement on the earlier stapled process, at a cost of about £110 per issue. The cost to subscribers has remained unchanged at 10/- for three issues or 4/- for single issues, post free.

The supply of suitable articles continues to be precarious, having regard to the need to serve a broad range of interests among our readers. Publication delays are being experienced again, following a period of recovery, mainly due to an inadequate reserve of articles.

Criticisms of the Journal have been invited from State Committees, and contributions have been received from some States.

A proposal to vary the subscription year and Journal numbering to be in accordance with international standards was under discussion by Council in April 1963.

Australian Telecommunication Monographs

A new publication—Australian Telecommunication Monographs—was under consideration in April 1963. A need has been felt for a publication medium for articles of particular merit, which because of their highly specialised content would not appeal to the general subscriber to the Journal. It is proposed to publish such articles from time to time as Monographs in the above series. The details of the proposal are being discussed with the Australian Post Office which has given general approval to the new publication.

Financial Arrangements

After negotiations over the past two years, an agreement was concluded with the Australian Post Office in December 1962 which ensured a contribution to the Society of £2,900 per year for three years, subject to joint review. The outcome is most satisfactory to the Council, and enables it to plan its operations more effectively than under the previous arrangement, whereby the Society paid all receipts (except for working expenses) to the Post Office, and the Post Office paid all printing bills.

Personnel

The then Deputy Director-General (Mr. F. P. O'Grady) was Chairman of the Council of Control at the beginning of the 1961/62 year but retired from the position in late 1961. Mr. C. J. Griffiths (Deputy Engineer-in-Chief) acted as Chairman until expiry of the Society's year on 31st May, 1962. The Director-General nominated Mr. E. Sawkins (Engineer-in-Chief) as Chairman for the 1962/63 year.

Other Council members have been unchanged over the two years covered by this report:—

State Councillor, New South Wales: Mr. N. A. S. Wood.

State Councillor, Victoria: Mr. A. C. Wright.

State Councillor, Queensland: Mr. J. Pryor.

State Councillor, South Australia: Mr. D. S. Watson.

State Councillor, Western Australia: Mr. E. L. Brooker.

State Councillor, Tasmania: Mr. A. N. Birrell.

Editor-in-Chief: Mr. N. M. Macdonald.

Treasurer: Mr. W. J. B. Pollock.

General Secretary: Mr. R. G. Kitchenn.

The Board of Editors comprised, in addition to the Editor-in-Chief, Messrs. R. C. M. Melgaard, E. R. Banks, and D. P. Bradley. Two of the Editors, Messrs. Macdonald and Melgaard, retired under Clause F3A of the Constitution on 31st May, 1962, and were reappointed for a further period of four years. The Council acknowledges its debt to the Board of Editors, to the various Sub-Editors in all States, and to authors who have contributed to the Journal.

The Editorial Board has been augmented by the reappointment to the Board of Mr. V. J. White, a former Editor of the Journal, following a greatly increased work-load in connection with the publication of the Journal.

Our European Agent at Australia House, London (Mr. A. Kellock) has continued to be of great assistance in promoting the Society's interests in Europe. Current bulk despatches to London comprise 75 Journals, which are sent on to individual subscribers by Mr. Kellock who acts as a State Secretary in this respect. Many European subscribers still order their Journals direct from Australia via commercial agencies. Mr. P. S. Bethell will replace Mr. Kellock for the 1963/64 year, following Mr. Kellock's return to Australia.

Circulation Audit Board

The Society has applied for, and has been granted, membership of the Circulation Audit Board, subject to the release of an initial Audit Certificate, the preparation of which is under examination at present. Council believes that C.A.B. membership will be of advantage in its dealings with advertisers and advertising agencies, and that the audit certificates of circulation will assist in the management of the Society.

THE NEW AERIAL SWITCHING SCHEME AT RADIO AUSTRALIA, SHEPPARTON—GENERAL DESIGN AND PERFORMANCE

*D. B. CLIFF, F.R.M.T.C., Grad.I.E.Aust., A.M.I.R.E.Aust.**

INTRODUCTION

One facility of prime importance at the International High Frequency Transmitting Station, Radio Australia, is that of providing flexible switching between transmitters and aerials. At this station, where a limited number of transmitters is required to operate on a number of different frequencies throughout any 24-hour period, the switching system must be capable of providing rapid connection.

When Radio Australia (Ref. 1) was first installed in 1944, access from any of the three transmitters to any of the nineteen aerials was required. The type of switching system installed was of the sequential type (Ref. 2) in which connection was made through a series of switches, these being remotely controlled from within the transmitter building. Monitoring of correct switch operation and transmitter interlock were also provided. Although a sequential switching system is inherently inflexible, the relatively small number of inputs to the system meant that access problems were readily overcome.

With the advent of an increasing number of transmitters and aerials in the expansion programme of 1956-1962, the switching system had to be enlarged. This proved to be possible only to a limited degree, as enlargement of the sequential system to the required degree to provide for the number of additional transmitters and aerial connections and give full availability (that is any transmitter should be capable of being switched to any aerial irrespective of the interconnection of other transmitters with other aerials) would have been very costly and have increased the complexity of the control system to a great extent.

LIMITATIONS OF ORIGINAL SWITCHING SCHEME

The system as it existed before this work commenced comprised three distinct groups of switches, of the type shown in Fig. 1. The groups were as follows:

1. A group of switches which allocated the lines from the transmitters to three lines to the "North" switching group and three lines to the "South" switching group.
2. The "North" switching group provided connections between the three incoming lines and the aerials situated in this area.
3. The "South" group provided similar connections for aerials in this area.

There were several undesirable limitations, inherent in this system, which became determining factors in transmission schedule preparation as the required facilities and programmes increased:

(i) Only three transmissions were possible to any one switching group. This meant that it was often not possible to broadcast to required target areas with the desired number of aerials, or that different target areas whose aerials were all in one group could not be served simultaneously.

(ii) A further restriction existed due to the design of the system in that only two of any group of three aerials could be used at any one time, that is the system lacked the desirable "full-availability" feature.

The effect of these limitations could not be foreseen when the station was planned. The system was more than adequate for the required service at the time, and was comparable with contemporary switching systems. The difficulties arose only as the demand for transmissions and facilities increased.

An appraisal of the situation at this stage indicated the need for a complete redesign of the aerial switching system, and the provision of a more suitable and flexible system. In addition to the undesirably complex control of an expanded sequential system, this principle was discarded because a large number of transmission line switches would have been needed if the desired "full availability" feature was to be achieved, or even approached. Each switching point introduces transmission line impedance irregularities which cause standing waves on the transmission line for which correction can only be performed at the point where the line from the aerial connects to the last switch in the group. Lines from that switch back to the transmitter are multi-frequency as they must carry transmissions to different aerials, and cannot conveniently be corrected to improve the standing wave ratio. Further, short lengths of line which would exist between switches when not in use could appear as resonant circuits, and have high voltages induced in them with consequent hazards to personnel and plant.

Several types of switching system were available for study at this time, but the most favoured type was similar to the so-called "crossbar" switch at Radio Lyndhurst, Victoria (Ref. 2) which had been installed for the 1956 Olympic Games and had given satisfactory operation since that time. (The term "crossbar" had arisen in reference to this switching principle, although this is technically incorrect. A more appropriate term is "matrix" which will be used for this paper.)

REQUIREMENTS OF NEW SWITCHING SCHEME

It was considered that a suitable type of switching system should fulfil the following criteria:

1. Give full availability.
2. A minimum number of switching points between transmitter and aerial, and hence a minimum of transmission line impedance irregularities.
3. A minimum degree of R.F. coupling between adjacent circuits.
4. A maximum of safety to personnel.

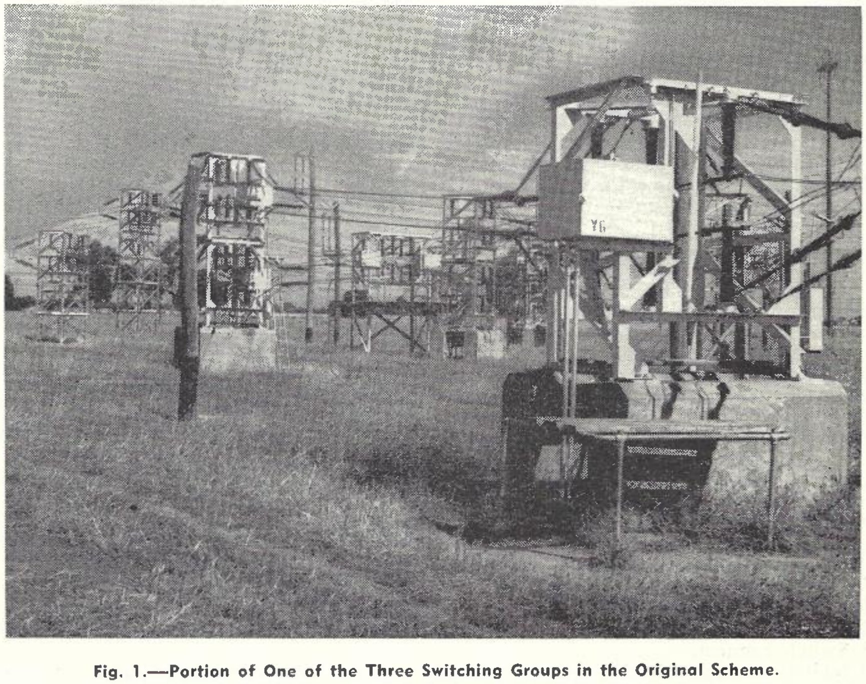


Fig. 1.—Portion of One of the Three Switching Groups in the Original Scheme.

* See Page 81

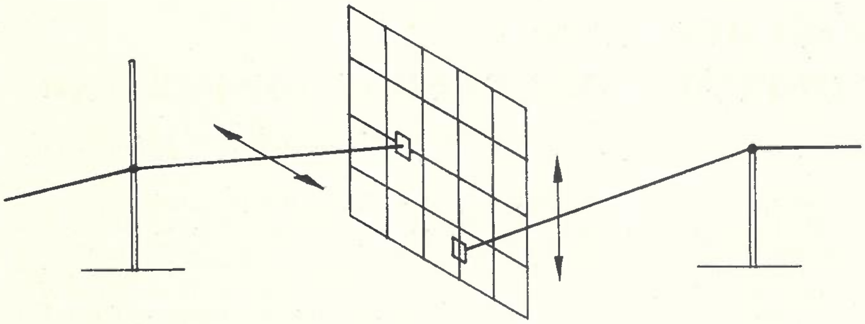


Fig. 2.—Principle of the Shepparton Matrix Aerial Switch.

5. A remotely controlled and monitored operation as the switch would be located away from the transmitter building, due to its physical dimensions.
6. The transmission line impedance should be 300 ohms balanced.
7. The switch capacity should be 10 transmitters and 36 aerials.
8. The switch should be capable of carrying 100kW of fully modulated R.F. power.
9. Operation of normal transmission schedules must not be interrupted during conversion to the new system.

The matrix switch was the most suitable to fulfil these requirements, and in addition, could be designed to meet the local conditions. The principle of the switch may be seen from Fig. 2 and the following brief description.

The four-wire lines from the transmitters terminate on the transmitter terminating frame. At this point they become two-wire and pass to the pivot structure and thence via a pivoting connection to the transmitter connectors. These connectors move horizontally over the inner circumference of the switching structure and mate with aerial connectors which move vertically over the outer circumference of this frame. The varying length of the aerial connectors as they move from bottom to top of the central frame is taken up by suitable telescoping joints at the outer or aerial terminating frame. From this frame the lines revert to a four-wire configuration to go to the aerials.

MATRIX SWITCH DESIGN

As far as could be ascertained, there was no other switch of this type operating at 100kW power levels in use or under development anywhere in the world, so it was necessary to design and engineer the project in its entirety. Although based on the earlier design used at Lyndhurst Radio Station as mentioned earlier, it is much larger in construction, has a greater number of connection points, operates at much higher power levels and is operated under remote control. The detailed design of the switch will be outlined under the following headings:

1. Operating sequence.
2. Control circuits.
3. Switch connectors.
4. Switch connector driving units.
5. Structural layout and design, including foundations.
6. R.F. Fittings.
7. Reliability and Testing of Prototype Switch.

1. Operating Sequence

The sequence of events in the setting up of a connection on the Lyndhurst switch was firstly considered as a possible basis for the Shepparton project. The sequence (see Ref. 2) is as follows:

1. The required aerial connector is raised to a level above that of the required transmitter connector.
2. The transmitter connector is brought round opposite the selected aerial position.
3. The aerial connector is lowered to meet the transmitter connector and is supported by it.

The release of the combination is the reverse of these events.

A relay switching sequence to fulfil these conditions was developed but was excessively complex, due to the required reversal of the aerial carriage motion, and it was considered sufficient for the following sequence to occur:

1. The transmitter connector be driven to a position opposite that of the aerial connector.
2. The aerial connector be raised to make contact with the transmitter connector.

The release is the reverse of these.

This change of sequence had the implication that the aerial connector would need support from the lifting device, and not from the transmitter connector.

2. Control Circuits

Prior to the detailed design of the control for the aerial switch a study was made of the logic required of a matrix control system as compared with the sequential logic of the original switch control system. The sequential logic in which a particular event depends on previous events, differed from the matrix logic found necessary for the new switching system, in which functions of the transmitter ("inlet") and aerial ("outlet") could only be associated in a particular connection. At the completion of this connection and for its subsequent release, information pertaining to the selected transmitter and aerial must remain associated. This association must be to the exclusion of all others, and since ten connections could exist through the switch simultaneously, this exclusion was necessary for each.

The following features were therefore required:

1. The circuit should be as simple and reliable as possible.
2. The essential nature of the matrix switch required that any transmitter should have connection to any aerial.
3. All switch connectors should have a home position from which a selection is made, and to which they return when a selection is released. This was essential if the control circuitry was

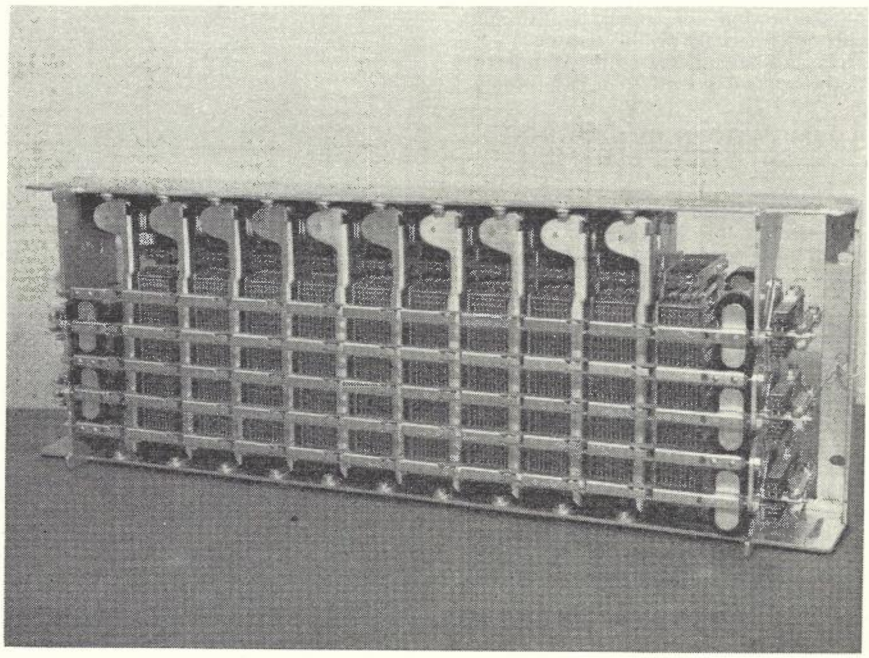


Fig. 3.—Crossbar Switch chosen for the Control System.

not to become excessively complex through catering for a connection with the switch connectors in random locations.
4. Only one combination should be selected or released at any one time.
5. Although individually selected, a maximum of ten connections could exist through the switch.
6. It would be desirable to utilize the existing aerial system control voltage of 50V D.C. to facilitate future cutover procedures.

In the initial stages of the control circuit design, many relays in the remote control desk and a large number of limit switches on the aerial switch structure were needed. It was not possible to achieve a reduction in the number of switches and relays until the possible advantages of some mechanical assistance in the sequence of operations were considered. A feature of the Lyndhurst switch was the use of a control rod at each aerial position, the function of which was to act as a stop for the transmitter connector. It was thought that the use of a similar rod which would act as a marker of the selected aerial and also as a control system element could be useful. The subsequent investigation resulted in the use of control rods which had rotational as well as vertical movements, which together with a number of other mechanical devices gave the required operation. Substantial simplification of the control circuit was then obtained. A diagrammatic explanation of the operation is set out in a companion paper in this issue of the Journal. (Ref. 3). With this electro-mechanical type of operation, only 82 limit switches were found necessary for the basic operation of the full structure, that is for 10 transmitters and 36 aerials. It was, however, necessary to add further switches to the system to provide interlocking facilities of the transmitter, monitoring of the home positions of the connectors, and a number of safety features necessary for the reliable operation of the switch.

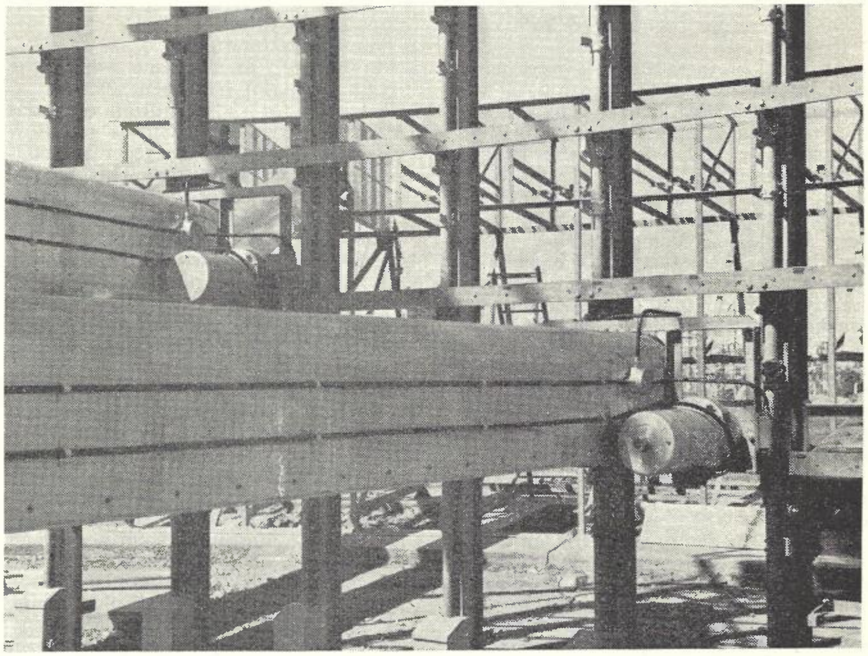


Fig. 5.—Transmitter Arm Drive Units mounted on the Arms.

With the basic electrical and mechanical circuit design complete, the Victorian Postal Workshops Drafting Section was approached with the request to translate these requirements into physical reality, and to proceed with the overall structural design of the switch proper. This Section had previously been responsible for similar work on the Lyndhurst switch, and some details of the work carried out on the matrix switch for Shepparton forms the basis of the companion paper already referred to.

A number of important auxiliary features were necessary in the control system, which affected both the switch structure and the design of the remote control in the transmitting building. These were:
1. The provision of transmitter interlock. This facility ensured that the required transmitter could not be fully switched on until its connection to an aerial was complete.
2. The protection of a transmitter-aerial connection from release while the transmitter was on the air. Protection and indication must also be available should the connection be broken.
3. A reliable method of monitoring the aerial connected to any transmitter at all times.
4. A method of monitoring at the control desk the operation of the automatic sequence of operations.
5. The provision of appropriate alarms to indicate the malfunctioning of faulty parts or sequences.
6. Several of the aerials used are capable of transmitting in a number of directions, the direction required being obtained by the operation of a number of transmission line stub switches. The control of these switches was also to be included in the new switching scheme.
7. The method of motivation applied to the arms should be controlled by 50V D.C. and operated by 415V A.C., 3 phase motors in order that the required reversal of drive could be readily achieved.
8. The control system was to be capable of operating in tandem with the existing system during the period of the cutover. Compatible characteristics

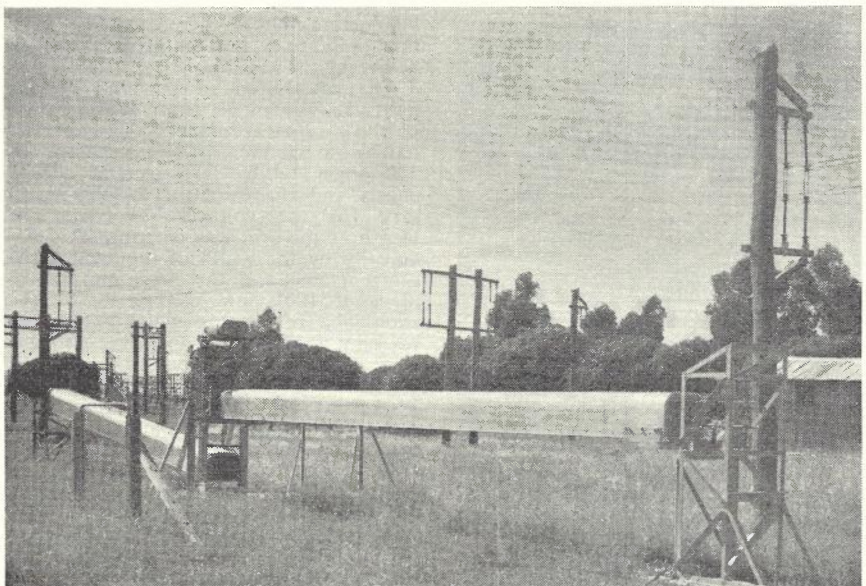


Fig. 4.—General View of "One-by-one" Prototype Switch.

were therefore required of both control methods.

As most of these features were associated with matrix information it was evident that a slave matrix would satisfy the requirements. After investigation, the solution adopted was the use of crossbar switches which, at the time, were being introduced into telephone equipment practice in this country. A very simple and comprehensive circuit for the auxiliary features was possible using the switches, a circuit which was readily fitted to that developed for the operation of the switch itself. The type of switch chosen is shown in Fig. 3, and was fitted with ten preselect magnets with associated five two-way bars, and ten hold magnets and bars. With the preselect magnets associated with aerial functions and the hold bars associated with transmitter functions, all the required information could be readily obtained.

The features required for the ten transmitters and thirty-six aerials were obtained by the use of four crossbar switches. Each hold magnet in one switch was commoned with the corresponding magnet on the other three and associated with a transmitter. Forty preselect magnets were available of which thirty-six were used, each being associated with an aerial. In operation, the circuit is so arranged that the aerial preselection occurs first. The successful conclusion of the selection operates a limit switch which in turn operates the cross-bar hold magnet associated with the transmitter. The limit switch concerned is mounted on the transmitter connector of the aerial switching structure and is operated when the R.F. contacts are made. At the completion of the selection, the aerial preselect magnet is released.

The circuits through the crossbar switch matrix were used to provide the following facilities:

1. Transmitter interlock.
2. Monitoring to indicate that the required aerial has been selected.
3. Provision for the operation of aerial direction changing switches to allow the direction to be changed while connected to a transmitter. This feature also includes protection to ensure that such operation is not possible while the transmitter is operating.
4. A release guard to ensure that the aerial cannot be released while the transmitter is operating.
5. Monitoring to indicate directly the aerial to which the transmitter is connected.

The display of transmitter — aerial connections needs ready interpretation by the operator. The provision of a grid of 10 x 36 lights as a method of indication, while being relatively simple to obtain, had the disadvantage that it did not readily show the connection, as the particular transmitter and aerial had to be found from designations at the grid extremities. A direct method was employed using digital display units. The display unit selected from the many types available contains twelve characters, each engraved on individual perspex strips which, when end lit, cause the characters to be visible from the front of the units. The aerials at Radio Australia are given local designations such as J15, that is, a 15 Mc/s aerial for transmission to Japan. With the use of three display units and three crossbar switch connections for each transmitter, it was possible to provide direct indication in the local terminology of the connection obtained.

3. Switch Connectors

As the moving connectors of the switch formed part of the transmission line and R.F. coupling between lines was to be kept to a minimum, it was evident at an early stage that the connectors should be hollow, rigid, and made of a shielding material. The conductors could then be mounted inside this "arm", which could be given motivation because of its rigid nature. A suitable material, "Alumply", was suggested by one of the authors of the companion article. This is essentially half-inch bondwood which is sheathed on both sides by aluminium. The resultant product is very stable and is unaffected by weather. It was further indicated that the material could be moulded to the required shapes, so that the original idea of a rectangular cross-section arm composed of four flat side sections of Alumply could be discarded, and a more suitable two-piece section designed.

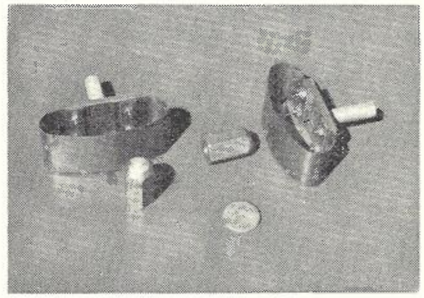


Fig. 7.—R.F. Contacts (The coin is 2/-).

Since the actual contact was to be made by the aerial connector moving vertically to mate with the transmitter connector, the displacement of the contacts would be on a horizontal plane. The conductors would be supported in the arm in the same plane. A variation of this configuration was required at the pivot end of the transmitter arm. At this point, the conductors should be in line vertically in order to pivot about the same vertical axis as the arm. The conductors should therefore twist from this point to a horizontal displacement as quickly as possible.

The calculation of the line spacing and size was made from consideration of the arm as a balanced screened pair having a characteristic impedance of 300 ohms, taking into account corona effects and the insulator lengths necessary for the voltages involved. The length of the arm was determined mechanically by the width of the arm at the centre frame and the maximum movement of 180°, and electrically by the avoidance of lengths which would be resonant at any of the operating frequencies. The resultant shape of the arm was essentially an inverted U, 25 feet long, 14 inches high and 17 inches wide. Across the bottom was attached a flat panel of "Alumply" which was removable for maintenance access to the transmission lines. These passed through the tube and were supported by four sets of insulators mounted from the top of the arm. In its final form the arm was sufficiently light to be carried by two men and can be seen in Fig. 4.

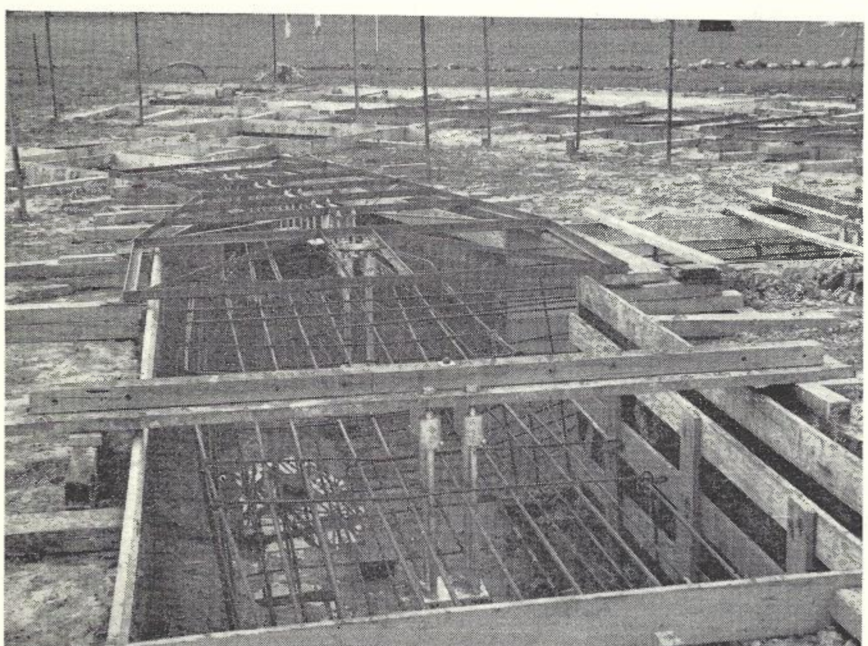


Fig. 6.—Foundation Excavations showing Bolt-holding Jigs.

4. Switch Arm Drive Units

A number of points concerning features of the arm driving units had already

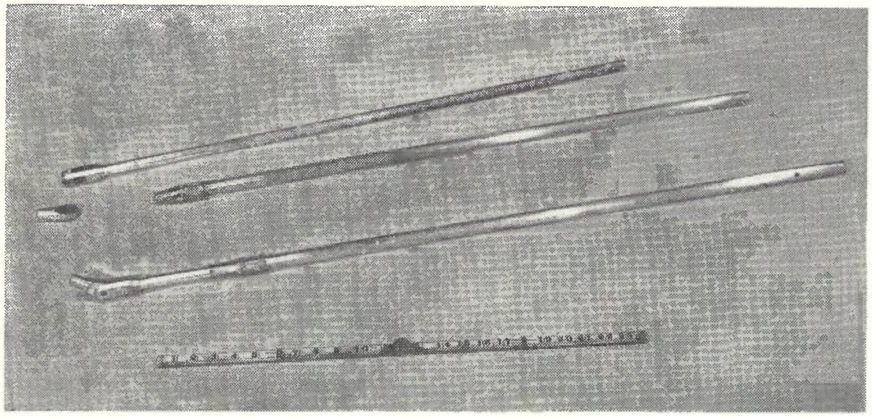


Fig. 8.—Telescoping and Pivot Fittings.

been fixed by the control circuit design, that is, the aerial arm lifting device would require a strong brake to hold the arm in position without slip, and both the aerial and transmitter arm driving units would require three phase motors to conveniently obtain the reverse drive.

One of the authors of the companion article was instrumental in suggesting both types of units. The novel way in which the transmitter arm was driven and a detailed description is given in the article. Fig. 5 shows a transmitter arm drive unit in position.

5. Structural Layout and Design

The design of the structure for the switch was one of the major problems of the project and is also dealt with in the companion paper. It is sufficient to mention here that extremely fine tolerances were necessary. Steel columns, 22 feet long, had to be straight to within $\frac{1}{8}$ inch over the full length. Rails to support the transmitter arm required an accuracy for the 25 feet radius of $\pm \frac{1}{8}$ inch. In the foundations for the structure, a similar order of accuracy was required. A surveyor was engaged in order that the relatively complicated foundation was placed accurately, and braced steel jigs were used to position the foundation bolts in the correct positions in the excavation before the concrete was poured, as shown in Fig. 6.

6. R.F. Fittings

A number of specialised fittings were required for the transmission lines. These were:

1. A pivoting joint in the conductors, located at the point where the transmitter arm pivoted.
2. The actual R.F. contacts which meet at the centre structure when a selection is made.
3. Telescoping fittings at the outer structure needed to take up the variations in position of the outer end of the aerial arms, as the inner end moves vertically on the centre structure.
4. Pivot joints to allow for variation in angle from the horizontal at the outer end of the aerial arm as it is raised or lowered. These fittings would be the same as for the transmitter arm pivot point.

The joints designed to provide pivoting were of simple fork and eye configuration, sweated into the ends of the copper tube conductors. It was thought desirable to attach a flexible strap across the joint to ensure proper conductivity in case the contacting surfaces of the joint became tarnished with weathering. This was simply a precautionary measure as the contacting surfaces should be self-cleaning.

The design of the actual switching contacts was influenced by the following considerations:

1. As the operational sequence required that the aerial arm be raised to meet the transmitter arm, the shape of the contact should allow this condition.
2. The contacts must be capable of carrying R.F. currents of the order of 30 amps. and corona must not occur.
3. The contacts should not be excessively large if impedance irregularities were to be minimised.
4. A tolerance of $+\frac{1}{4}$, -0 inch was required in the mated position.

Experience with the Lyndhurst switch indicated that a point contact, under sufficient pressure, was quite efficient, reliable and capable of carrying the required R.F. current. An advantage of this type over a flat configuration was that the contact was definite and was not prone to small arcs as would occur if flat contacts did not engage correctly. The final form of the contact is shown in Fig. 7.

The principle of telescoping fittings was accepted when initially determining the operation of the aerial arm. Telescoping sections had been successfully used in the 100kW transmitters at Radio Australia for many years and had indicated that the operating currents could be handled adequately. The fittings were carefully designed to ensure that proper contact was made between the sliding surfaces. Because of the nature of the fitting, a single, high pressure contact was not possible, and a number of low pressure points were provided. The final fittings provide a maximum travel of 20 inches, this being the variation at the rear end of the aerial arm. The telescoping fittings are described in detail in the companion paper, and are shown with the pivot fitting in Fig. 8.

7. Switch Reliability and Testing of Prototype Switch

The relatively simple forms of switch driving methods, fittings and control circuits indicated that the reliability that could be expected from the switch would be good. The control system operated on a "fail safe" basis, that is, in the event of a component failure or power failure, the resultant condition would be safe. In addition, protection against spurious earth faults in the control circuit was obtained by placing all relay and contactor coils at the earth end of the circuit. Reliability of the operational sequence and all components was ensured in a thorough testing programme, described later, although the

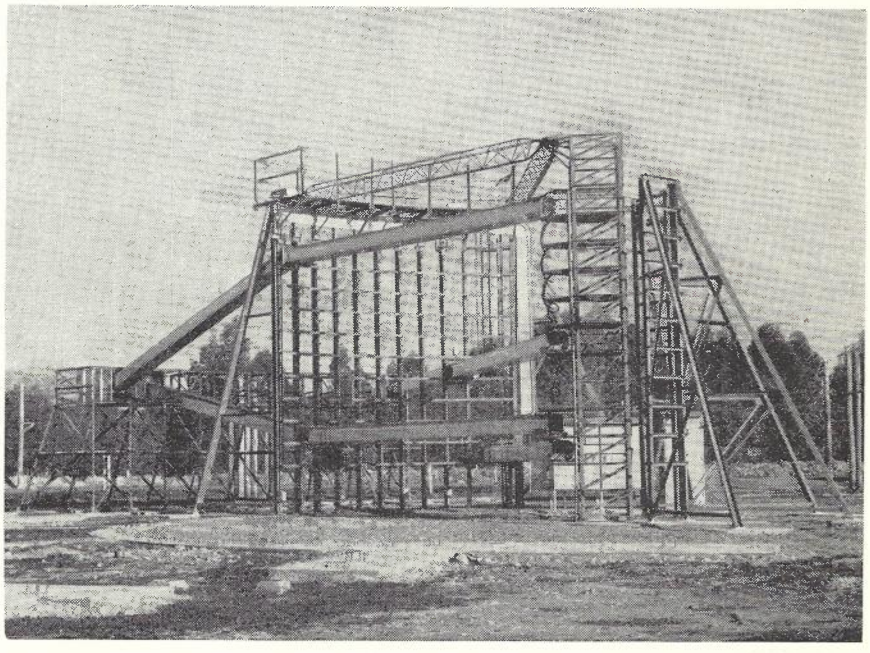


Fig. 9.—Partially Completed Switch Structure equipped for Testing.

tests performed in all cases were carried out during developmental stages.

The first important tests were static in nature and were performed on a sample arm which had been obtained. The tests were:

1. The measurement of the characteristic impedance of the arm with the transmission lines in position. This was to verify the calculated figures.
2. Voltage and power tests to ensure that the insulators would successfully withstand the expected transmission conditions and that the conductor diameter was sufficiently large to ensure corona free conditions.

The determination of characteristic impedance was made by the method of open and short circuit measurements. The measured value agreed with the figure calculated theoretically.

The voltage and power tests were carried out with the arm and its conductors inserted in the transmission line to an aerial. The output of a 100kW transmitter was switched to the line, and the transmitter brought gradually to full power. When this had been successfully achieved, the transmitter was 100% tone modulated, again successfully. Following this, a quarter wavelength short-circuited stub was placed on the line between the arm and the aerial, and was progressively shortened to cause a high standing wave ratio to occur in the arm. The VSWR reached was 5:1 which was not exceeded as damage to the transmitter may have occurred. This process was repeated on another transmitter frequency, and all tests were completely satisfactory. These tests had the effect of producing voltages in the arm considerably greater than would be experienced under normal operation.

In order that more extensive testing could be performed it was decided to build a "one by one" prototype switch. This would be equipped with one transmitter arm, one aerial arm, drive units, control circuitry, and would be inserted in a working transmission line. The testing of this prototype would indicate the suitability of the drive units and would check the operation of select and release sequences under repetition. In addition, appropriate wiring methods could be determined, especially at the pivot point of the transmitter arm and a suitable type of limit switch could be selected. The prototype structure installed for field testing is shown in Fig. 4.

It was not possible with the prototype to obtain confirmation of the expected operation of the switch over the large matrix area of the final structure on which the very fine tolerances were concerned. In order for this to be done, the first quarter of the structure was erected initially, that is 9 positions, and equipped with three hoists, four drive motors and seven arms. This allowed the following tests to be performed:

1. Operation of the arms over the much greater area of the structure.
2. Operation of control rods, which for the large structure were obviously much longer and heavier than for the prototype.
3. Measurement of R.F. coupling between adjacent arms and between arms and switch frame.
4. Measurement of the effect of insertion in transmission lines.

With automatic remote control installed, the operation of the switch was observed over the matrix area. A number of mechanical improvements were indicated which later led to minor changes in some components, and a number of techniques were developed to ensure correct alignment and adjustment procedures.

In order that R.F. coupling between lines through the switch could be measured under the worst possible conditions, two of the aerial arms and two of the transmitter arms had been installed in adjacent positions. Coupling figures were measured by connecting these two transmitter arms to the two aerial arms, thus representing adjacent transmitters connected to adjacent aerials. The values of coupling were measured at frequencies from 6 Mc/s to 26 Mc/s and averaged approximately 57db. A figure better than 50 db is considered satisfactory. In order to observe the behaviour of the steel work and other metal fittings from the point of view of induction effects, three transmission lines were connected through the switch, and normal transmissions operated. Steel members, and especially switch arms, were examined but were found to be free from induction, as was control and power wiring. The effect of continuous transmission on line fittings and contacts was found to be negligible, and only a few degrees rise in temperature was noted on contact faces and telescoping joint fingers.

The effect of the insertion of the switch in the transmission line was determined by the measurement of standing wave ratio on both aerial and transmitter sides of the switch. Adverse effects would appear as a degradation of this

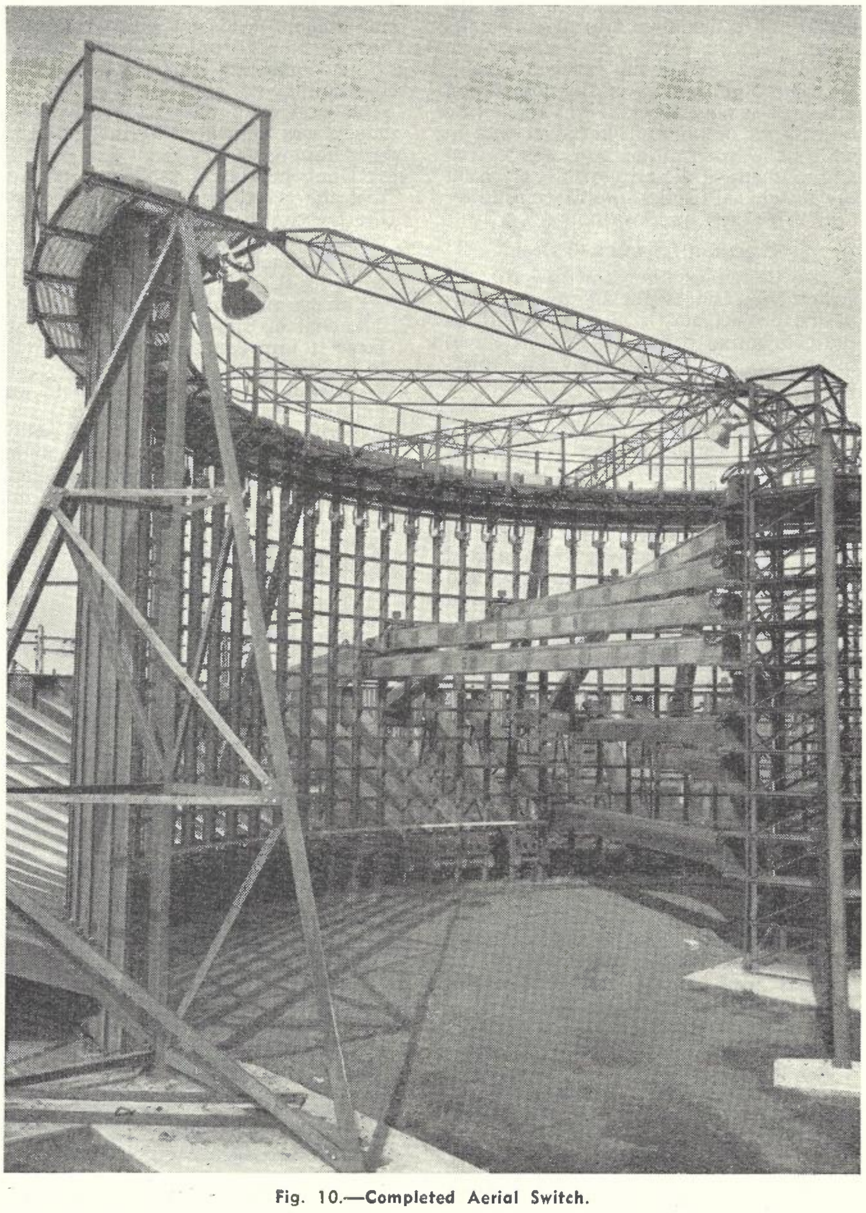


Fig. 10.—Completed Aerial Switch.

ratio. The results were as shown in Table I.

TABLE I

Frequency Mc/s	VSWR	
	Aerial Side of Switch	Transmitter Side of Switch
7.22	1.7	1.7
9.58	1.43	1.56
11.74	1.14	1.14
15.315	1.45	1.47
17.84	1.3	1.5
21.6	1.49	1.54

The structure equipped for this series of tests is shown in Fig. 9.

Following the conclusion of these tests the first section was fully equipped with arms, hoists, motors and associated wiring, incorporating the modifications found necessary. The three additional sections forming the complete switch were manufactured, installed, and the control desk in the main transmitter hall was wired and tested thoroughly. Fig. 10 shows the completed switch, and Fig. 11 shows the remote control desk.

CUTOVER PROCEDURES

The introduction of the switch had to be performed without affecting the normal operation of the station. Careful planning was therefore necessary in the various stages of the cutover to ensure that this requirement was met, and that completely satisfactory, highly reliable service would continue after the point of no return in the cutover was passed. Extensive preliminary re-arrangements of transmission lines were performed and a number of switches in the original system were re-located to give access for the new lines.

The most important part of the cutover and the point of no return was the complete elimination of one of the switching groups, after which individual aerials were connected to the corresponding outlet on the matrix switch.

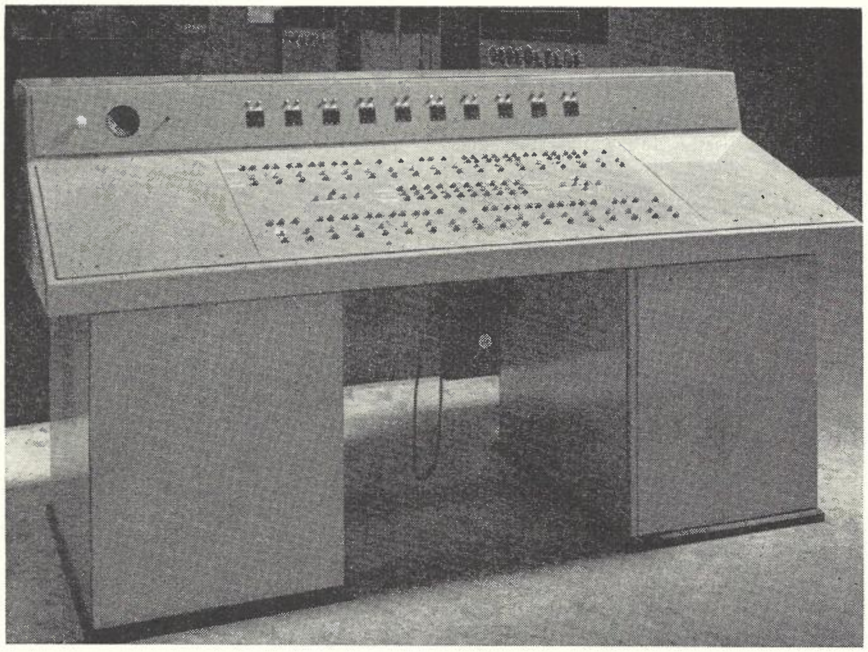


Fig. 11.—Aerial Switch Control Desk in Transmitter Hall. All switching operations are carried out from this location and the final selection is indicated on the panel.

CONCLUSION

The problem which initiated this project was unique in Australia. There was no precedent available for assistance in the design work with the exception of the smaller switch at Radio Lyndhurst, and the operating sequences, control, structure and all fittings had to be designed by staff of the Postmaster-General's Department. The major items of structure, hoists, motors, arms and limit switches were obtained by contract to P.M.G. specifications.

ACKNOWLEDGMENTS

The author wishes to express his thanks to the Drafting Section for their work on the mechanical design of the switch and to engineering colleagues for their assistance. Special credit is due to the Radio Australia construction and line staffs who were responsible for the difficult installation of the switch and associated line work. This paper is based on material which was delivered to the Institution of Radio Engineers Convention 1962 in Sydney.

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2. S. S. Minz and F. J. Norman, "Open Wire Transmission Line Switch for Use at High Frequencies"; Telecommunication Journal of Australia, Vol. 11, No. 5, page 143.
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TECHNICAL NEWS ITEM

REVIEW OF DIMENSIONS OF PRESSURE-TREATED HARDWOOD POLES

The standard poles used by the Australian Post Office are hardwood, treated with preservative by a full length pressure-treatment process. Following a recent series of pole strength tests conducted by the C.S.I.R.O. on full size poles, the actual strength of wooden poles is now known accurately. This data has been applied to pressure-treated poles as used by the Post Office and has resulted in a reduction in dimensions in most categories by as much as 25%. As the treatment preserves the sap-wood, the strength of the poles is, then, determined by the diameter over the sap-wood rather than the diameter of the true-wood as was the case with untreated poles.

Although pole sizes have been considerably reduced, an adequate factor of safety has been incorporated in the design. Rationalisation of sizes has been carried out, reducing the number of sizes from 53 to 20 and thereby reducing the number of items to be stocked in pole depots. A substantial reduction in purchase and handling costs will result and the magnitude of this saving could reach 20%.

Supplies of pressure-treated poles in accordance with the revised specification will commence in the latter part of 1963.

THE NEW AERIAL SWITCHING SCHEME AT RADIO AUSTRALIA, SHEPPARTON— MECHANICAL AND STRUCTURAL DESIGN

L. C. GEMMELL and J. M. FULLARTON†*

INTRODUCTION

A companion paper (Ref. 1) in this issue has detailed the requirements which brought about the development of the switching scheme and dealt with the electrical aspects of the design. In this article, it is intended to outline the mechanical and structural design and highlight some of the problems peculiar to a structure of this nature for which close tolerances are essential. Previous experience had been obtained in the mechanical work associated with a switch operating at lower power and manually operated (Ref. 2). The new switch, however, was to be mechanically operated by electric motors remotely controlled from the transmitter building. The electrical requirements resulted in a much larger and heavier structure, and the mechanical design dictated very close tolerances and a degree of precision seldom required in construction work of this nature.

DESCRIPTION OF THE SWITCH

The new aerial switching system for Radio Australia, Shepparton, was required to provide for the interconnection of any one of ten transmitters to any one of thirty-six aerials. The switch was to be used in an outdoor environment without weather protection and is shown in schematic form in Fig. 1.

The conductors in the switch consist of a pair of $\frac{3}{4}$-inch diameter by 18 s.w.g. copper tubes spaced 7 inches apart. To prevent interference between pairs of conductors, each pair of conductors is carried in a twenty-five feet long screening tube called an arm, made of formed plywood faced inside and out with aluminium. On the transmitter side of the structure there are ten of these arms which move in a horizontal plane. On the aerial side there are thirty-six of these arms which move in a vertical plane.

* See Page 81
† See Page 82

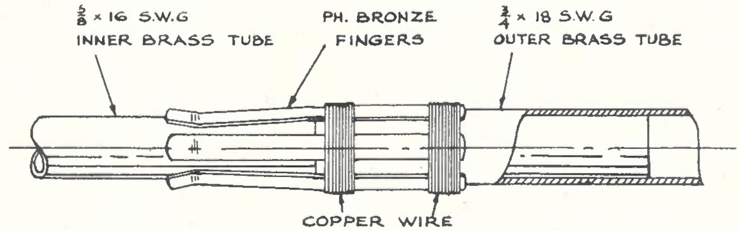


Fig. 2.—Sliding Contacts used in Switch.

The actual structure can be divided into three main sections:
(a) The Transmitter Terminating Frame.
(b) The Switching Structure.
(c) The Aerial Terminating Frame.

A description of the structures is as follows:

(a) **The Transmitter Terminating Frame:** This is a fabricated steel mast 36 inches square and standing 23 feet 8 inches high. On one side, the wires from the transmitters terminate into the copper tube conductors. On the other side are the pivot positions for the horizontal arms. The mast is braced at the top by five struts of a tubular steel construction which connect it to the switching structure. To avoid distortion in the mast due to tension in the 600 lb. copper conductors from the transmitter, a terminating frame is placed just behind the mast. This takes all wire loads and slack connections are made to the mast itself.

(b) **The Switching Structure:** This is a curved grid of steel work standing on a concrete base and braced at each end and at intermediate points by built-up steel structures. The radius of curvature is 25 feet $9\frac{5}{8}$ inches, and the structure stands 28 feet high and spans approximately a full semi-circle. The outer ends of each of the ten transmitter arms are supported on two ball-bearing wheels which run on ten curved rails bolted to the structure, one above the other. The arms are driven by $\frac{1}{2}$ h.p. geared electric motor units. As frictional adherence of the plain wheels on the rails would not be sufficient to overcome resistance in high winds, the drive is by a rack and pinion arrangement. The rack consists of a $\frac{5}{8}$-inch pitch single roller chain fixed alongside the rail and this is engaged by a chain pinion on the output shaft of the motor unit. The motors are fitted with very effective solenoid-operated multiple disc brakes which stop the arm as soon as the power is cut off. This has been found to operate with an error of less than a quarter-inch of travel.

The thirty-six vertical arms are guided by nylon wheels which track in between the flanges of the I beams. They are raised and lowered by wire rope wound on individual hoist motors which are mounted on the top of the switching structure. These motors have solenoid-operated band brakes which operate as soon as the power is cut off.

There are thirty-six control rods mounted to the frame. The control rods are of tube and have flags fixed to them at specified intervals to perform various operations as explained later in accompanying diagrams. The rods are lifted $3\frac{3}{4}$ inches and rotated through 60°. Each rod is hydraulically damped on its return stroke.

A ladder is positioned at the rest position end of the structure and serves to provide access to the ends of the transmitter arms for servicing motors and contacts. It also provides access to the catwalk around the top of the structure which allows for maintenance of the hoists.

When the selected transmitter arm rotates around to its required position and the appropriate aerial arm is brought up to meet it, a pair of contacts come together and the switch is ready for transmission. The actual contacts consist of a pair of silver-tipped brass domes which mate on elliptical phosphor-bronze springs. These springs are wide enough to permit a positional error of approximately $\frac{3}{4}$-inch either vertically or horizontally.

(c) **The Aerial Terminating Frame:** This consists of a series of steel frames 12 feet 7 inches high, joined together in an arc of 48 feet 10 inches radius. The lines from the aerials terminate on this frame and, as each line consists of four 600 lb. copper wires, considerable loads are imposed and substantial concrete

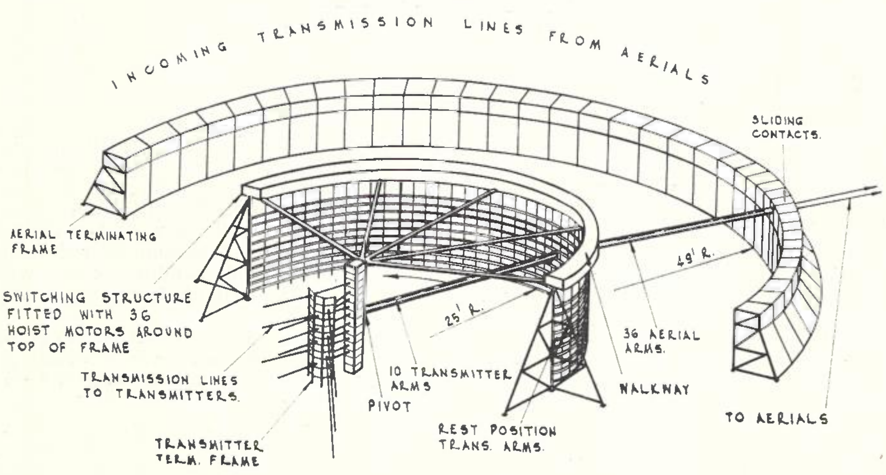


Fig. 1.—Schematic Form of Matrix Aerial Switch.

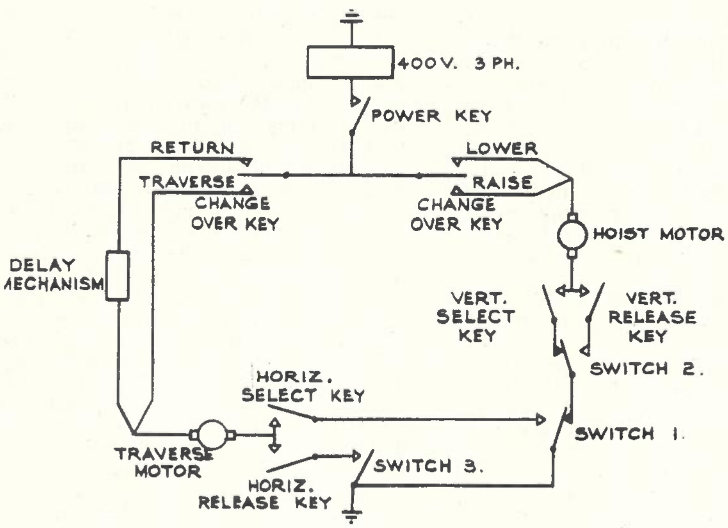


Diagram 1.

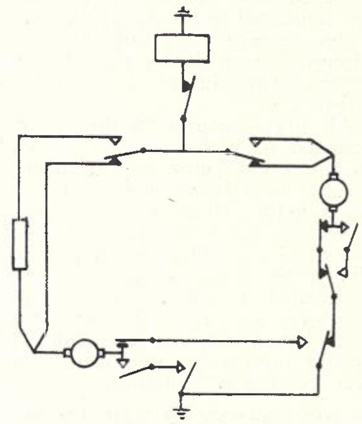
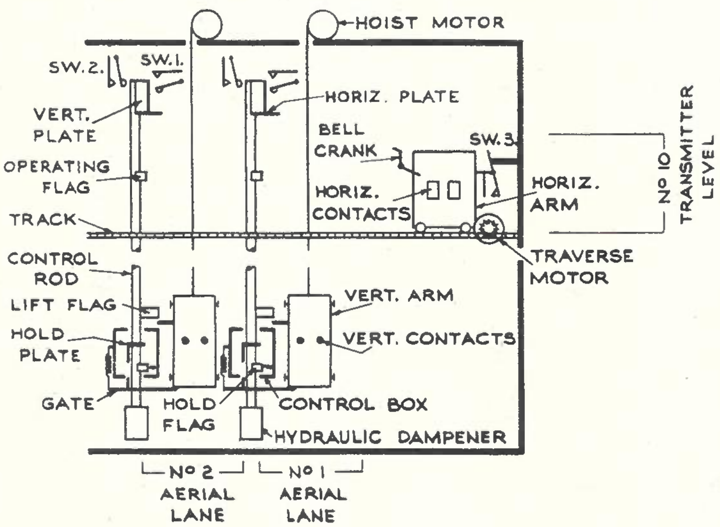


Diagram 2.



Stage 1.

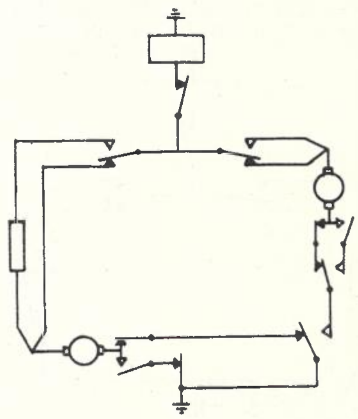
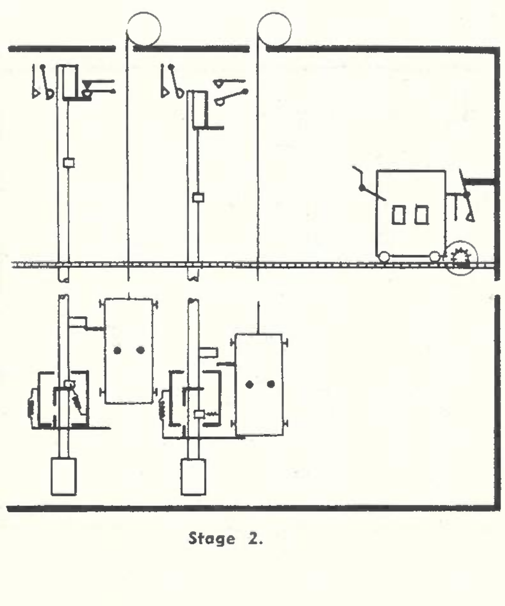
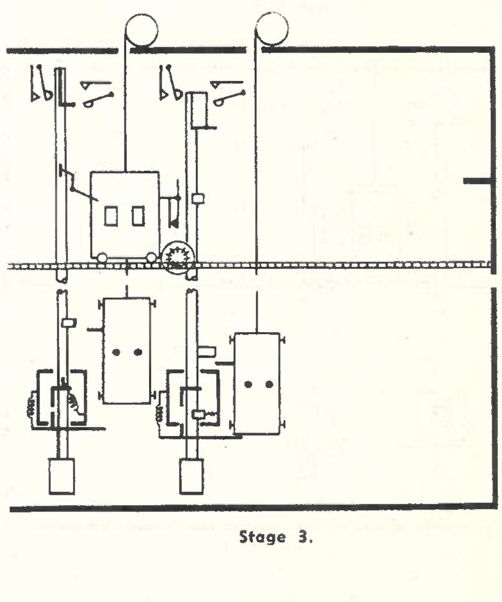


Diagram 3.



Stage 2.



Stage 3.

Fig. 3.

foundations are required. The outer ends of the aerial arms are supported on nylon wheels running on rails, allowing a horizontal movement as the inner end is raised and lowered. The conductors are connected to the aerial lines by telescopic contacts consisting of brass rods sliding through spring phosphor-bronze fingers. The sliding contacts are shown in Fig. 2.

All the structures in the system are designed to withstand a wind load of 80 m.p.h. The most heavily loaded section is the end stay on the main switching structure which exerts a calculated uplift on its foundations of approximately 14 tons. There are approximately 107 cubic yards of concrete in the foundation for the aerial terminating structure, and 85 cubic yards for the switching structure. The whole structure is sub-divided into four segments, each serving nine aerials.

OPERATION OF THE SWITCH

The sequence of events in the operation of the switch can readily be seen from the sketches, Stages 1 to 5 and Diagrams 1 to 6 which comprise Figs. 3 and 4. As an example, these show the switching of No. 10 transmitter to No. 2 aerial. Similar sequences occur for all other combinations. The No. 2 aerial arm is shown at the rest position at the bottom of the switching structure. The No. 10 transmitter arm is at the rest position at the right-hand side of the switching structure. All control rods are in the down position. There are two switches (Switch 1 and Switch 2) mounted at the top of the switching structure in each aerial lane. There is one switch (Switch 3) mounted on each horizontal arm. The operating circuit is then as shown in Diagram 1, and the position of vertical and horizontal arms as in Stage 1.

The horizontal select key for No. 10 transmitter arm and vertical select key for No. 2 aerial arm are closed. The changeover keys are switched so as to raise and traverse the vertical and horizontal arms respectively. The power key is closed and the circuit is then as shown in Diagram 2. The hoist motor commences to raise the vertical arm which strikes the lift flag and so raises the control rod. The horizontal plate at the top of the control rod strikes Switch 1 and opens the hoist motor circuit, thus stopping the motor. The power is now supplied to the traverse motor. When the vertical arm moved away from the control box, the gate which is under spring tension closed. The position of switching is then as shown in Stage 2 and the circuit as shown in Diagram 3.

The traverse circuit now being closed, the horizontal arm moves across the switching structure and Switch 3 which was kept open by the stop at the rest position now closes. The bell crank mounted on the horizontal arm strikes the operating flag on the control rod (this was set up in Stage 2) and rotates it through approximately 30°. The horizontal plate at the top of the control rod having also moved through 30°, releases Switch 1 and opens the traverse circuit which stops the traverse motor. The horizontal arm is now in position to receive the vertical arm. The lift flag attached to the control rod moves clear of the vertical arm. The hold flag also attached to the control rod moves onto the hold plate thus keeping the control rod in the up-position. The position of switching is then as shown in Stage 3 and the circuit as shown in Diagram 2, except that Switch 3 is closed.

The hoist motor circuit being closed, once again the vertical arm restarts, moving upwards. On reaching the horizontal arm, the projection on the vertical arm strikes the bell crank which further rotates the control rod through approximately another 30°. The vertical plate at the top of the control rod strikes Switch 2 and opens the hoist motor circuit thus stopping the hoist motor. The transmission contacts are now mated. The position of switching is then as

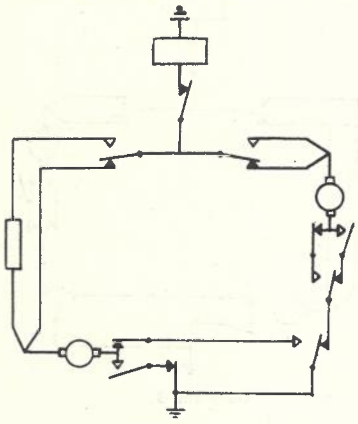


Diagram 4.

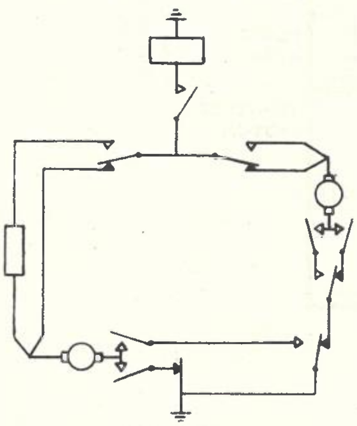


Diagram 5.

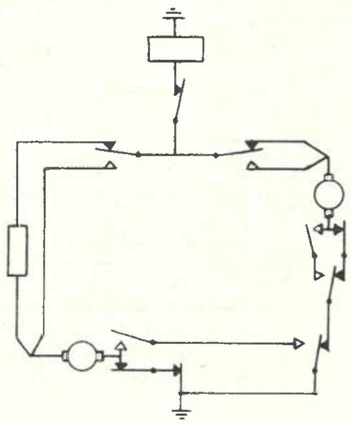
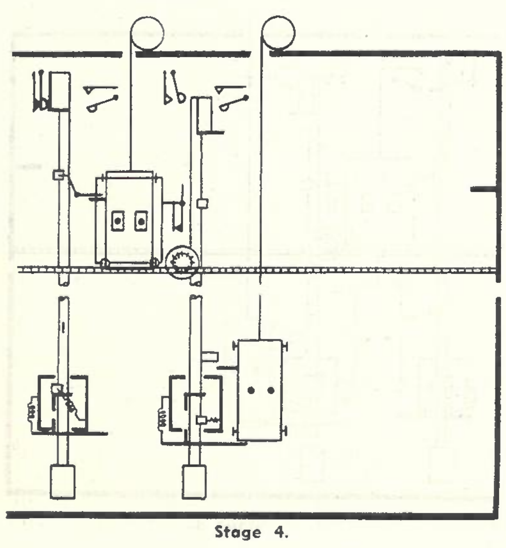


Diagram 6.


Stage 4.

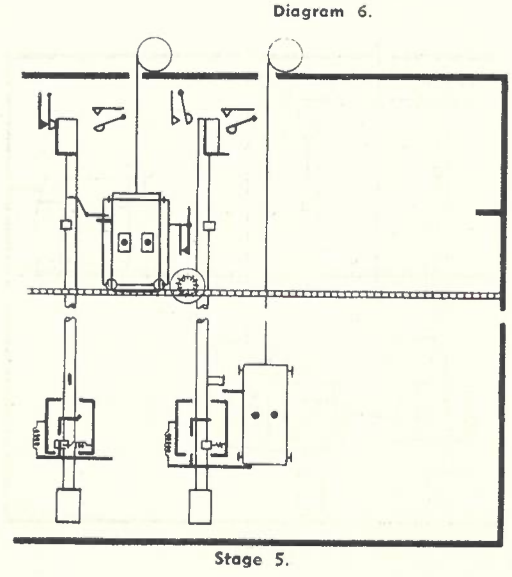

Stage 5.

Fig. 4.

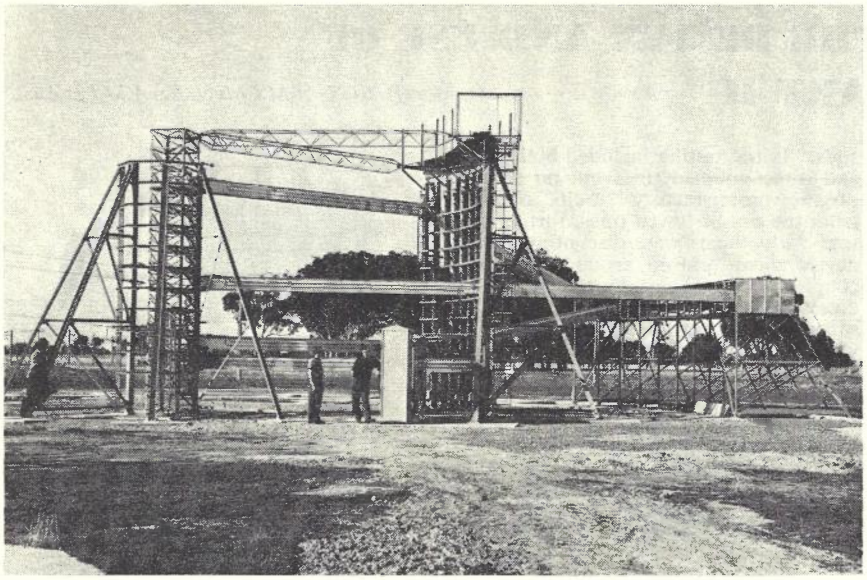


Fig. 5.—View of Partially-built Switch (10 x 9).

shown in Stage 4 and the circuit as shown in Diagram 4. The hold flag having moved through another 30° also now over-rides the hold plate, thus allowing the control rod to drop to the down position. The control rod is held from returning to its original position by the gate and in this position ensures that Switch 2 is kept open. The position of switching is then as shown in Stage 5 and the circuit remaining as shown in Diagram 4.

The power key is opened. The horizontal and vertical select keys are opened. The circuit then is as shown in Diagram 5. All is now ready at the switching structure for the transmission from No. 10 transmitter to No. 2 aerial.

RESTORATION OF SWITCH

The horizontal and vertical release keys are closed by the operator. The changeover keys are switched to lower and return the vertical arm and horizontal arm respectively. The power key is closed and the circuit is then as shown in Diagram 6.

A delay mechanism in the traverse circuit delays power to the traverse motor until the vertical arm has lowered sufficiently to break the electrical transmission contacts. If this were not done damage could result to the contacts. Both vertical and horizontal arms are now moving towards their respective rest positions. The vertical arm on reaching the rest position strikes the gate depressing it, thus opening it and allowing the control which is under spring tension to rotate back home through 60°, opening Switch 2 which stops power to the hoist motor. The vertical arm is now at the rest position. Switch 3 mounted on the horizontal arm strikes the stop at the rest position thus opening the traverse circuit stopping the traverse motor. The horizontal arm is now at the rest position. The power key is opened. The horizontal and vertical release keys are opened. The changeover keys are returned to neutral. The position of switching is then as shown in Stage 1 and the circuit as in Diagram 1.

STRUCTURAL DESIGN

At a preliminary stage of the design it became obvious that extremely small tolerances would be necessary in the complete switch structure, and this would require an accuracy of working which is normally seldom attained in work of this nature. Indeed, the achievement and maintenance of very close tolerances has been one of the major problems of the design of the structure. It was necessary to ensure that steel from commercial suppliers was straight to within a small fraction of an inch over the entire length or was appropriately straightened to the required degree.

The tolerances in position of the completed structure also were required to be very small, and some mention has been made of this in an earlier section of this paper. It might be mentioned also that the curved rails to support the transmitter arms were to be positioned to an accuracy of $\pm \frac{1}{8}$-inch at a radius of over 25 feet over the full arc of nearly 80 feet. As the operating structure was located outdoors in an inland location subject to wide variation in ambient temperatures, the effects of such variations on constructional materials had to be fully considered in order that the tolerances would not be exceeded under temperature extremes.

CONCLUSION

The design of the mechanical and structural details was carried out by the drafting personnel at the Workshops Drafting Office while the electrical and transmission details were carried out by the personnel of the Radio Section. The collaboration between the two Sections was excellent, and contributed a good deal to the successful completion of the project.

The first stage of the switch (10 transmitters to 9 aerials) shown in Fig. 5 taken on May 11, 1961, was completed despite considerable operational difficulties. Fig. 6 taken on September 12, 1962, shows the project nearing completion to the final stage (10 x 36).

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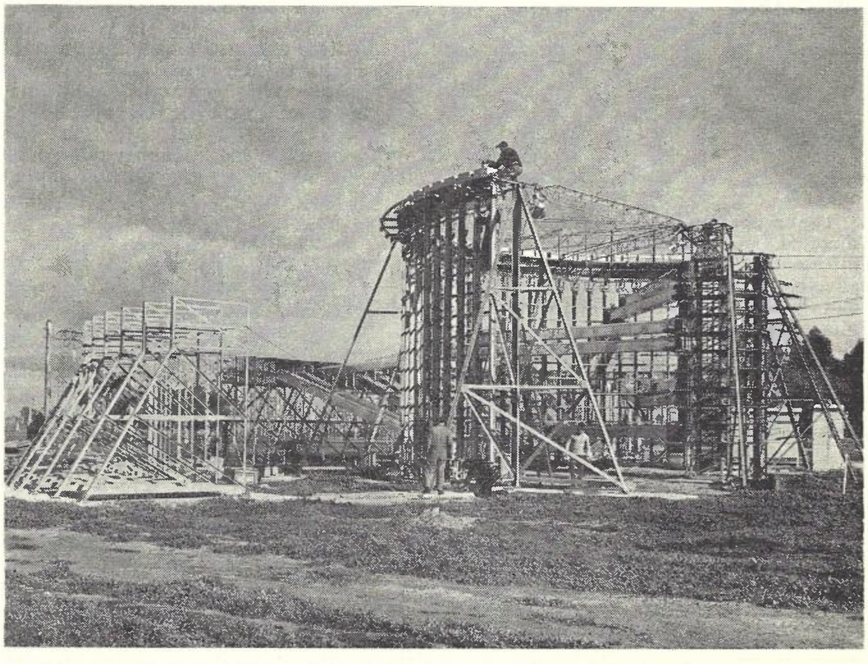


Fig. 6.—Putting Finishing Touches to Complete Switch (10 x 36).

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

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

INTRODUCTION

The first part of this article outlined the general use of cable ploughing and associated equipment by the Postmaster-General's Department. This part gives details of some of the tests and experiments carried out in the process of developing equipment now being used. The work was carried out by the New South Wales Administration, not as a full time research project, but in association with routine ploughing operations in the field. For this reason, the testing equipment used had to be portable so that it could be transported from job to job by sedan car and occasionally by air. Because of the amount of equipment required on any one site at a time, as much data as possible was collected at each trial, whether or not it had a bearing on the immediate problem. The main features determined in the tests are outlined below, some of which had been foreseen and were being looked for, while others became apparent in the course of testing.

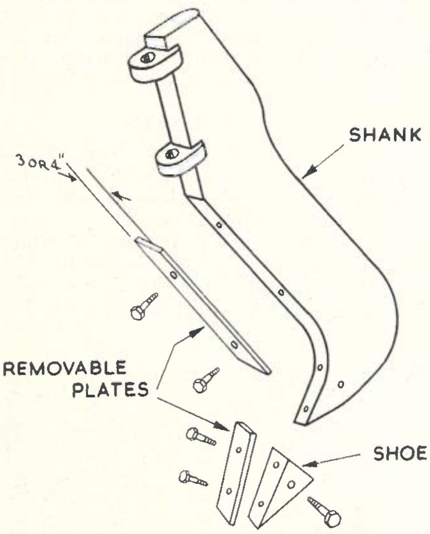


Fig. 1.—Test Tine with Detachable Plates.

The programme of investigation was directed at gathering the minimum information felt to be necessary for the effective design of ploughing plant, mainly the tine and cable box requirements, the type of linkage and the power characteristics required of the prime mover. The conclusions reached are based on these field tests and elaborate theorising has been avoided. Further tests are still being carried out.

TINES AND LINKAGES

General

Various tines were made for direct mounting to tractor and for towing, with detachable plates of various sizes (Fig. 1) to increase the width of both tine and shoe which were then used in different soils. Initial testing included both towed and direct-coupled tines but on account of the unsatisfactory results obtained from the use of towed tines, further testing with them was discontinued and development centred around the direct coupled tine. The advantages of the direct coupled tine, particularly its superior inherent longitudinal stability, were discussed in Part I of this article.

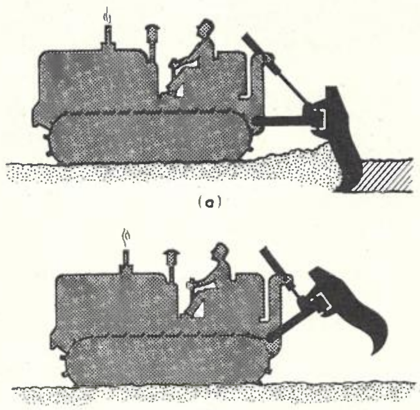


Fig. 2.—Three Point Linkage, (a) tine down, (b) tine raised.

Types of Linkages

There are three types of geometrical linkages available for attaching the tine to the tractor. These are:—

(i) A swinging link or three point linkage, attached to the rear of the tractor (Fig. 2).
(ii) A swinging link or three point linkage, with the swinging arm attached to the track roller frame and the hydraulic ram attached to the rear of the tractor (Fig. 3).
(iii) A four point or parallelogram linkage mounted on the rear of the tractor (Fig. 4).

The three point linkage mounted on the rear of the tractor is the simplest and cheapest mounting available. It has the disadvantage that it produces a large change of angle between the tine face and the ground when the tractor is moving over undulating ground, (Fig. 5), and when the tine is being raised or lowered. As the cable sheath may be damaged if the plough box face is not parallel to the ground, this angle must be kept approximately constant. If the tine is designed for the correct angle of penetration at full depth, any change in depth alters this angle and tends to make the tine either bury itself or force itself out of the ground. To some extent this tendency could be overcome by fitting hydraulics to control the angle of penetration, but this is unnecessarily complicated.

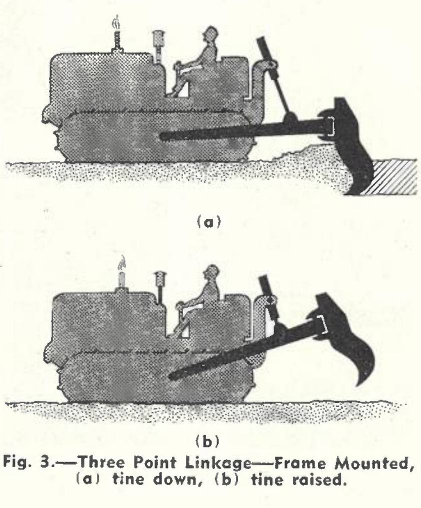


Fig. 3.—Three Point Linkage—Frame Mounted, (a) tine down, (b) tine raised.

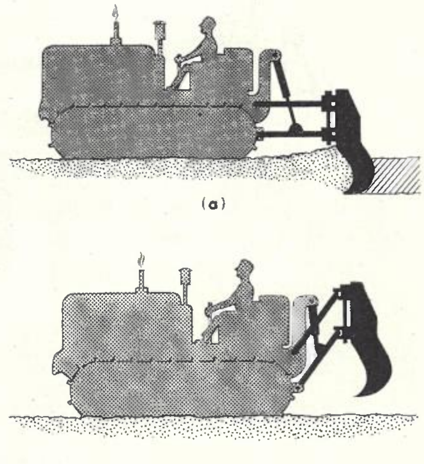


Fig. 4.—Parallelogram Linkage, (a) tine down, (b) tine raised.

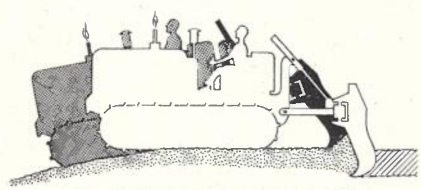


Fig. 5.—Movement of Tine when Tractor Pitches.

The three point linkage with the swinging arm attached to the track roller frame makes for rigidity and relieves the rear of the tractor of most of the strains when ripping. It also provides less angular movement in the tine between the fully up and fully down position. It requires a wide ripper beam to clear the tracks, however, and generally it suffers from the same disadvantages for ploughing as does the rear mounted three point linkage. It is not used in the Department for ploughing.

The parallelogram linkage holds the ripping angle of the tine more or less constant whatever the depth of penetra-

* See Vol. 13, No. 6, Page 501.

tion, and the bottom of the plough box parallel to the ground. The one ripper can be used at any depth as the angle of penetration is always the same. Although this type of linkage requires more pinned connections, it is by far the best for use with cable ploughs and has become the standard mounting for Departmental cable plough boxes.

Hydraulics

For satisfactory operation the lifting and lowering of the ripper and plough must be carried out by double acting long stroke hydraulic rams capable of raising the rear of the tractor when the tine tip is resting on the ground. The stroke must be such that the tine can be kept at full depth even with a considerable angular movement of the tractor. This means in practice that the combination of the linkage and rams should have a travel some 20 per cent greater than that from the fully up to the nominal full depth position.

Even with this, however, there is some difficulty about having enough clearance under the tine in the fully up position, for loading and off-loading from a float, unless the parallelogram linkage has very long arms. A satisfactory method of overcoming this is to design the linkage to give a vertical movement of the tine tip of from 6 inches above ground level (which is satisfactory for travelling around the job) to full ploughing depth plus 20 per cent of this depth. When the tractor and tine have to be loaded, the linkage is lowered until the tine rests on the ground, the pins removed, the linkage lowered further to align with the bottom holes, the pins inserted, and then tine and linkage raised—see Fig. 6(b).

Full hydraulic power should be available whenever the engine is running, whatever the gear selection or clutch position. This means that the hydraulic pump must be coupled directly to the engine, the simplest mounting position being to the front of the crankshaft.

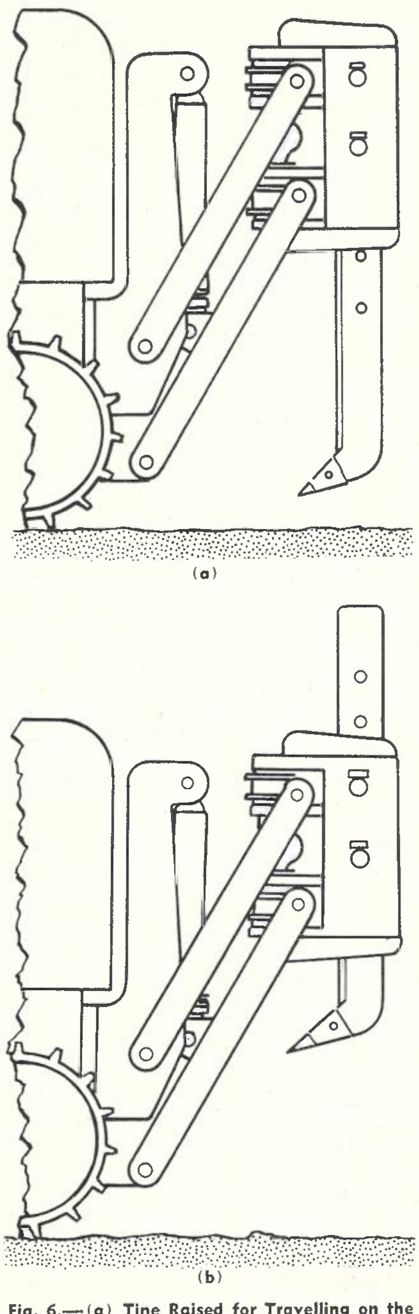


Fig. 6.—(a) Tine Raised for Travelling on the Job. (b) Tine Raised for Loading.

Automatic Depth Control of Tine

The essentials of design for automatic depth control of the tine are:

(i) Parallelogram linkage.

(ii) Arms parallel to ground in the full depth position.

(iii) Matched shoe and tine face.

A considerable amount of testing has been done to establish the fundamentals of a design but so far the only definite information brought to light is that a parallelogram is essential, with the arms parallel to the ground in the fully down position. Although the width and length of shoe can be varied to match the reaction on shoe and tine face in any soil, it is not practicable to do this on the job. Some thought was given to fitting the tine with variable wings hydraulically set from the driver's cabin but this presented too many problems. The most successful attachment tested so far and the one most likely to be used in future, is a simple skid pinned to the tine and adjustable to any desired depth. The tine requirement for this to be successful is a shoe width and length such that there is always a resultant downward force exerted by the soil reaction when the hydraulics are in the float position (Fig. 7).

Drawbar Pull Requirements

The test tines were fitted to the rear of various tractors, with hydraulic gauges in the top and bottom links and pressure gauges in the hydraulic rams actuating the linkage in order to measure the down and up pressures required by the various tine designs. At the various tine widths and depths and in the varying soil conditions a minimum of six readings was taken over distances of up to half a mile. The results are graphed in Fig. 8.

The spread of the various readings is not shown because of the difficulty of taking readings at exactly the right depth in undulating country. The assumption has been made here that the average of six readings, taken at a depth varying by plus or minus 10 to 15 per cent from a mean depth, is sufficiently accurate for practical purposes.

When the drawbar pull required to move any tine exceeded the pull of the tractor on which it was mounted, one or more tractors were attached in tandem in front, the towing ropes being attached to the rear towing bar in every case so that the total pull registered on the gauges. As a further check, all the tests were repeated using only one gauge in the tow line, the tractor carrying the ripper free-wheeling and its rolling resistance subtracted from the drawbar pull registers. There was little or no difference in the readings recorded under both conditions.

Once the pulls had been established with the test tine, various other tines were then tested with packing on them to bring the whole side areas out to the front width, and cable boxes or simulated cable boxes attached behind to test the effect of side friction of the soil on

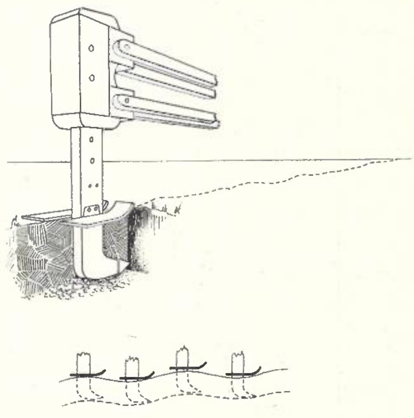


Fig. 7.—Tine Fitted with Skid.

the pull required. It was found that, provided the width and depth of the tine was equal to, or greater than, the width and depth of the cable boxes, no difference was recorded in drawbar pulls with and without cable boxes. For practical purposes it is the width and depth of the front of the tine that is significant.

Impact Loading on Tines

It was hoped to have strain gauges available when the first tests were being carried out to measure the impact loading on the tine when the tractor and tine combination is brought to rest suddenly by the tine striking rock. As suitable gauges were not immediately available, the movement in the linkage was measured to give an indication of the loading when the tractor and tine were brought to a sudden stop. Two Allis Chalmers HD.16 torque converter tractors were used in tandem, the rear machine pushing against the tine; the all up weight for each machine was 40,000 lb. and their speed in the test 3 ft.

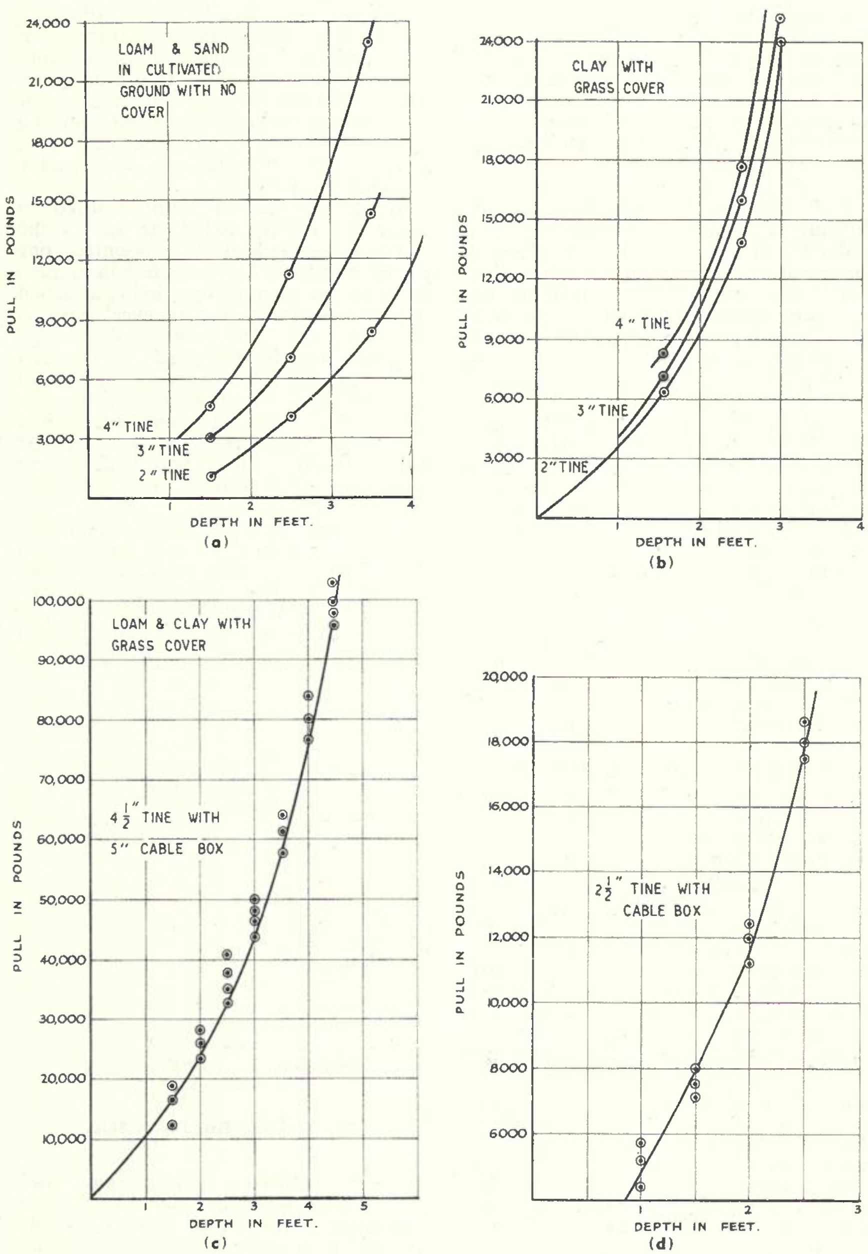


Fig. 8.—Drawbar Pull Required to Rip under Various Conditions.

per second (approximately 2 miles per hour). When they were brought to rest suddenly from this speed by the tine hitting rock, the movement registered at the tip of the tine, as nearly as it could be measured under the circumstances, was approximately 1 inch, from which the impact loading was calculated at 135,600 lbs. As it was intended that two tractors of this size would be the maximum used with any of the tines, they were designed to withstand shock loadings of 200,000 lb. Tines subsequently built to meet these conditions have proved excellent in service.

Because the original calculations had been made on such a rough and ready basis, it was hoped to use strain gauges at a later date even though the tines were standing up in service. Before this could be done, however, data became available from the Caterpillar Tractor Company of America on similar tests on their machines based on the use of strain gauges (Fig. 9), by courtesy of the company's Australian representatives. From this it can be seen that the rate of increase of load diminishes at the higher tractor speeds, the linkage and tine acting together like a high rate spring, and four times as much energy (doubling of the tractor speed) is necessary to produce twice the deflection and twice the loading of the components within the elastic limits of the materials used.

Details of Tine Design

Shape of Tine: At first sight, it seems simple enough to tow a piece of steel such as a tine through the ground, and for shallow depths, down to about a foot, it is a simple matter. When it comes to ripping down to 2 ft. and more, however, the picture changes, largely because of the greatly increased loads imposed on both the tine and the tractor. When harrowing with an agricultural tractor using a shallow tine, the tractor driver has little trouble in controlling the machine but when a 2 ft. tine is selected at random and attached to the same machine, it is the tine rather than the driver that dictates what happens.

On test there was no difference in the drawbar pull recorded for the various shanks (Fig. 1) so that in this respect the straight shanked tine is satisfactory.

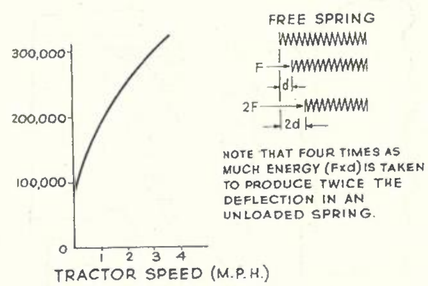


Fig. 9.—Impact Loading on Tine Brought to a Sudden Halt.

However, it was clearly shown that if the leading edge of the tine is sloped forward at the top, a condition is reached where the tine begins to pull out of the soil. Under this condition, the test tine required a downward thrust of 2-2.3 tons to keep it in the ground at a depth varying between 2 ft. 6 ins. and 2 ft. 9 ins. in heavy clay.

With another tine, whose leading edge was nearly vertical, the down thrust in these conditions was just over one ton. With a straight tine tested in loam at 2 ft. 6 ins. penetration, no down thrust was recorded once the tine was at this depth. The hydraulic rams were disconnected from the linkage and the linkage left completely free. Over a number of rips some hundreds of yards in length, the tine rose and fell less than four inches from the mean position.

Width of Tine: In practice, this was found to be governed by the width of the cable box, which exceeds the minimum width of tine needed to withstand stresses encountered at the various depths. Tine widths used are 2 ins. to 2½ ins. down to 2 ft. 6 ins. and 3½ ins. wide, to depths of 3 ft. 6 ins. It was found that, although cable ploughing can be carried out with a cable box wider than the tine, it is essential that the tine be deeper than the cable box, otherwise the cable box rides on the ground and the tine will not penetrate. In practice it has been found that the tip of the tine should be from 4 ins. to 6 ins. deeper in the ground than the bottom of the cable box, also the tine is preferably ½ in. wider than the cable box.

Angle of Penetration: For most soil conditions, including rock, the best angle of penetration (Fig. 10) of the shoe seems to be between 30° and 50° to the horizontal, although the width and depth has a very definite effect on this angle in soil. It was possible, with each tine tested, whether straight shanked, sloped or crescent, to get it to hold its depth by varying the width and length of the shoe.

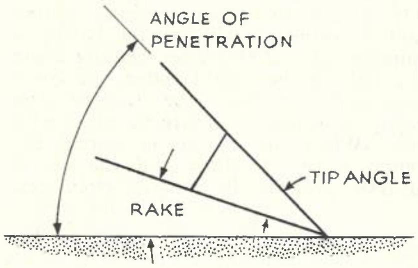


Fig. 10.—Relief at Bottom Face of Tine Shoe.

Leading Edge Angle: No difference in pull could be observed when two tines were pulled through the ground, one having a flat front, the other 45° faces and otherwise identical. The pointed front is preferred, however, because it is easier to keep the sharp leading edge hard-faced than it is the flat faced one. The flat cutting edged tine wears at the edges, whereas the 45° one seems to wear evenly along both faces.

Relief at Bottom Face of Shoe: The amount of rake (Fig. 10) on the bottom of the shoe does not appear to matter, provided there is a minimum clearance of 10°. Without this, there is difficulty in keeping the tine in the ground. Considerations of strength in the shoe dictate that this angle should be shallow.

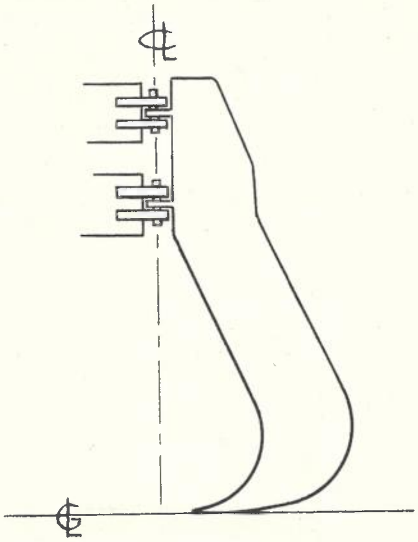


Fig. 11.—Position of Tine Tip in Relation to Mounting—Swivelling Tine.

Position of Tine Tip in Relation to Mounting: It is essential in swivelling tines that the centre line of the swivel is forward of the tine tip to provide castor action. (Fig. 11). If this is neglected and the tip is moved forward from this line, buckling takes place as soon as the tine is subjected to high tip loading.

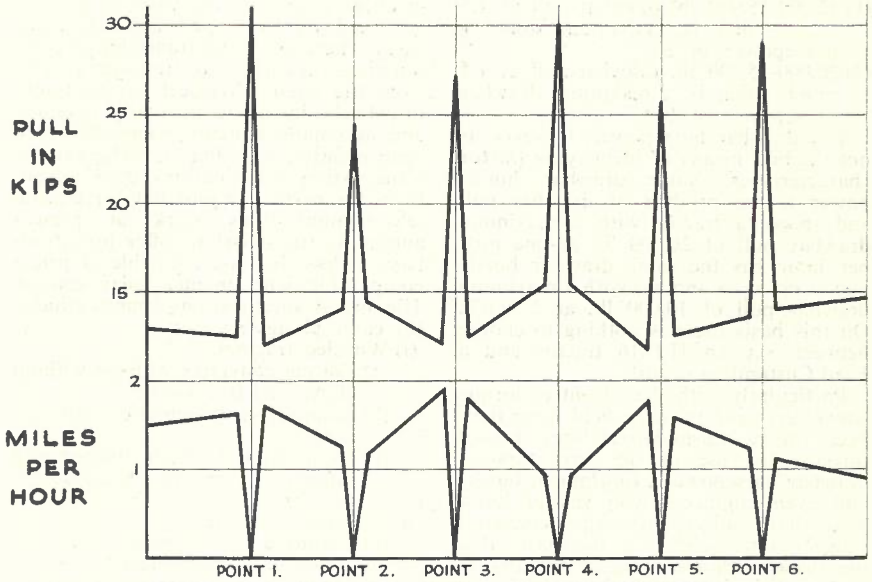


Fig. 12.—Drawbar Pull versus Speed of Tractor when Ploughing.

Fixed and Swivel Tines

Whether the tine is on a rigid or swivel mounting does not affect its ability to straight rip soil in any way, certainly not as far as cable ploughing is concerned. In rock, however, it is an advantage to have a swivelling tine. When a layer of rock or boulder is caught in the tine and the tractor loses traction, by lifting the tine out of the ground and reversing the tractor, the tine tends to fall to one side and the rock can be freed. This is more difficult to do with a fixed tine. Also, in fissured rock, a swivelling tine is an advantage because it can follow the fissure to some extent without affecting the tractor steering. On some cable jobs the swivelling tine can be a disadvantage, particularly if much reversing is called for, because the swivelling tine cannot usually be reversed up to the previous rip.

The main objection against the fixed tine is the difficulty of steering the tractor (the rudder effect of the tine) though the extent of this depends on how far behind the tractor the tine is mounted. In practice, for straight line working with crawler tractors using close-coupled tines, it makes very little difference whether the tine is on a fixed or swivel mounting. With rubber-tyred machines, however, a swivel mounted tine is essential to allow the tyred tractor to keep on a straight course. The "rudder" effect is most marked here. If the tractor slides off course, the tine tends to keep it there. In practice, a double swivel has been found necessary on these machines. For ploughing around curves and for easier correction of drift when straight ploughing on side slopes, a swivelling tine is essential with both crawler and tyred machines. The mounting found most suitable consists of a swivelling tine attached to a swivelling link in turn mounted on a swivel pin on the tractor.

Some experiments were carried out with hydraulic steering on the tine. A double acting hydraulic ram was connected between one side of the tine and the frame so that the tine could be angled in the same way as a ship's rudder. Although this was an improvement on both the fixed or swivelling tine as far as steering was concerned, it was not found to be as convenient in use as the double swivel. Generally, the double link has been found preferable and this has been adopted as the standard mounting for all new machines.

POWER REQUIREMENTS

In Part I of this article the considerations leading to the use of crawler and rubber tyre machines were outlined. In this section the drawbar pull needed and power requirements involved are examined. Fig. 12 is a graphical representation of the performance of an actual machine on a typical job and illustrates the constant horse power condition, with an increasing effort with a diminishing speed. The test was carried out with a plough tine mounted on a rubber tyre machine and with a crawler tractor, tow line and strain gauge in tandem. Both tractors had torque converter transmissions. The tow line was kept slack until the rubber tyre machine lost traction, at which point the crawler machine took up the slack and the sum of the drawbar pulls was recorded. With the ground surface conditions prevailing at the time, the maximum drawbar pulls available were 10,000-12,000 lb. with the rubber tyre machine and 25,000-28,000 lb. with the crawler machine. A no-slip test was also carried out at this stage and a similar shaped graph obtained. This test was performed by shackling fixed wire ropes to the wheels of the rubber tyre tractor to eliminate wheel slip. This test showed the ability of the torque converter transmission to adjust drawbar pull to load changes.

From these and other similar tests an assessment of the power requirements was made, giving two classes of tractor to cope with the range of cable ploughing requirements in this country:—

(1) 12,000-15,000 lb. drawbar-pull at 1.5 m.p.h.—that is, maximum drawbar horsepower of 80.
(2) 30,000-35,000 lb. drawbar-pull at 1.5 m.p.h.—that is, a maximum drawbar horsepower of 140.

The drawbar horsepower, however, is not the best means of identifying tractor characteristics. Since drawbar horsepower is the product of drawbar pull and speed, a tractor with a maximum drawbar pull of 20,000 lb. at one mile per hour has the same drawbar horsepower rating as another with a maximum drawbar pull of 10,000 lb. at 2 m.p.h. On this basis there is nothing to choose between say an H.D.16 tractor and a Ford Customline sedan!

Particularly with the advent of torque converters to the tractor field there have been many misunderstandings caused through the use of the term "tractor drawbar horsepower". Equipment buyers and even engineers who should know better have objected to torque converter transmissions solely on the basis that the drawbar horsepower of tractors so equipped is less than that of similar machines fitted with mechanical transmissions. This is because the efficiency of the torque converter itself is less than the efficiency of a mechanical coupling, and means that for any value of drawbar horsepower a torque converter machine must be fitted with an engine of some 20 per cent higher rating than would be required if a mechanical coupling were used.

When drawbar horsepower is used to compare machines, as it is with mechanical transmission machines, certain assumptions are always made—namely, that the machines being compared have much the same gear ratios and speeds and that the engines are rated for continuous operation. Without these assumptions the drawbar horsepower comparison is meaningless. Comparing mechanical transmission machines with torque converter machines on the basis of drawbar horsepower is equally meaningless.

Because of the variety and range of tractor equipment available, a study and trials were made of the characteristics and performance of various machines to see if any of them offered any immediately obvious advantages over their competitors. Some of these results are shown in Table I, the drawbar pulls shown being those actually recorded on test. It should be mentioned that laboratory conditions did not apply. The machines tested were simply working machines and at the time of test, were for all practical purposes in good working order. The figures obtained emphasised the similarity of design with the exception, among the crawler machines, of the horsepower per unit track width. Subsequent tests showed this to be a critical factor for ploughing as with equal powered machines of similar weight, the machine with the lowest horsepower per unit track width gave the better drawbar pull in varying soils. In other words, crawler tractors for cable ploughing should have as wide tracks as possible.

Once the power requirements are met on any machine, the ability of the machine to handle the varying loads is governed by the type of transmission used. There are many transmission combinations available to transmit powers from the engine flywheel to the tracks or wheels, including manually operated and automatic systems, some of which were mentioned in Part I. The various transmission combinations offer advantages for particular jobs but for general telecommunications work at present automatic transmissions offer no advantages unless they are available at prices comparable with manual gear change. The broad specifications found suitable for cable ploughing are:

(i) Wheeled tractors.
  (a) Torque converter with or without clutch and free wheel.
  (b) Manual or automatic transmission.
  (c) Final drive through limited slip differentials and hub reduction if possible.

(ii) Crawler Tractors.
  (a) Torque converter with or without clutch and free wheel.
  (b) Manual or automatic transmission.
  (c) Final drive through clutch brake.

The most important feature is the use of the torque converter and this is dealt with in the following paragraphs.

HYDRAULIC COUPLINGS AND HYDRAULIC TORQUE CONVERTERS

General

A hydraulic torque converter is a device which performs a function similar to that of a gear box, namely to increase torque while reducing speed, but whereas a gear box provides only a small number of fixed ratios, the hydraulic torque converter automatically provides a continuous variation of ratio from the lowest to the highest for which it is designed. Torque converters have been available for many years in road vehicles fitted with internal combustion engines but it is only in recent years that they have become available for earth-moving equipment. This is because most fluid drives, to keep them within acceptable dimensions, require an engine speed of over 1,600 r.p.m. and it is only recently that the compression ignition engines for tractors have been designed to run at this speed.

The simplest means of transmitting torque hydraulically is by a fluid coupling in which the ratio of input to output torque is always one to one (Fig. 13). It consists of two elements, a pump and a turbine, each element having a number of radial blades leading from the hub to the outside edge. A cover completely encloses the turbine and pump and this enclosure is filled with oil. When the engine is started the pump begins to turn and the oil is thrown towards the outside circumference of the pump as well as being guided across to the turbine. When the oil hits the turbine blades with enough force, the turbine turns. This movement slows the oil which then travels inwards towards the hub of the turbine, across to the pump and the whole sequence repeats.

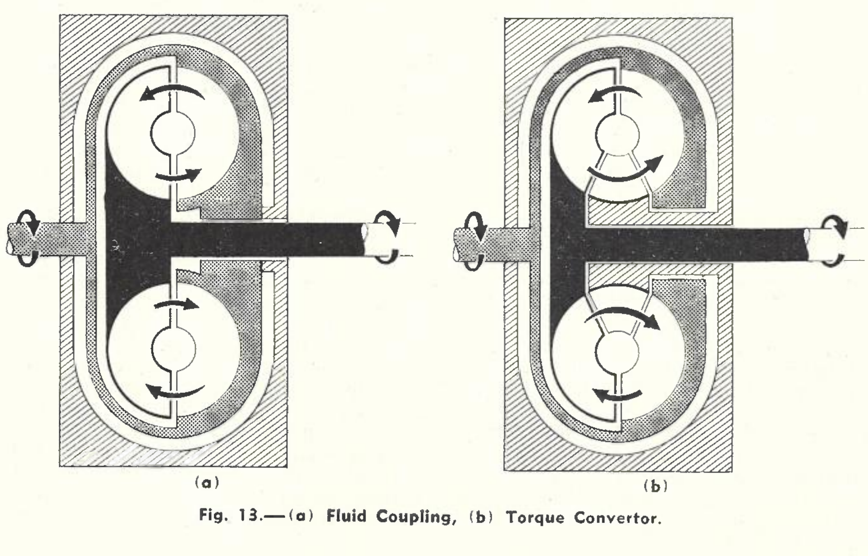
The following basic relationship for torque, speed, horsepower and impeller dimensions in a fluid coupling holds good for all centrifugal pumps:

> The power capacity is proportional to the cube of the impeller speed and to the fifth power of the impeller diameter; and the torque capacity is proportional to the square of the impeller speed and the fifth power of the impeller diameter.

The fluid coupling is the basic hydrodynamic drive. The work done by the engine in driving the impeller is turned into kinetic energy of the fluid which is in turn imparted to the turbine. The drive is transmitted by the absorption of energy as the fluid gathers speed on the outward flow in the impeller and the release of energy as the fluid loses speed during the inward flow through the turbine. The torque transmitted depends on the amount of fluid transferred from the impeller to the turbine and on the change of fluid speed.

Operating Conditions

Fig. 14 indicates the following conditions:



(a) (b)

Fig. 13.—(a) Fluid Coupling, (b) Torque Convertor.

(i) No slip (no load) — impeller and turbine rotating at the same speed.
(ii) Moderate slip (normal load)—impeller rotating at same speed as in (i), turbine lagging slightly.
(iii) Maximum or 100 per cent slip (stall load)—impeller rotating as before, turbine stalled.

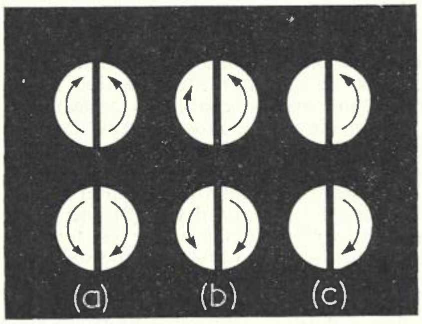


Fig. 14.—Operating Conditions of Fluid Coupling, (a) no load, (b) normal load, (c) stall load.

If the impeller and turbine rotate at the same speed, the turbine sets up a head of fluid equal and opposite to the head of fluid set up by the impeller. Since the heads balance, there is no movement of fluid between the impeller and the turbine. Therefore, there is no transfer of kinetic energy from driving to driven member, and no power is available at the output shaft. The path described by any particle of fluid will be one of pure rotation about the axis of the unit. When there is no slip, there is no transfer of energy from the impeller to the turbine, therefore, no power is available at the output shaft, and no power is absorbed from the engine.

When there is moderate slip (normal load), the turbine lags behind the impeller, producing a differential head between the fluid in the impeller and in the turbine. Furthermore, the differential increases with an increased difference in speed. This head produces the movement of fluid from impeller to turbine at the outer diameter. A circulation of fluid is then set up in the chamber of the coupling. During this circulation, the flow from the impeller to turbine at the outer diameter is balanced by the flow from turbine to impeller at the inner diameter.

At stall the impeller rotates at the same speed as before, but the turbine is stalled and no head is generated by the stationary turbine to counteract the head produced by the impeller. Since this situation produces the maximum differential in head the volume of fluid transferred from impeller to turbine is also a maximum and the axial component of velocity is as large as possible. Hence, there occurs the highest possible rate of fluid circulation and the maximum transfer of kinetic energy from impeller to turbine.

A summary of the foregoing conditions shows that the torque capacity of a fluid coupling is zero when operating without slip. As load is applied to the output shaft, the slip increases. When constant input speed is assumed, the torque absorbed and transmitted increases until the maximum torque capacity is attained at 100 per cent slip (turbine stalled).

Theory of Torque Converters

In order to make the hydraulic coupling perform as a torque multiplier, it is necessary to add a reaction member or stator between the load and the power source which is attached to the housing of the converter (Fig. 13b). The oil circulates in the same manner as in the hydraulic coupling but in the converter the blading is curved in all the elements, pump, turbine and stator. The pump pushes the oil outward and in the direction the pump is turning, the oil striking the turbine causing the turbine to turn. After striking the blades, the oil is directed inward towards the inner circumference of the turbine. As the oil leaves the turbine it is moving in a direction opposite to the pump rotation. The stator being held stationary causes the oil to change direction and adds its motion to that of the pump.

To illustrate the flow of fluid from one blade to the next, Fig. 15a shows

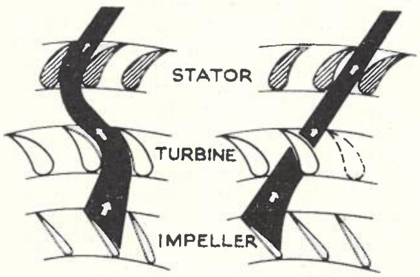


Fig. 15. — Operating Condition of Hydraulic Torque Converter, (a) flow at stall, (b) flow at racing.

one blade above the other in proper sequence as arranged in an actual converter beginning with the impeller. The arrows indicate the direction of fluid flow. Arrows pointing from left to right are assumed to be positive in velocity direction and represent fluid that has undergone an increase of momentum. Arrows pointing from right to left are negative in velocity direction and represent fluid that has undergone a decrease of momentum. Thus the fluid leaving the impeller has had its momentum increased with the force coming from the engine. As it flows across the turbine vanes, the velocity direction changes from positive to negative. This means a decrease of momentum and the submission of a force upon the turbine vanes attempting to produce clockwise rotation. The fluid leaving the turbine vane has velocity but in a negative direction which changes to positive by passing through the stator blades. Thus a velocity change has been made, increasing the momentum of the fluid as it returns to the impeller, adding to that which can be produced by the engine. With the fluid now leaving the impeller possessing greater momentum the nett change of momentum across the turbine can also be greater, meaning a greater transmission of torque.

Fig. 15b shows the flow of fluid at no slip and it will be noted that the velocity direction remains unchanged. This shows that the torque multiplication will vary with the extent of correction by the stator to the direction of fluid flow.

Torque Converter Heating

Torque converters are made in single, double or polyphase combinations, depending on the required torque ratio at stall, but all designs also aim for as broad a range of operation as possible. Because the object of using the torque converter in a tractor transmission is to have an automatic means of meeting changing demands for drawbar pull (torque) and speed, any change in torque or speed means a corresponding change in efficiency, with the power loss in the converter being dissipated as heat. At the extremes this would result in the total engine horsepower being dissipated as heat. This is not a practical proposition and the normal practice is not to work a converter within its extremes but normally over a range above a 70 per cent efficiency with heat exchangers fitted to dissipate 30 per cent of engine horsepower.

While tractor testing was in progress it became evident that there were occasions when prolonged use of the torque converter at higher slip (that is, maximum torque) could not be avoided, giving rise to elevated oil temperatures. It also became evident that full use was not being made of the high torque output from the converter.

It has already been mentioned that manufacturers generally fit heat exchangers to take care of a heat dissipation of some 30% of the transmitted horsepower, which is satisfactory for the speeds and torques used on bulldozing and clearing work. However, at the lower speeds and higher torques used when ploughing, this heat exchanger capacity becomes inadequate at times. This can be overcome by fitting torque converters designed to handle the low speed-high torque requirements but unless expensive torque converters are adopted, the problems of elevated oil temperatures arise again at the other end of the scale—namely when the converter is operated at limited slip. The solution adopted has been the fitting of larger heat exchanger capacity when required at a cost of between £200 and £400 per machine. The increase in fuel consumption when operating the unit below the 70% efficiency curve is negligible and even at an increase in fuel consumption of more than one gallon per hour, it would have a negligible effect on the hourly operating costs.

As a means of ensuring that the heat exchanger capacity of a torque converter machine is adequate for cable ploughing work, the "six minute test at 60°F" has been adopted. This consists of running the machine at full stall for six minutes at an ambient temperature of 60°F. At the end of this time the oil temperature must be below the maximum oil temperature allowed in the system. Although the criticism can be made that these are arbitrary figures, in fact they have been derived from some thousands of operating hours' experience. The six minute test is the best available at present and so far there have been no torque converter troubles when ploughing in such varied climatic conditions as from near freezing in the Mt. Kosciusko area in New South Wales, to over 100°F in the north of Queensland.

Merits of Torque Converters

The advantages and disadvantages of torque converters can be summarised thus:

Advantages:

(i) There is no mechanical coupling between the engine and the transmission so that shock loads are not transmitted.

(ii) The engine cannot be stalled when a load is suddenly applied to a machine.

(iii) There is high output torque at low machine speed.

(iv) The range of the output torque from the transmission is increased from any gear depending on the type of torque converter used. This range can vary from 2.0 to 6.5 times the engine output torque in any gear, depending on the design of the converter.

Disadvantages:

(i) The fuel consumption is higher than in a mechanical transmission machine with the same horsepower, though this is more theoretical than actual.

(ii) The engine cannot be started by towing the machine if the battery or starter engine is out of order.

(iii) There is little braking effect from the engine to the wheels or tracks.

(iv) When the load is lessened suddenly, the machine pulls away without the operator touching the throttle or the gears.

(v) There is "creep" in the transmission at idling speeds when in gear.

These disadvantages can largely be overcome. An over-run coupling can be fitted in the torque converter so that the engine can be tow-started and used for braking on hills, and, provided the transmission is in neutral, there can be no creep.

The torque converter automatically proportions the amount of torque delivered to the output shaft through infinite gradations up to its maximum, depending on the load applied. However, it does not necessarily do this according to the desires of the operator or even for maximum efficiency. The disconcerting habit of torque converter tractors pulling away when the load is dropped is familiar to all operators. This disadvantage has been overcome by training of the operators and provision of a foot decellerator has helped. However, this feature of automatically proportioning the torque to the load means that cable ploughing is carried out with a minimum of jerking of the machine and consequently a minimum of straining of the cable, and this represents the major advantage in the use of the torque converter.

SOIL TESTING

General

When designing and using cable ploughing equipment the basic factors involved are the characteristics of the machine itself together with a knowledge of the soil properties and how they react to the forces involved in ploughing and in traction. Because the machine characteristics remain more or less constant in any one unit wherever it is operating (other than at high altitudes) the variable becomes ground conditions.

Thus Fig. 8 illustrates the drawbar pull required to plough under certain conditions and Table 1 lists drawbar pull available from a representative selection of tractors. However the drawbar pull actually available may be less than that listed in the table to an extent depending on the traction available from the ground on which the tractor is operating. Thus while the drawbar pull required for ploughing at a particular depth remains substantially the same in a particular soil irrespective of the surface conditions, the tractive effort available from a machine to give this drawbar pull varies according to the surface conditions which in their turn vary with the weather. For example ploughing in an area on a dry surface may require a drawbar pull of, say, 30,000 lb. to pull the tine and cable box at 3 ft. depth; after rain, the same drawbar pull is still required, but, because tractive conditions have deteriorated the available drawbar pull is only 25,000 lb. In this situation the alternatives are to wait until the surface dries out, to plough at a shallower depth, to bring in another tractor and use the two in tandem or try to improve the traction of the original machine so that the required drawbar pull is available whatever the surface conditions.

Extensive investigations have been made into the relationship between soil conditions and tractor operations (1). However, the resulting data is not necessarily readily applicable to ploughing operations because it usually relates to tractors operating on disturbed soil—such as in agricultural and earthmoving operations—whereas tractors engaged in cable ploughing normally operate on undisturbed soil.

Hence investigations were directed towards tractor operations on undisturbed soil as well as disturbed soil with the following objectives:

1. To develop a method to determine in the field which of the available tractor types should be used for cable ploughing in any particular type of soil.
2. To discover means of improving the traction of different tractors in varying soil conditions.

These are described in the following paragraphs.

Selection of Tractor to Suit Soil Conditions

Tests were made in various country areas to obtain some idea of soil conditions in relation to traction and ploughing and to enable an assessment to be made of the most suitable tractor units for use in each area. Two methods were used for this—The Torsional Shear Test and the simulated Grouser Test. The first is a standard test (2) and consists briefly of forcing a circular torsion box with internal vanes into the soil and measuring the torque required to cause failure of the disc of soil in the box when a twisting force is applied to the box. The method was abandoned however as the results were inconsistent, especially between different operators. In most cases the cylinder of soil was sheared off during the process of hammering the casing into the ground.

The second method — the simulated Grouser Test (Fig. 16) — was devised locally with the object of achieving consistent results which can be simply extended to achievable drawbar pulls. The apparatus consists of mild steel plates, 8 ins. x 3 ins. with centre plates 3 ins. wide, of various depths, simulating the grouser of a crawler tractor's track. By loading the plate and measuring the maximum tension parallel to the soil surface needed to draw the assembly through the soil, readings of the unconfined soil shear are obtained. Fig. 16 shows the original method used; later, the hand winch was replaced by a hydraulic cylinder powered by a 12 volt D.C. motor-hydraulic pump combination run from a car battery. The readings obtained are shown in the graphs in Fig. 17.

As the purpose of the test is to select a suitable tractor type for use on the soil under test, it is necessary to extrapolate the results of this test where the maximum load is 300 lbs. with a pull of 400 lbs. to apply to a tractor weighing say 40.000 lbs. capable of a drawbar pull of 45,000 lbs.

A suitable empirical formula has not

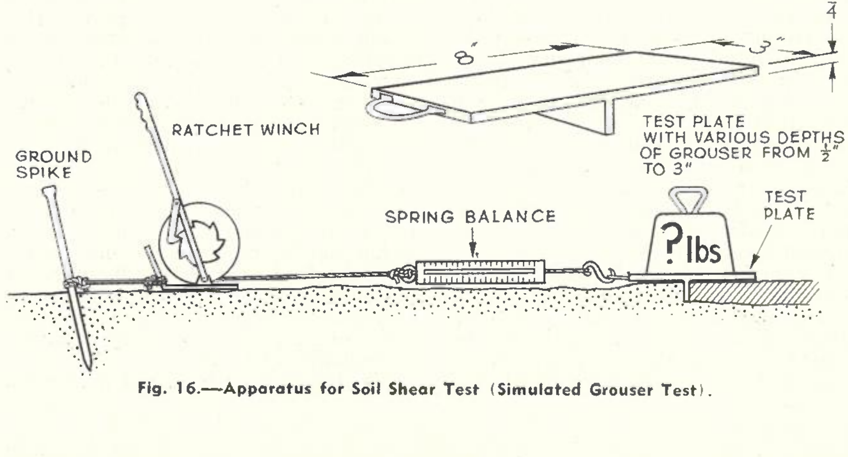


Fig. 16.—Apparatus for Soil Shear Test (Simulated Grouser Test).

yet been developed but for crawler machines, by extending the figures obtained with the test plates to the actual area of track on the ground, a sufficiently accurate figure for the drawbar pull exerted by a tractor operating on this soil is given by using a multiplication factor of 0.5.

For example:

(a) Test plate—400 lb. pull.
Extended in a straight line relationship for an Allis Chalmers HD.16 assuming that the pull is uniform along the full width of the grousers and that each grouser takes an equal part of the load, this comes to 81,000 lb. Multiplying this by 0.5 gives a theoretical pull of 40,000 lb.
Measured drawbar pull in the same condition on the actual machine was 37,000 lb., this is, the test figure x 0.455.

(b) Test plate—200 lb. pull.
Extended for Oliver OC.9—24,000 lb. pull. Multiplying this by 0.5 = 12,000 lb. Actual measured pull was 13,000 lb. or the test figure x 0.54.

These tests have been carried out in many areas over a wide variety of soil condition and tractors allocated to jobs on the basis of the test results. The results of tractor operations have shown a sufficient degree of co-relation with the test results and the test is now used with confidence as a basis of allocating tractor types to jobs. Sufficient data has now been accumulated about the soils in many areas so that the allocation is made without repeating the actual test.

Improving Traction of Crawler Machines

A further series of tests was undertaken in an attempt to devise means of improving traction; that is, given a particular type of soil, how can the traction of a machine operating on it be improved?

Consider first the theory of traction in soil (confined here to crawler tractors for which the theory is comparatively simple compared with the theory of traction of wheels).

A number of equations have been put forward, one of these being (2):

Gross tractive effort $= 2\ lS(w + 2h)$
where "l" is the length of track on the ground, "w" the width of track, "h" the grouser height, and "S" is the shear strength of the soil under an imposed load $L/2$ on each track, where L is the tractor weight.

Traction while ploughing depends on a mixture of soil friction and cohesion and although basically cohesion is the shearing strength of the soil at zero pressure, in practice it has different values depending on the pressure imposed on it, the rate of loading and moisture content. Similarly, the angle of internal friction is dependent on the intensity of pressure P to which it is subjected and the resistance r to sliding along a plane at right angles to the direction of P.

The relationship is given by

$$\tan\theta = r/P .$$

The shearing strength S of a soil is determined from the cohesion C and the angle of internal friction θ where the relationship is $S = C + P \tan\theta$. Both C and θ are complex and rapidly varying quantities and this is a simplified relationship.

The obvious way to improve the traction of a crawler tractor would seem to be to increase the grouser height. In the tractive effort equation given previously, however, doubling the grouser height from 1 in. to 2 ins. on a 22 ins. wide track gives only an 8% increase in tractive effort. To check this in practice a number of tests were carried out on grouser widths and heights and their effect on traction measured. The tests were confined to soils having a measurable shear strength such as clay, loam and clay loam mixtures with a grass top. Tests were not carried out on sand.

Soil data for the tests was obtained from a soil shear box of normal design split horizontally with an area $A = 144$ sq. ins. With a vertical load W applied uniformly to the top surface of the sample and a horizontal force F required to slide the top over the bottom and thereby shear the soil:

Intensity of pressure $P = W/A$.
Intensity of shear resistance $S = F/A$.

These tests with the shear box were carried out to give a value for the confined shear strength and to check values for internal friction and cohesion. The value obtained for the shear strength was used directly in the equation.

Track width tests were then made on undisturbed soil using a number of different tractors in order to have available different weights and drawbar pulls. Test tracks, 11 ins. wide (Fig. 18) were laid on the ground single width, double width and triple width by turn, a fresh patch of ground being used for every test. Wooden battens were placed across each track or each track combination and secured to them, and then the test tractor run on to them. The machine's tracks were secured to the test tracks by shackles at the front. This allowed the machine to run along the test track for its own length before the shackles came

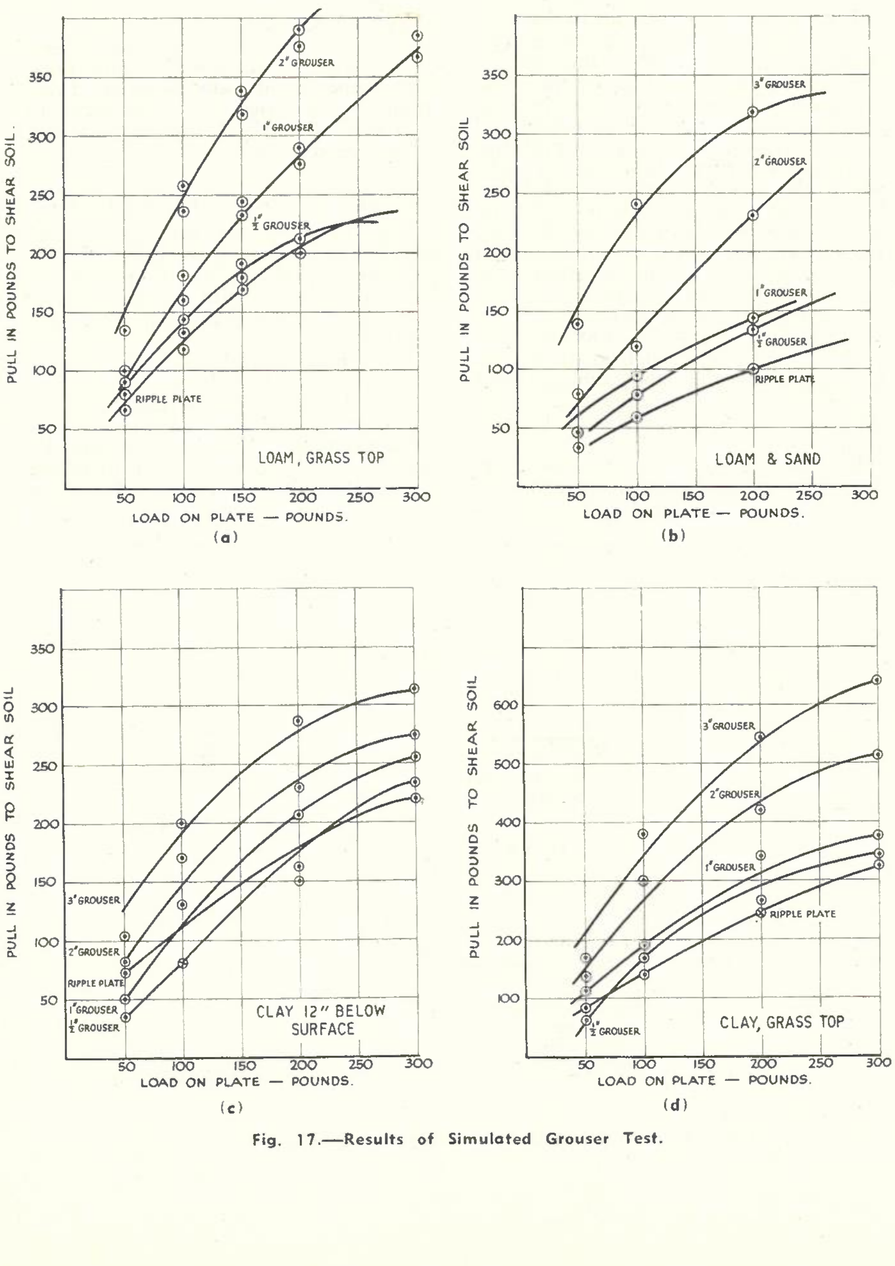


Fig. 17.—Results of Simulated Grouser Test.

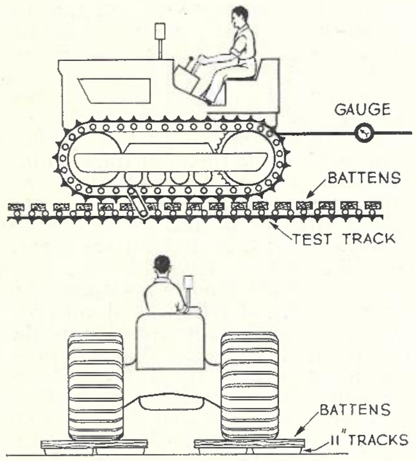


Fig. 18.—Track Width and Grouser Height Tests.

up against the drive sprockets. The results of these tests are shown in Fig. 19 which shows the drawbar pull in pounds resulting from the same tractor and length of track and depth of grouser where only the width of the track is altered. This indicates that trebling the width increases the drawbar pull by a maximum of 50%.

For **grouser height** tests, worn tracks were used with suitable depth mild steel grousers welded on them from ½ in. in height up to 4 ins. The results of this test are shown in Fig. 20. Here doubling the grouser height from 1 inch to 2 inches gave an increase in tractive effort from 16,000 lb. to 18,500 lb. or almost 16% and doubling the height again from 2 ins. to 4 ins. gave an increase from 18,500 lb. to 23,600 lb. or an increase of 28%.

From the equation for traction effort for the test machine with 16 ins. wide tracks, doubling the grouser height from 1 in. to 2 ins. gives a theoretical increase of 11% and doubling from 2 ins. to 4 ins. gives an increase of 20%. Similar tests carried out with a 22 ins. wide track produced more or less similar results again for the increase in tractive effort.

The discrepancy between the calculated and actual figures probably arises because conditions of measuring the value of S, the shear strength of the soil, in the shear box to apply in the equation differs from the actual conditions in the test. In particular the grass roots increase the shear strength of the soil while they are undisturbed. Furthermore, when the shear of the soil is tested in a shear box the soil is confined, but under the tracks, as soon as the soil is compressed locally in front of the grouser beyond its elastic limit and then sheared, it spills out from the side of the track and is recompressed again, in the process giving rise to a component somewhat greater than 4 lhS. This sheared section of the soil when the tracks are slipping is thus not rectangular but a trapezium and the area lh becomes $lh/\cos\theta$ where θ is the angle the side of the sheared section makes with the vertical.

The **grouser pitch** was also investigated from one per track length, that is, one grouser per side of the machine in the ground at any time, up to the conventional one grouser per track plate. Readings obtained for the drawbar pull varied from 14,300 lb. with 1 in. grousers, one per side, up to 23,600 lb. pull on the same machine with 4 in. grousers at 6¼ in. pitch. No conclusions, other than that the grouser pitch of 1 per track plate is satisfactory, could be drawn.

Patterned grousers were also tested, mainly chevron patterns with 90° to 120° included angles, in an attempt to increase the side friction, that is, the "hS" component and for test data on tyre traction. These tests have so far been confined to test plates of similar dimensions to tracks and tyre widths. The results indicate an increase of tractive effort of some 14% over that obtained with the straight grousers in the soils tested. It is hoped to continue these tests and find out whether this increase applies generally and if patterned tracks are economically justified.

Traction in Dry Sand

Tests were not carried out in dry sand because here traction is almost entirely dependent on the weight of the unit and the co-efficient of friction of the sand. No tractive improvements can be suggested except to increase the weight and the horsepower. Generally, no problems have arisen from ploughing in sand where the drawbar pull recorded has been of the order of 9,000 to 12,000 lb. at 2 ft. in depth. Using tractors of some 100 horsepower and a minimum weight of 10 tons with a sand co-efficient of friction of 0.7 the maximum drawbar pull which can be realised is:

$0.7 \times 10 \times 2{,}240 = 15{,}680$ lbs.

This is the figure obtained in practice with both crawler and rubber tyred machines. The testing of traction of rubber tyred machines is still in progress.

In clay and clay loam with grass cover, the performance of machines is altogether different from that in dry sand. In some of these soils after rain, the rubber-tyred machines cannot obtain traction at all on the wet top while in others there is traction on the grass but once this is torn up traction is lost. When crawlers are used in these soft, wet conditions, the drawbar pull drops when the grass cover is disturbed and the machines often become bogged.

The main conclusions about track design features for ploughing work are that the widest possible tracks available as standard should be used with a minimum of 2½ in. grousers on machines of under 100 horsepower and a minimum of 3½ in. on those above that. Although there is some loss in the drawbar horsepower because of the increased friction and some extra wear on the track rollers when turning, it is not considered that this is significant compared to the benefits obtained at ploughing speeds of between 1 and 2 miles per hour. Some increase in the heat exchanger capacity will be required and generally heat exchangers dissipating 50% of the engine horsepower prove satisfactory for all types of machines.

On the rubber tyred machines, larger tyres than are at present being used, with deeper treads, are required. Tyres similar to the rice-field tyres seem to offer a solution, though the walls would have to be reinforced.

COSTS OF CABLE PLOUGHING

The following are the total actual cable layer costs of some cable ploughing jobs carried out in various parts of New South Wales with crawler units of the types discussed in this article, ploughing to 3 ft.:

Hours on job—483.
Hours Travelling—103.
Cable Laid—69 miles.

The present operational hire costs of the crawlers is £2 per hour and for 25-ton float 3/- per mile. No travelling charge is made on a tractor. Travelling

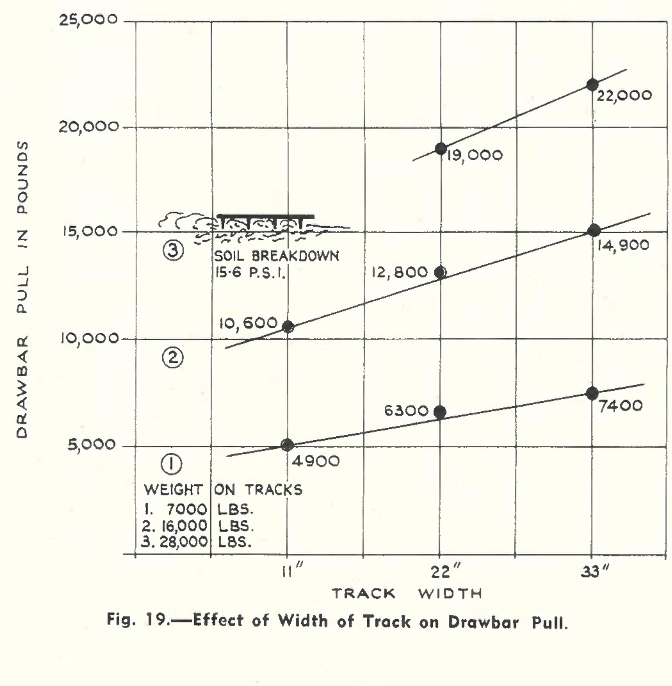


Fig. 19.—Effect of Width of Track on Drawbar Pull.

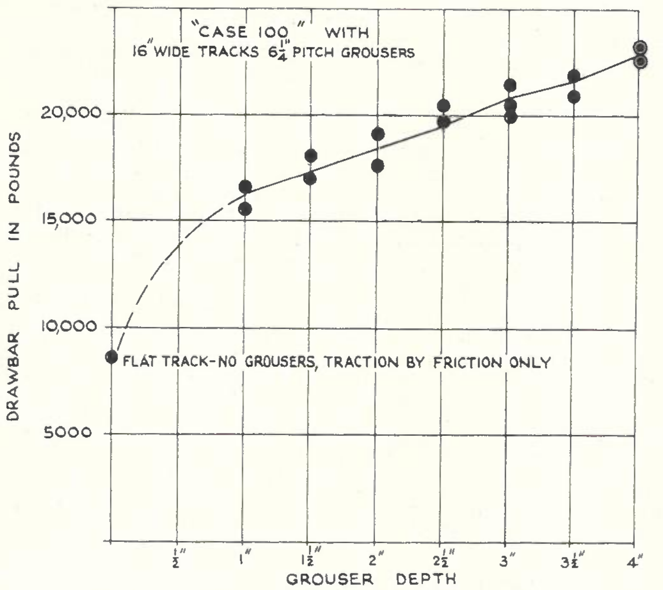


Fig. 20.—Effect of Grouser Depth on Drawbar Pull.

speed is 15 m.p.h. This gives an overall cost of £17 per mile of cable laid.

The following are the total actual cable layer costs of some jobs carried out by the rubber-tyred units ploughing to 2 ft:

Hours on job—693.
Hours Travelling—351.
Cable Laid—117 miles.

The operational rate for the rubber-tyred units is 30/- per hour, giving a total machine cost of £1,566 for 117 miles or £14 per mile. Although only actual running costs are shown here, commercial hire rates need only be substituted for the hourly rates given above to make an exact comparison with contractor's hired plant.

Table 2 gives the complete costs for a number of jobs of cable laying, per mile of cable, including material handling and transport and all incidentals.

It will be apparent from the foregoing that the trend of development of cable ploughing machinery is to more elaborate and more expensive equipment and a comparison of costs with the older, less expensive plant would be of interest. A direct comparison between the old drawn ploughs laying cable at shallow depths and present three-foot penetration ploughs is not reasonable because of the much better and more difficult job done by the later equipment. Further, a direct cost comparison is difficult because of changing money values. Nevertheless, a study of cost trends indicates that the overall cost of ploughing cable with modern plant is, due to its greater efficiency, actually substantially lower. Thus it is estimated in terms of current money values that the cost of laying cable with the old drawn ploughs at shallow depths, jointing it and reinstating the ground afterwards, varied between £119 and £185 per mile. This includes operational hire rates for the tractor, plough, cable trailers and staff necessary but does not include cable costs or administration charges. On the same type of job today, but ploughing to a depth of 3 ft., the costs are of the order of £60 per mile, with the machinery charges accounting for some £20 of this.

MEN AND MACHINES

Although "equipment is only as good as the people who use it" may be an overworked phrase today, it is as true as it has ever been. It has added meaning when applied to earth-moving equipment, for the conditions under which the work is carried out are far from ideal either for the machines or for the men who drive, service and repair them in the field. Although skill is a first requirement for anyone dealing with complex machinery, to this, for the people working with tractors, must be added sheer physical endurance for them to be able to keep working long hours in extremes of temperature, clouds of dust and heavy rain and live in a tented camp or temporary accommodation for long periods. Modern machines can stand up to the duties imposed on them under conditions of somewhat inadequate maintenance. The biggest advance in recent years in this connection has been in the provision of packed races in the track rollers that do not require to be serviced for some 500 hours or longer and the adoption of hydraulic controls for the tracks and clutches which has substantially prolonged their life by reducing the frequency of adjustment.

As equipment becomes increasingly complex, more attention needs to be paid to the people who maintain it. It is not sufficient to lay down procedures in handbooks. The conditions under which these procedures are put into effect must be taken into account. It is altogether a different matter setting injectors in a dust storm, for instance, when they have to be immersed in a container of fuel oil and the work carried out by a sense of touch only, to setting them in an air-conditioned workshop.

The present-day trend is towards machines which perform more complex

TABLE 1 — PERFORMANCE DATA FOR A NUMBER OF TRACTORS

Machine	Maximum Drawbar Pull	Track Length	Width	Grouser Depth	Weight of Machine	Engine H.P. Total	Tyre Size	Track area sq. ins.	Weight per unit area lb/sq. ins.	H.P. unit wt. (tons)	H.P. sq. ft. Track area	H.P. per unit track width (ins.)
Crawler												
Caterpillar D.4	10,000-12,000	62"	13"	1.75"	14,500	63		1,612	9	9.75	.48	2.4
Case 1000	17,000-18,600	79"	16"	2"	20,000	100		2,528	7.9	11.2	.48	3.1
Oliver OC.9	12,000-13,000	67"	14"	1.5"	14,590	62		1,876	7.8	9.55	.41	2.2
Oliver OC.12	14,000-16,700	67"	16"	2"	14,600	65		2,144	6.8	10	.36	2
Allis Chalmers HD.16	33,000-37,500	110"	22"	2"	38,000	175		4,840	7.9	10.3	.44	4
Euclid C.6	44,000-48,500	115"	22"	2.75"	45,000	220		5,060	8.9	11	.52	5
Rubber-Tyred												
Michigan 85A	13,000-15,000				19,000	107	1400 x 24			14.0		
Le Tourneau LW.16	15,000-21,300				26,000	122	1800 x 25			11		
Conquip 62 h.p. Ford	8,000-11,000				14,000	62	1300 x 24			9.9		
Lorain 100 h.p. (Cummins)	12,000-14,300				22,000	110	1400 x 24			11.2		
Fordson Major (Crane)	6,000- 7,500				9,000	52	1500 x 28			12.95		

TABLE 2 — COSTS OF PLOUGHING

Cable Size Prs./ lb.	Labour £	Material £	Equipment and Incidental Charges £	Administration £	Total £
10/10	46	184	20	38	288
10/20	46	268	20	38	372
25/10	48	332	20	40	440
25/20	48	494	20	40	602
50/10	55	638	20	45	758
50/20	55	972	20	45	1,092
75/10	57	911	20	48	1,036
75/20	57	1,388	20	48	1,513

operations yet require less skill of the operator but, on the other hand, demand greatly increased skill of the machine programmers and maintenance staff. The degree of skill required to repair a tractor is much greater than that required to operate it. But it must be remembered that the operator of a £20,000 cable ploughing train has under his control equipment that can do the work of several hundred men. Most ploughing jobs are carried out over an extended area where supervision of every phase of the work is difficult. The men on the job must be the best available. Even so they are still only semi-skilled. The use of tradesmen to operate the machines, in which case they would be both mechanics and operators, has been considered for some time. This would overcome the one difficulty of righting minor mechanical faults that cause frustrating delays and are beyond the skill of ordinary operators.

Staffing is a problem which warrants the closest attention if the best results are to be obtained from ploughing equipment, but is one which is very difficult to solve within the framework of the personnel policy of a large complex administration.

CONCLUSION

Ploughing cable into the ground is one of the most economical means of providing physical conductors between subscribers and exchanges and the use of the present equipment has resulted in substantial savings during the time it has been in use. Although the major development work is more or less complete, much remains to be done to improve traction on both rubber-tyred and crawler types of cable layers and to improve cable handling methods. Under investigation at present is the use of larger low pressure tyres having a ground contact pressure similar to tracks. The combination of tracks for working and rubber tyres for travelling, incorporated in one machine, is being considered along with hydrostatic transmission and four wheel drive - four wheel steer machines.

ACKNOWLEDGMENTS

The author wishes to acknowledge the valuable contributions made to the investigations, described in this article, by many individuals, both in the Postmaster-General's Department and in private industry. In the Department were Messrs. E. W. Corless, G. Buckland, C. W. Robinson, G. F. Gardner, K. Coldwell, H. M. Fitzpatrick and W. E. Sayers. Mr. G. I. Mosdell of the Lidcombe Workshops, and the staff there, made up so many of the bits and pieces and helped to test them. Among the commercial firms were Oliver (Australasia) Pty. Ltd., J. I. Case (Australia) Pty. Ltd., Blackwood Hodge (Australia) Pty. Ltd., Ateco Pty. Ltd., Tutt Bryant Ltd., Allis Chalmers (Australia) Pty. Ltd., Clark Equipment (Australia) Pty. Ltd., Le Tourneau Westinghouse Pty. Ltd., Caterpillar (Australia) Pty. Ltd., whose help and co-operation are much appreciated.

Considerable assistance was received also from a number of references which were consulted during this study and these were not mentioned in the text. As they may prove of value to readers interested in the subject, they are listed under "Further Reading".

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TECHNICAL NEWS ITEM

NEW CROSSBAR EXCHANGES

On 18th May, 1963, a pilot crossbar installation of 2,800 numbers capacity at Petersham Telephone Exchange (N.S.W.) was placed in service with 1,200 working lines. This was the culmination of over two years' intensive effort by the Australian Post Office and the three manufacturers to complete all the modifications necessary to the basic design in order to make it work in the Australian step-by-step network. The crossbar equipment for the Petersham installation was ordered from L M Ericsson (Sweden) to facilitate design and factory testing of new circuits which had to be designed. Although this equipment was ordered in 1959, installation was delayed deliberately to ensure that all the equipment installed would be to the final design. In addition to its primary function of field testing the new design, Petersham has been used as a training ground. Senior technical staff who have been trained there will form the nucleus of the installation and maintenance groups who will install and maintain crossbar equipment totalling 100,000 new exchange lines each year.

A further crossbar exchange was placed in service at Cleveland, in the Brisbane local service area, on 23rd June, 1963. This installation brought into operation the first crossbar equipment to be made in Australia. The Cleveland exchange has a capacity of 600 subscribers' lines and at cutover more than 400 subscribers were provided with automatic service. Sixteen outgoing and 18 incoming junctions connect Cleveland to the inner Brisbane exchanges and there are also direct junction routes to Wellington Point, Victoria Point, and Redland Bay.

Locally manufactured and assembled crossbar equipment is at present being installed in the new 2,000 line exchange for Whyalla (S.A.) and in a number of smaller exchanges. During the 1963/64 financial year it is expected that a further 150 automatic exchanges will be placed in service. Some will replace manual exchanges and others will be completely new exchanges required in expanding areas. More than 100 of these will be provided in country areas.

TECHNICAL NEWS ITEMS

LECTURE BY MR. OSCAR MYERS ON AUTOMATIC TRUNK SWITCHING PROBLEMS

Members of the Society in Melbourne were very fortunate in having the opportunity of attending a lecture by Mr. Oscar Myers on "Problems of Automatic Trunk Switching". Mr. Myers is Director, Telephone Switching Development, with the International Telephone and Telegraph Corporation, New York, but until recently was engaged on the development of switching systems in the Bell Telephone Laboratories. He has been very closely associated with all major switching developments which have taken place in the Bell System since the early 1930's and is recognized throughout the world as a leading authority in his field. Mr. Myers was closely associated with the design of the card translator used with the Bell No. 5 and 4 crossbar equipment and in later years has been in charge of a switching system engineering group working on the problems associated with the introduction and extension of Direct Distance Dialling. A recent example of work in his Section was the Traffic Service Position now being introduced to reduce operator requirements and permit person to person D.D.D. calls.

By arrangement with the Institution of Engineers, Australia, Mr. Myers also delivered a lecture in Sydney on "The Various Approaches to Electronic Switching" in the Institution's lecture theatre at Science House on 9th May. This lecture was widely publicised by the New South Wales Division of the Telecommunication Society, in addition to the normal Institution publicity, resulting in an overflow audience in excess of 200.

The Melbourne lecture was delivered on 15th May, 1962, at the Radio Theatre, Royal Melbourne Institute of Technology, to a capacity audience. It outlined mainly the history of automatic trunk switching development in the U.S.A. and the object lessons to be gained from experience there, and concluded with a review of some very interesting recent developments.

AUTOMATIC TRUNK SWITCHING EVOLUTION

In his opening remarks, Mr. Myers said that a necessary preliminary to the design of an automatic trunk switching system was the conviction that such an arrangement was technically and economically feasible. He went on to say that present-day system designers were reassured on these matters since there were a number of established systems which were working acceptably. Economic feasibility still needed to be determined in each case, but there was little doubt that automatic trunk switching could be justified in most networks with substantial volumes of traffic. In spite of reassurance on both these points a designer still faced a number of problems, but in the 1920's there was considerable doubt in America even as to feasibility. Toll dialling experience was limited in those days. There had been several successful trials of short haul operator toll dialling in a few small step-by-step networks. Initially "terminal only" calls were handled over one-way trunks. It was not until the late 1930's that calls were switched over more than one link and that both-way trunks were developed. Composite signalling was used for supervision and for dialling in a decimal code. Numbering was arbitrary.

Part of Audience at Lecture given by Mr. Oscar Myers on 15th May, 1963, at Royal Melbourne Institute of Technology. Front row (from left): Messrs. R. W. Turnbull, C. Prosser, E. Sawkins, O. Myers, K. Brown, C. Sonnenberg, R. Butler.

There had also been a trial of a common control type automatic trunk switching system in Seattle, Washington, starting in August 1925. This switching system used panel type switches and a modified form of composite signalling over the toll lines. The trial was not entirely successful due to signalling difficulties on the open wire circuits along the foggy Puget Sound coast. Furthermore traffic savings had not been as great as had been originally estimated, and equipment costs were higher than estimated.

By the late 1930's toll traffic in the U.S.A. was growing at such a rate that it was clear that some form of automatic trunk switching was needed on a broad basis and serious planning and development was started on a toll crossbar system. The No. 4 Toll Crossbar System emerged from this development. For practical reasons its development began with a two-wire switching scheme, even though the advantages of four-wire switching were relatively well understood. However, this was rectified very early in the development when the two-wire version was abandoned in favor of a four-wire design. As experience was gained, it became apparent that there were more serious limitations that ultimately resulted in the abandonment of the original scheme and in a major redesign of the system which was then redesignated 4A.

All of the early toll crossbar design was based on the arrangements that had been successful in the step-by-step intertoll dialling networks. The No. 4 system operated with arbitrary route codes, switching was limited to two or three intertoll links in tandem, the intertoll code digits could not be retransmitted, and alternate routing was not used although it was already in use in local crossbar operation.

During the early 1940's a much broader view of future requirements began to emerge. Development was started on a nationwide switching system, initially for operator dialling, but with provision for ultimate customer dialling. A number of subordinate plans for numbering, trunking, signalling, transmission, and switching were integrated into one overall plan.

However, even at that stage, it was not possible to anticipate the extent to which traffic would increase once fast service and good transmission became common. There were therefore several successive redesigns to increase the capacity of the 4A system. The latest design allowed for 16,000 inward terminations and 24,000 outward terminations in a single unit. These terminations included intertoll trunks, toll connecting circuits, and circuits to and from operators. In spite of what appeared to be a very large capacity, it was still not adequate. Los Angeles, for example, was served by two of these systems and foresaw the need for seven ultimately. Both Chicago and New York and their environs were each served by several of these large systems but in addition enormous volumes of toll traffic were handled on crossbar tandem, No. 5 Crossbar and trunk concentrator systems which supplement the 4A systems.

Mr. Myers said that to some extent the picture presented on capacity was one-sided, as for example, the hazards involved in "too many eggs in one basket" had to be considered. A complete switching machine could be incapacitated for one reason or another, whereas when the traffic was distributed over more than one machine the likelihood of complete outage was greatly reduced. Another thing to be considered was the ability of alternate routing to improve the efficiency of a group of switching systems serving one area to such a point that the trunking penalty of operating with the several systems was largely avoided.

SIGNALLING PROBLEMS

The designers of the early automatic trunk switching systems were faced with the need of developing new signalling systems while at the same time providing for compatibility with the several signalling systems used in the local exchanges with which the toll exchanges connected. With respect to trunk signalling there were a number of decisions to be made: inband or out-of-band; voice frequency or direct current; link-by-link or end-to-end; continuous or spurt; binary or self-checking; and digit-by-digit or "en bloc" outpulsing.

One choice at least was easy. The introduction of carrier and repeaters in intertoll trunks dictated some form of voice frequency or at least alternating current signalling. Also it was rather easy to decide on a self-checking inter-register pulsing scheme, which turned out to be the 2 out of 6 multi-frequency pulsing which has proved to be exceptionally satisfactory.

Costs and simplicity argued for a two-state continuous line signalling design. This started as a 1,600 cycle single frequency scheme because of the use of emergency narrow band circuits in the toll plant. When the narrow band circuits were eliminated the 1,600 cycle signalling units were replaced by the more desirable 2,600 cycle units. In general, the latter had performed quite well. They were less subject to "talk-off" than the 1,600 cycle units. At present a solid state design was replacing the vacuum tube design. It was felt to be important that the same signalling unit could be used at both ends of a toll circuit and that it would be compatible with composite signalling, some of which was still in the plant and might be encountered on built-up connections. The use of common denominator arrangements at every switching point was decided on; these were the E and M leads which have been major factors in the flexibility of the trunk switching systems.

"En bloc" outpulsing was adopted for multi-frequency signalling for simplicity since the outpulsing time was partially covered up by translation and switch set-up times in succeeding offices and post-dialling delay was not appreciably increased. Digit-by-digit outpulsing was used however for decimal pulsing to minimize post-dialling delays. For completing into local offices it was also necessary to provide for revertive pulsing, call indicator pulsing, and call announcer operation. The first two were inherited from earlier North American arrangements and were only of local interest. Call announcer was a method of machine sending of voice to a manual office from voice recorded on film and controlled by the registers of the automatic system.

MAINTENANCE PROBLEMS

The designers of the nationwide trunk dialling systems in North America were well aware of the maintenance problems that were likely to be troublesome because of experience with large local networks using tandems. They knew that every additional link and every additional switching centre complicated the maintenance. Furthermore they were well aware of the fact that customers who were accustomed to excellent service on local calls would react unfavorably to less satisfactory service on expensive toll calls. Consequently a large amount of thought and effort went into insuring reliability, in avoiding troubles, and in providing tools for detecting, locating, and clearing troubles. At every point where a substantial service hazard was involved, duplicate equipment was introduced. Since practically all operations were self-checking, and since automatic trouble records and second trials on duplicate circuits were made when troubles were encountered, the switching gear was well protected. A great deal of effort was also spent on test circuits and routiners.

In spite of all this, system ineffective attempts have been averaging over 6% on long distance calls as compared to 2.8% average in the local networks, many of which were large and complicated. Ineffective attempts included all causes of failures to complete except line busies and don't answers. More than half of the ineffective attempts on trunk calls were due to customer errors, and also on local calls (about 1.5%). Both figures were decreasing rapidly as intensive efforts were being made to improve performance and to educate customers. The worst cities had several times as many ineffective attempts as the best.

The established objective for the United States and Canada was long distance service as good as local service. To meet this objective there was now a great deal of activity in improving test circuits particularly to make more marginal tests; to extend automatic transmission testing to cover most of the trunk network and some of the toll connecting network; to add more service observing equipment, mechanized if possible; to provide special bureaux for trouble reports and analyses; and to introduce network management concepts and arrangements.

Mr. Myers said that maintenance was an old problem to which some very able people had given a lot of thought. Out of this thinking had come ideas of preventative and corrective maintenance, and more recently the concept of auto-diagnosis for electronic systems. Several different concepts of auto-diagnosis have been suggested. In one, idle circuit time would be used for placing and checking diagnostic calls through a system; in a second, every call would be processed through stand-by equipment at the same time the working equipment handled the regular call and the results compared; and in still another, test and diagnostic microroutines would be stored in the program and be activated when the maintenance force thought they were needed.

The thought has occurred that an extension of the self-checking, trouble reporting, second-trial philosophy, restricted up to now to a single exchange, could be extended to cover a network in successive stages. What was proposed was modification of existing signalling systems, or a new signalling system of much higher speed, with backward signals to report congestion, trouble, and the identification of equipment involved in a blockage, that is, in a failure to switch. The registers at each point would remain connected until a backward signal indicated that the next switching point had successfully recorded several or all of the digits, and had selected a trunk and linkage, or that failure or congestion had occurred. To the extent practical a detailed record would be made of the cause of blockage along with the identification of the elements involved. This would be followed by either a retrial or by selection of an alternate route. It was the feeling that an arrangement of this type, along with improved test gear, and more extensive service observing would go a long way to meeting the desired service objectives of automatic trunk switching.

NETWORK MANAGEMENT

Even in manual days the North American trunk network would become overloaded on certain holidays, and when catastrophes like earthquakes and hurricanes occurred. Under these conditions delays were posted at outward boards. These postings plus the ingenuity of the operators in finding underloaded—and unauthorized—routes generally managed to cope with the situation.

When automatic systems were introduced, the overload problem became more difficult to handle, in spite of posted delays, for several reasons. For one thing, the machines could not search out routes like operators could. For another thing the operators' excessive attempts were difficult to control. Still another reason was the attempts by operators to outwit the machines by seizing and holding registers before they were needed and by setting up and holding circuits to inward operators at congested points. The tendency of an overload to spread with a hierarchical automatic network was a very important factor. An overloaded trunk exchange could back up traffic in all other exchanges that tried to route calls through the overloaded point. When customer dialling of trunk calls was started the overload problem became even more acute because customer subsequent attempts were difficult to control. The network became even more sensitive to situations all over the country.

Numerous things were tried and two proved to be specially helpful and were in use in many places. One was a "sender (register) overload control" scheme. Whenever the senders at a trunk exchange reach a predetermined level of occupancy, the length of time they will wait for a proceed-to-send signal from a point ahead is reduced and the call is routed to an announcement trunk which tells the calling customer or operator that serious congestion exists and asks that a subsequent attempt be held back for a relatively long time. When this overload control arrangement was first introduced an interrupted tone was returned instead of a verbal announcement. This had practically no effect on the customers although most operators would hold back their subsequent attempts. The verbal announcement has been effective, however.

Another modification that has been worth while was a redesign to provide for directional reservation under heavy load conditions. Under conditions of congestion it was desirable to complete calls that have advanced through the network and to block calls that are just getting started. This could be done by providing arrangements on end links to give priority to incoming calls. The North American scheme for doing this was to provide an automatic arrangement to measure the load on the group. When this reached a critical level, outward access was limited to a small number of trunks while inward access was unrestricted.

In spite of measures such as these, critical overload situations still developed on holidays like Christmas; when natural catastrophes like earthquakes, hurricanes, and major fires occurred; and on other occasions. Heavy overloads were particularly bad on common control systems because they could easily reach a level that degraded the carrying capacity of a system even below its engineered level. In addition, an alternate routing system could spread the overload far and wide.

Mr. Myers said that in these modern networks it was impractical to operate one part of the network without consideration of other parts. In particular, in a hierarchical network the higher ranking entities became focal points for overloads because these were in the final routes to which alternate routing tended to drive traffic. Because of the interdependence of the parts it was obvious that the old concept of treating each exchange as an entity in itself was obsolete, and that an overall team approach was needed.

This had led to the concept of a team of network managers who could provide for co-ordinated activity and control on a regional or continental basis. The Bell System had established a set of goals for network management which had been published and which were:

"To ensure a maximum flow of traffic in the network, provide for an overall view of the traffic flow and of the performance of switching equipment.
"Provide a clearing house for ideas and suggestions for making use of the network facilities and reducing the number of uncompleted calls.
"When traffic congestion occurs, localize it to prevent its spread, so that it will not needlessly interfere with calls that can be completed.
"Make advance plans to handle the highest possible traffic load on predictable peak days.
"Contribute to the proper functioning of switching systems and equipment.
"Recommend changes — based on observation of the operation of the switched network—that can contribute to improvements in performance.
"Arrange for special action when necessary.
"Provide information for engineering."

The details of how all of this could be done were beyond the scope of the lecture. However, a number of regional management centres were already operating, some with status boards with telemetered information on traffic conditions. This information covered the status of trunk groups, senders, and markers. Private lines connected all major management centres, and a teletypewriter party line was used for broadcasting information. Out of experience with these centres, numerous improvements in procedures and designs would no doubt be suggested. One that was already obvious was the need for translators and route control devices that were electrically settable from management points.

Mr. Myers concluded by saying that in view of the astonishing growth in trunk switching, and the rapidly growing worldwide network, it was clear that we are entering a very interesting and challenging era in communications.

MEETING OF PLAN SUB-COMMITTEE FOR ASIA (INTERNATIONAL TELECOMMUNICATION UNION)

The International Telecommunication Union (I.T.U.) is engaged in planning the development of the international telecommunication network, through the Committee for the General Plan for Development of Telecommunication Networks, established within the Union. Three Regional Plan Sub-Committees are responsible for preparing the plans within their respective regions for integration into the overall plan and for examination of technical, operating and tariff questions raised by the application of the various stages of the plans. The Plan Sub-Committee for Asia met in Geneva in February 1963. The meeting was attended by 84 delegates representing 18 member countries as well as private operating agencies. The Australian delegation comprised three officers of the Australian Post Office, including the delegation leader, and one from the Overseas Telecommunications Commission.

In addition to drawing up new plans of estimated traffic and circuit requirements between countries in the Asian area for the next five years, attention was given to problems of planning for ultimate world-wide automatic telephony and the future possibilities of space communications, as these may affect the Asian region. The meeting also focused attention on the rapid rate of development of intercontinental circuits including the COMPAC and SEACOM sections of the Commonwealth round-the-world cable. Plans for world-wide numbering and switching were examined and the numbering plans, which were based on an initial Australian proposal, were endorsed with only minor modification for application in the Asian area. These plans will also be examined by the full Plan Committee at a meeting in Rome in November 1963.

The meeting also examined a number of new technical questions raised by Asian countries and these were set for study by the appropriate Committees of the I.T.U.

INSTALLATION OF AN 1,800 PAIR POLYTHENE INSULATED AND SHEATHED CABLE

*R. D. JOHNSTON, B.Sc., A.M.I.E.Aust.**

INTRODUCTION

The provision of additional railway tracks in the rail system feeding the near western suburbs of Brisbane involved the replacement of a number of old wooden road over-bridges by prestressed concrete structures where widening of rail cuttings was required. This posed a particular problem at Burns Road Bridge, near the Toowong Exchange, the main exchange for the western district of Brisbane, where existing cables cross the rail line to service the highly developed residential suburbs of St. Lucia and Indooroopilly. These cables, totalling 1,600 pairs, were armoured cables attached to the old wooden bridge. A survey of the area indicated that at least 3,500 pairs would be required to meet the 20-year development figure.

CHOICE OF PLASTIC CABLE

Two alternative methods of replacing these armoured cables were possible:

(i) To provide a new conduit track set in concrete across the new bridge from the exchange to link up with existing conduits on the other side. The section would have both vertical and horizontal angles, both including an angle of about 135 degrees, and a large part of the conduit would be laid under the road surface.

(ii) To provide a new conduit track to a suitable point where a multi-duct run could be laid under the four lane rail tracks.

The disadvantage of the first alternative was the existence of an expansion joint in the bridge, which necessitated a break in the conduit approximately 1½ inches wide. With lead cable and the severe vibration of vehicular traffic it was evident that severe intercrystalline fracture would probably occur at this point. However, the second alternative was costly, did not make use of existing conduits and was difficult to achieve because of ground contour.

About this time, several drums of large size polythene insulated and sheathed cables had been made for experimental purposes, including some 1,800 pair 4 lb. conductor cable. This cable had a maximum capacity of 0.0802 mf. per mile with an average of 0.0777 mf. per mile. Although this was higher than normal, the short lengths of cable to be used would involve only a very slight increase in attenuation. Manufacturing tests included:

(i) an application of 5KV DC between cores for 2 seconds;

(ii) after insulation, immersion of the insulated conductor in water for not less than 12 hours and while immersed, tested with 500V DC; and

(iii) after twinning, 500V DC on the twinned conductor after immersion in water for at least two hours.

* See Page 83

This type of cable appeared to be suitable electrically for the application, and it was considered it would overcome the fatigue problem and permit a much less costly installation. Alternative (i) was therefore adopted and two 1,800 pair 4 lb. cables of this type were drawn into ducts laid across the bridge and cut over.

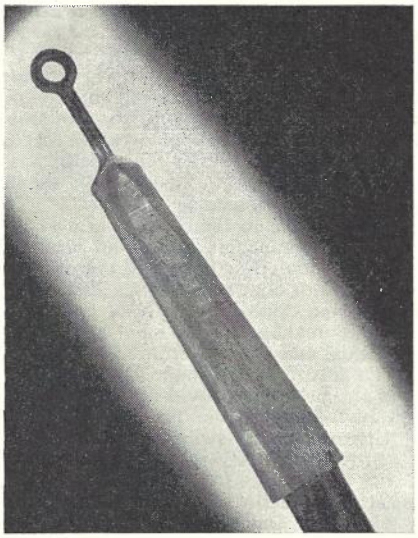

Fig. 1.—Epoxy Resin Pulling Termination.

MAKE-UP OF CABLE

The basis of the cable formation was a unit of 25 pairs wrapped with a coloured nylon whipping. The core of the cable comprised eight separate units of 25 pairs, while in the next two layers, four 25 pair units were formed into a 100 pair unit, the whole again being wrapped with a distinctive whipping. The number of 100 pair units in each layer varied from six to ten.

INSTALLATION OF THE CABLE

Although the section lengths were short, the poor tensile properties of polythene prevented a direct pull on the sheath and necessitated the use of a different technique. The success of epoxy resin terminations on large size P.I.L.C. cables led to its adoption in this case. By this means the pulling-in stress was transferred by an eye bolt to the combined cable components (Fig. 1).

The eyebolt was attached as follows: The cable sheath was cut off for about some 14 inches and fanned back. A suitably tinned 12 inch eyebolt was then wiped to most of the conductors. Next a cone 15 inches long was made of 7 lb. lead, 3⅜ inches outside diameter at the large end, and 2 inches outside diameter at the smaller end. This was placed over the eyebolt, large end towards the cable sheath, and pulled up till about 2 inches of sheath was overlapped by the lead cone. The small end of the cone was then soldered to the neck of the eyebolt.

After this had cooled, the eyebolt was held vertically downwards, and the cone filled with epoxy resin. When this had set, a strong drawbolt firmly attached to conductors and to the sheath (by shrinkage of the resin) was attained.

Formulation used for the termination was:

Epoxy Resin (Epoxide equivalent approximately 190 and viscosity at 25°C. 10,000-15,000 cps), 100 parts by weight.

Reactive Plasticiser (Thiokol Liquid Polymer LP33), 30 parts by weight.

Curing Agent (Hardener HY956), 18 parts by weight.

The normal proportions of Thiokol, 50 parts and curing agent, 20 parts, were reduced, the Thiokol for added strength and the curing agent because of the heat of the reaction had a deleterious effect on the thin polythene conductor insulation. Curing time was approximately four days.

Lubrication for drawing-in was provided by French chalk blown into the ducts by a compressor and the cable hauling was completed quite easily.

SHEATH JOINTING

The plastic cable had to be jointed at each end into standard P.I.L.C. cable operating under gas pressure. The joint

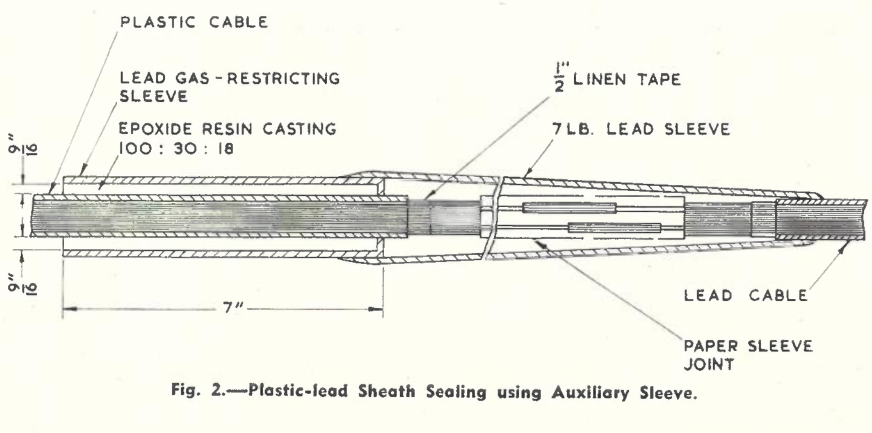

Fig. 2.—Plastic-lead Sheath Sealing using Auxiliary Sleeve.

therefore had to provide an adequate sheath seal and also allow for passage of gas. Principal requirements set for the joint were:

(i) it must be possible to open and reclose the joint three or four times;

(ii) the sleeve must be absolutely gas and moisture tight; and

(iii) the sleeve must be rigid, strong and durable.

The method adopted (see Fig. 2) was the auxiliary sleeve method. The sleeves, made of 7 lb. sheet lead, were 15 inches long, about 4 inches outside diameter, and fully open one end. The other end was partially closed by a lead ring, soldered to the end of the cylinder, but with the central hole just large enough to push over the 2½ inch diameter plastic cable. These lead containers were then used at the jointing manholes as casting moulds for an epoxy resin pour.

The cable ends were strapped up vertically, and the sheath was roughened with a file where the moulds were to be sited. The moulds were then pushed down over the cable to the position about 4 inches from where the joint proper would be made. Radiator hose worm type clips on the cable under the mould were used to support the moulds, and leakage was prevented at the bottom by the use of caulking compound.

The epoxy resin mix, similar to that used for casting terminal boxes, was then mixed and poured into the moulds. After several hours the hard resin block had fully cured and cooled, shrinking tightly onto the plastic sheath.

At the time the work was performed it was not known that epoxy resin bonds to oxidized polythene. The procedure used now is to flame over the surface of polythene with a liquid petroleum gas torch to cause oxidation of the surface which will be in contact with the resin. The adhesion between the resin and the polythene sheathing is then due both to bonding and shrinkage.

The temporary end seals of rubber hose held on by worm clips were replaced on the end of the cable and the cable set up for jointing. After the conductors were jointed, wrapped, and insulated against heat, a lead sleeve was wiped onto the outer lead casing of the epoxy sleeve, and onto the lead sheathed cables at the other end of the joint (see Fig. 3). The whole operation was then successfully tested for the absence of air leaks.

The epoxy resin seal required an additional 2 feet of jointing wall. No joints were required in the plastic cable section itself.

CORROSION EFFECTS

The provision of this section of polythene cable in a run of lead cable could have caused greatly accelerated electrolytic corrosion to the discontinued metallic sheath causing a discharge to ground of the stray current previously flowing along it. It could also have materially affected the current distribution existing previously and possibly, the location and capacity of existing drainage rectifiers. To overcome this it would have been necessary to provide a metallic connection between the ends of the lead cable or alternatively, carry out a corrosion investigation of the area.

Measurements were not made prior to the armoured cables being removed from the bridge so the precise effect of the isolation was uncertain. As an investigation was in progress at the time, no attempt was made to link the lead sheaths. Two rectifiers were installed in the isolated network and another one in an area adjacent to it although it is probable this latter rectifier would have been required in any case.

In addition to the investigation a number of earth circuit power leads existing previously were converted to metallic circuits to remove one possible cause of corrosion.

CONCLUSION

The final cost of the work was approximately 9 per cent. higher than that for a normal P.I.L.C. 1,800 pair cable. However, with experience in the make-up of the cable, jointing and sleeving, costs would have been more nearly equal. A short section of cable about 8 ft. in length has been placed in a spare conduit and positioned across the expansion joint. It is proposed to withdraw this after about two years to determine what deterioration has occurred in the sheath.

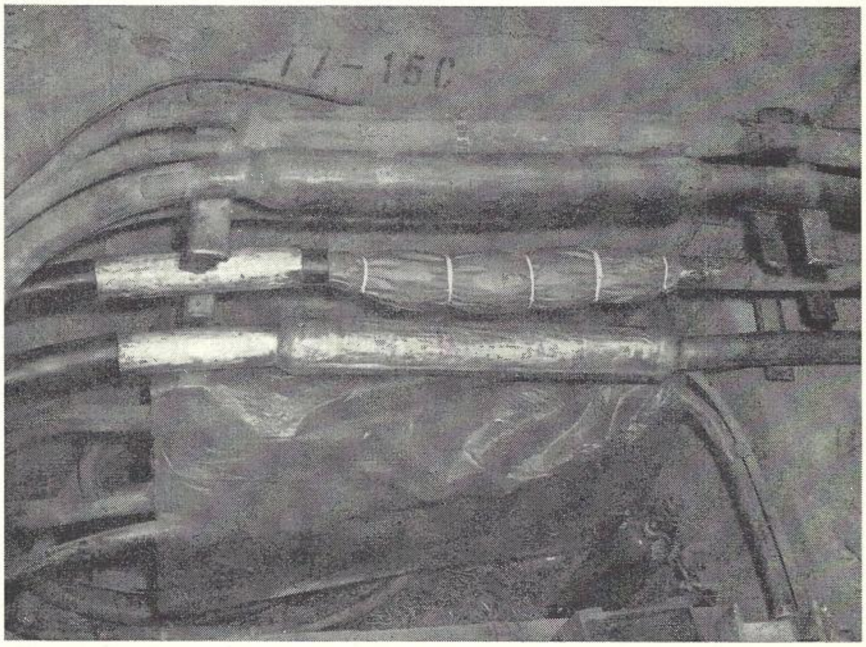

Fig. 3.—Plastic-lead Joint in Manhole. In the upper joint, the auxiliary sleeve is in place and the main sleeve has yet to be fitted; the lower joint is completed.

BACK COPIES

The Society has available in quantity, back copies of most issues of the Journal from Volume 5 onwards. Volume 12, Number 1, is out of print, but reprints of the two articles on coaxial cables may be obtained for a total cost of 3/-. These Journals may now be supplied on demand from State Secretaries* at 10/- per set of three or at 4/- per single copy. Back copies of some earlier numbers are available, but it is recommended that inquiry first be made to the State Secretary,* as to the availability of any particular number. In the event of the Society being unable to supply any number, it will act as an agent to assist subscribers in obtaining a copy. The Society does not repurchase Journals, but readers having copies which are no longer required should give details to the State Secretary,* who may thus be able to advise other readers where the back copies may be obtained.

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AN AUTOMATIC HOWLER CONNECTION CIRCUIT AND CABLE FAILURE ALARM

P. GLICK, B.Sc., B.E., A.M.I.E.Aust.*

INTRODUCTION

When a subscriber lifts his receiver and, without dialling, fails to restore his handset properly on the switch hooks, his telephone is then out of service for in-calls. The automatic howler was designed partly to correct this position by scanning discriminating selector repeaters (D.S.R.'s) and connecting the howler automatically to those in the "looped-normal" condition, and partly because of the "called subscriber held" problem, which we will now consider.

If at the end of a normal call one of the subscribers involved fails to restore his handset correctly, his telephone will then remain "out-of-service" until the handset is restored. In addition, if the offending subscriber is the calling party he will also hold the called subscriber's telephone out of service. If the offending subscriber is the called party, his own telephone only is held out-of-service, and effectively it is out-of-service for in-calls only, since the faulty condition will be noted and corrected as soon as he tries to make an out-call.

From the point of view of another subscriber who is trying to reach the out-of-service subscriber, however, it makes no difference which of the above conditions causes the called line to be out of service. There is, however, a great deal of difference in the corrective action required.

AUTOMATIC HOWLER

In trying to find an automatic cure for the Called Subscriber Held (C.S.H.) problem it was considered desirable to separate the two parts of the problem and deal with them individually. The circuit to force the release of a final selector, which is held on the A relay side, is still undergoing preliminary trials. The release of a final selector held on the D relay side, however, may be accomplished very simply by cutting the strap from spring D3 to spring H1 on the H relay of the final selector circuit CE185, converting the final selector from "last party release" to "calling party release". (In practice, at Lane Cove exchange where the automatic howler was first tested, the modification was accomplished even more simply by slipping a short piece of "spaghetti" insulation over the end of the D3 spring. This does not even require the unjacking of the switch, and is just as satisfactory on a long-term basis.)

When the final selector releases, the uniselector hunts and seizes a free D.S.R. and a junction to the main exchange. It was to prevent this from happening that final selectors were designed as "last party release" circuits. However, in an exchange equipped with an automatically connected howler, this is no longer a serious defect, and there is no reason why final selectors in such an exchange should not be converted to "calling party release". This immediately cures those C.S.H.'s which are held on the D relay, and leaves the field clear for a simplified attack on the remainder of the C.S.H. problem.

A side effect of the operation of the automatic howler at Lane Cove has been the education of subscribers in regard to the necessity of correctly replacing the handset on the switch hooks at the end of a call. During the first week of operation the frequency with which the howler was connected was quite high, but after this period it fell away rapidly to negligible proportions. This in turn has led to a more efficient usage of first rank junctions.

Circuit Operation: The circuit is shown in Fig. 1. When the start relay ST operates after key KST has been thrown, earth from the home contact of HB6 arc operates S relay via ST4 operated.

On the next operation of P relay from the 1 second earth pulse, earth from P2 via S1 operated, operates the HB magnet, and on the release of P the HB uniselector is stepped to contact 1, and S relay is released.

Earth pulses are then fed from P1 (pulsing), T3 normal, HB4 arc to the HA magnet. HA uniselector steps off its home contact and the R relay is operated in series with the shelf lamp. (A and B shelves). The A and B shelf lamp lights and R1 lights the rack lamp. R2 opens the homing circuit of HA magnet and R3 operates relay HC. HC operating has no function at this stage.

HA uniselector steps to the earth pulse. If a DSR is encountered with dial tone earth on the Test lead, the T relay will be unbalanced, and will operate. T operating opens circuit of DS relay at T5, and DS will release after its delay period (30 seconds). DS releasing completes the circuit to Y relay, and if the graduated howler is in its home position (the position from which the lowest level output is obtained) Y will operate and lock via Y4. Y1 and Y3 connect the howler to the DSR.

If the subscriber hangs up, or commences to dial, T relay will release, and release Y relay, thus disconnecting the howler, and the HA uniselector then continues to search.

When the HA uniselector reaches contact 42, R relay releases and earth from HA8 arc via HB6 arc and ST4 operates the S relay, and on the next pulse HB uniselector is stepped from P2 and HA uniselector from P1. The HA uniselector then drives home from HA7 arc, R2 normal, HA dm, magnet coil to battery. The HB uniselector is now positioned on the next rack, and the same sequence of operation proceeds with the HA uniselector of this rack.

When a looped DSR is detected by the operation of the T relay the six minute delay is started by the operation of T2, and if the T relay remains operated for six minutes the BH relay will be operated by the Z pulse, and will light the rack alarm lamp and extend an earth condition to sub-section floor alarm.

Operation of the Night Service key KNS disconnects the alarm circuit, at KNS2, and completes a stepping circuit for the HA uniselector at KNS 3, so that after the howling period of six minutes, the operation of BH relay will step the HA uniselector to the next DSR and searching will continue.

If the circuit is switched off while testing is in progress, the ST relay will release. The HC relay will be held operated from R3, and HC1 will cause P relay to continue pulsing. The HA uniselector will continue stepping (but not testing) until contact 42 is reached, when R releases, HC releases, HA uniselector drives home, and HB uniselector drives home via ST3, HC1 and HB8 arc.

CABLE FAILURE ALARM

It was noted when the automatic howler connection circuit was in operation that it occasionally gave an indication of trouble on the subscriber's circuit before the subscriber himself was aware of any difficulty. Since a cable failure invariably produces a number of permanent loops which cannot be "howled down", a count of "unhowlable loops" encountered by the equipment when night-switched can be used as an indicator of cable failure.

Instead of counting the total number of unhowlable loops, the equipment counts the number on each rack. When more than two racks exceed the predetermined quota, an alarm is extended to the nearest attended exchange. The quota is manually set up on a rotary "Oak" type switch (SWA). The setting used at Lane Cove was initially 3 unhowlable loops per rack, at which setting it detected a 30-pair cable failure before any other indication was given. Since then the setting was reduced to 2 per rack, and so far no spurious alarms have been raised.

Circuit Operation: Set SWA, the "quota" switch, to the desired position, operate start key KST and night service key KNS. The howler steps and tests for loops. Having switched to a looped D.S.R. the howler is placed on the line for 6 minutes. After this period the "BH" relay in the howler circuit operates and extends ground via "BH" 3 to the operate winding of the Mix and Genest type counting relay "CR" which will operate "CR" contact one. Any additional loops that are not howled down in 6 minutes operate the "CR" relay, once for each loop. When the pre-set value of the control selector is reached, ground is extended to "CF" relay which operates and locks to the ground at "KRS1".

Having found its quota on any rack, the howler testing circuit is opened by "CF" 4 allowing it to step rapidly over the remaining switches of that rack, so that a possible cable failure can be

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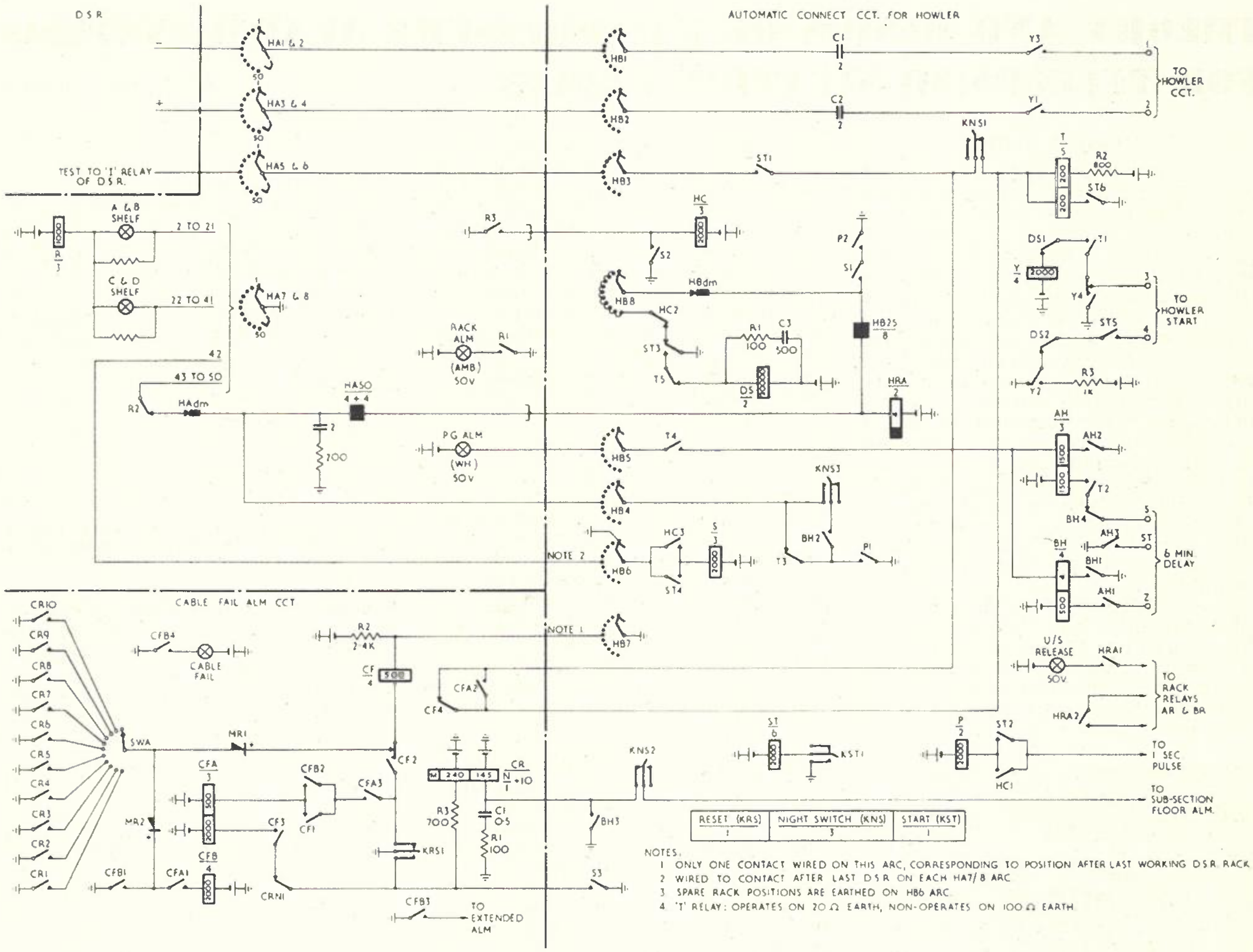

Fig. 1—Automatic Howler Connection Circuit and Cable Failure Alarm.

identified with minimum delay. When the "S" relay of the howler circuit is operated after passing the last D.S.R. on the rack, the "CFA" relay is operated after the counting relay "CR" has been reset.

"CFA" 1 prepares the cct. for "CFB" relay. "CFA" locks via "CFA" 3 to ground at "KRS1". On a complete cycle a sample is taken of any two racks, and if the preset number of loops occur on any subsequent rack, ground will be sent via "CR" contacts to operate the "CFB" relay. "CFB" relay holds from "CFB" 1 via "CFA" 1.

"CFB" 2 provides a hold cct. independent of "CF" 1 to prevent the release of "CFA" on the completion of the cycle of racks when an alarm is in operation. "CFB" 3 extends an urgent alarm. At the end of a complete testing cycle of all racks, if one rack has passed its quota and operated "CF" and "CFA", but no other rack has done so, ground via "HB" 7 shunts "CF" relay, "CF" in releasing opens "CF" 1 thus releasing "CFA" relay, so that all relays are normal when the first rack is to be re-tested. This ensures that the same loops do not cause false operation of the alarm.

The alarm is reset by the operation of the re-set key "KRS".

CONCLUSION

The automatic howler connection circuit and the cable failure alarm described in this article have proved effective and a number of additional installations are proposed. In the Lane Cove installation the howler is not automatically connected to P.B.X. lines due to the risk of operators receiving acoustic shocks by coming across exchange lines on which the howler is operating at full volume. It is understood that a new howler is being developed at Headquarters which will operate effectively at low levels and when this becomes available there should be no need to prevent it being connected automatically to P.B.X. lines.

ACKNOWLEDGMENTS

I would like to record my indebtedness to Supervising Technician C. Leggatt, who turned some rough and incomplete sketches into a working Automatic Howler Connection Circuit, and to 5th Year Technician-in-Training (now Technician) R. Winser, who performed a similar operation on the Cable Failure Alarm Circuit.

THEORY AND DESIGN OF GAS PRESSURE ALARM SYSTEMS FOR TELECOMMUNICATION CABLES

*N. G. ROSS, B.E.E.**

INTRODUCTION

Two previous articles (1, 2) published in this Journal have described actual gas pressure alarm (g.p.a.) installations with particular reference to protection of coaxial cables. These types of cable were novel to the Postmaster-General's Department at the time and, because of their high channel-carrying capacity a reliable and adequate alarm system was necessary. The telecommunication cable network, however, consists of a very large range of types and sizes of cable, and a g.p.a. system designed for, say, a non-layer 6-tube coaxial cable may not be suitable for fault indication on, say, an 1,800/4 P.I.Q.L. cable. Thus to enable the systematic and economical design of g.p.a. systems for any telecommunication cable network, an accurate knowledge of the behaviour of gas flow in cables is essential.

For the purpose of gas flow analysis, cable networks may be conveniently divided into two classes. If the internal gas escapes to the atmosphere from one end of the cable network, all other points in the network being isolated from any external source of gas under pressure, the system is referred to as "static" or "sealed". If the internal gas escapes to atmosphere from one end of the cable network, the network being fed with gas at a controlled rate from a reservoir connected to it, then the system is described as operating under "continuous flow". A fault which develops in a continuous flow system fed from one point only will involve a "continuous-flow" on one side of the fault and a "sealed-flow" from the other side, and hence both analyses must be applied in the design of an alarm system.

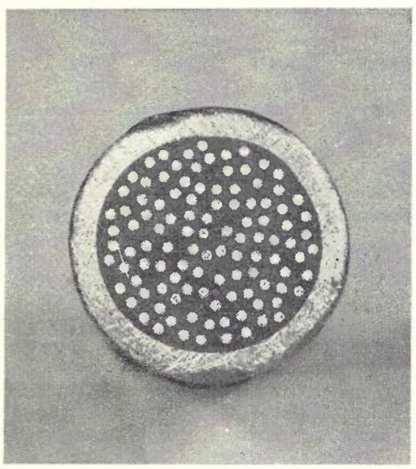

Fig. 1.—Cross-section of a Lead Covered, Star Quad, Paper Insulated Cable.

The formulation of a theory to explain gas flow behaviour is dependent on the initial assumption of a number of important variables. To attempt to include all the variables would be mathematically hopeless and the result (if one could be obtained) too unwieldy for application. Therefore, variant theories (3, 4) have been developed, each one incomplete in itself, which purport to accurately predict gas flow behaviour. The purpose of this article is to briefly examine each hypothesis, present the experimental evidence collated in Australia which supports or weakens each theory, and develop a design technique for g.p.a. systems.

TYPES OF FLOW

Before considering the mathematical aspects of the fluid flow in tubes, it is necessary to distinguish between the various types of possible or conceivable motion. The motion is termed "steady" if at every point occupied by the fluid the velocity is constant with respect to time, in magnitude and direction. The flow can then be represented by streamlines in the steady state; the tangent to a streamline shows the direction of the velocity at that point.

The alternative to steady flow is, of course, unsteady flow where the velocity varies in magnitude and direction with time. Thus in setting up a "lamellar" (streamline) flow, for example by passing fluid into a pipe at slow speed, the fluid will pass through a transient stage where the motion is irregular. In time, these irregular motions will be damped out and steady flow will result. If, however, the velocity of fluid flow were to be continuously increased, a stage would be reached where streamline flow breaks down, resulting in a chaotic irregular motion of the individual fluid particles, known as turbulence.

Fig. 1 shows a typical cross-section of a lead-covered, star quad, paper insulated cable. Whilst the cross-sectional area inside the sheath appears to be very tightly packed, the space between the insulated conductors and the porosity of the insulation account for from 50 per cent to 70 per cent of the total cross-sectional area. The air space between the metallic conductors provides numerous capillary paths for the flow of gas. Thus the arrangement of conductors, that is unit twin or star quad, and the number of conductors and their diameter will be determining factors in impeding the gas flow. Fig. 2 shows the cross-section of a 6-tube coaxial cable with interstice and core paper insulated quads. Taking into account the polythene discs spaced at 1.3 inch intervals along the inner coaxial conductors, the ratio of air and paper space to the total space enclosed by the sheath has been calculated as 83 per cent.

The assumption of streamline or lamellar movement lends itself to a mathematical formulation of the flow equations. With turbulent flow, the individual fluid particles move short distances in every direction so that it is impossible to trace their movements mathematically, but mathematical relationships may be obtained by considering the average motion of aggregations of fluid particles, or by statistical methods.

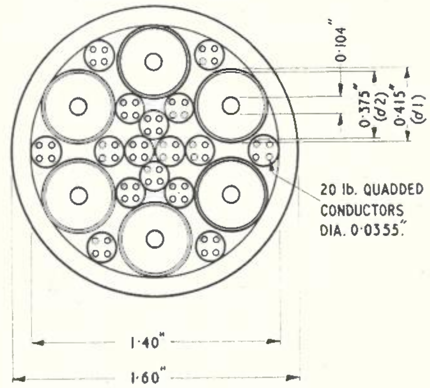

Fig. 2.—Cross-section of a 6-tube Coaxial Cable with 6-20 lb. Interstice Quads and a Central Core of 10-20 lb. Quads.

LAMELLAR FLOW

Theories developed overseas by investigators have been based on the assumption of lamellar flow, that is, the flow takes place in one direction, "x", (along the cable length) and is confined within concentric cylinders of radii "a" and "$a + da$", as in Fig. 3, whenever a variation in the significant parameters occurs over the cable length, for example, pressure difference, temperature changes.

The theories are developed from three basic equations of gas flow:

(i) **Mass continuity** (based on the principle of conservation of mass): If we consider an elemental cylinder within the cable of length "dx" and radius "a" (Fig. 3), then for a compressible fluid such as gas of density "ρ" entering end 1 with a velocity of "u", the variation in mass of the fluid within the element in any given time must be equal to the difference between the mass of fluid entering end 1 and that leaving end 2 in the period concerned. This leads directly, as shown in Appendix 1, to the following equation:

$$\frac{\partial \rho}{\partial t}+\frac{\partial (\rho u)}{\partial x} = 0 \quad \ldots\ldots\ldots(1)$$

(ii) **Dynamic equilibrium** (based on Newton's second law of motion): The elemental cylinder in the gas flow stream depicted in Fig. 3 is subject to external

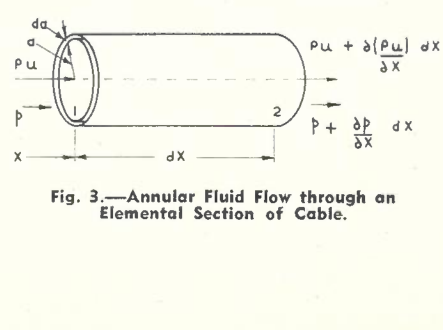

Fig. 3.—Annular Fluid Flow through an Elemental Section of Cable.

* See Page 82

forces, viscous forces and pressure (p) variations. For axial flow in one dimension, it can be shown (4) that the fluid acceleration is given by:

$$\rho\frac{Du}{Dt} = \rho X - \frac{\partial p}{\partial x} + \mu\left(\tfrac{1}{3}\cdot\frac{\partial^2 u}{\partial x^2} + \nabla^2 u\right);$$

$$\frac{\partial p}{\partial y} = 0; \quad \frac{\partial p}{\partial z} = 0,$$

where $\frac{D}{Dt} = \frac{\partial}{\partial t} + u\frac{\partial}{\partial x}$ (for one dimension)

and $\nabla^2 = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}$,

where μ is the viscosity coefficient and is given by the ratio

$$\frac{\text{force per unit area}}{\text{gradient of velocity}};$$

the viscosity of a gas increases with temperature. X is the so-called body force per unit of mass and is identifiable in our application with the gravitational force.

This equation is, in fact, an approximation but high order effects (for example, temperature stresses) are negligible at ordinary pressures. Further simplifications can be tolerated for gas flow in cables as velocities will be well below that of sound, so we may neglect second order differentials of u and product terms in the direction of flow. Also, cables are generally laid horizontally with few sharp changes in altitude, and as we are considering light gases, gravitational effects can be neglected. The final form of the dynamical equation becomes:—

$$\rho\frac{\partial u}{\partial t} = -\frac{dp}{dx} + \mu\left(\frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2}\right)$$

in cartesian co-ordinates ....(2)

$$= -\frac{dp}{dx} + \mu\left(\frac{\partial^2 u}{\partial a^2} + \frac{1}{a}\cdot\frac{\partial u}{\partial a}\right)$$

in polar co-ordinates

(iii) **Gas state:** The relationship between pressure p and density ρ for the gas under isothermal conditions, is given by

$$p = k\rho \quad \ldots\ldots (3)$$

where k is a constant for the particular gas and conditions under consideration. The assumption of isothermal flow is a reasonable one, since temperatures inside and outside the cable are of the same order, and velocities are well below that of sound.

It can be shown (Appendix 2) that

$$k = \frac{RT}{M} \quad \ldots\ldots\ldots\ldots (4)$$

where R is the absolute gas constant,
M is the molecular weight of the gas, and
T is the absolute temperature of the gas.

For convenience we define

$$k = \frac{V'}{c} \quad \ldots\ldots\ldots\ldots (5)$$

where c is a constant called the volume factor per unit length of cable, and
V' is the volume per unit length.

$$\text{Thus } c = \frac{M}{RT}\cdot V' \quad \ldots\ldots\ldots (6)$$

FIRST LAMELLAR FLOW THEORY (3, 5, 6, 7, 8)

The flow is considered to take place in a cylinder of radius "A" and length "l" illustrated in Fig. 4, with a pressure of P_1 at entry and a pressure P_2 at exit.

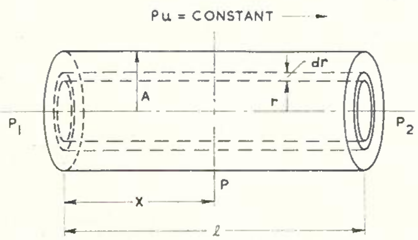

Fig. 4.—Pressures Existing in a Homogeneous Cable Length in the Steady State.

The assumptions are now made that:—

(i) the system is subject to small accelerations and hence $\frac{\partial u}{\partial t} = 0$, and

(ii) the frictional force opposing motion is proportional to the density and speed of the gas, averaged over the cross-section.

Under these circumstances, equation 2 reduces to

$$\frac{dp}{dx} + r\rho u V' = 0 \quad \ldots\ldots\ldots (7)$$

where r is a constant of proportionality.

From equations (1) and (3)

$$\frac{1}{k}\frac{\partial p}{\partial t} + \frac{\partial(\rho u)}{\partial x} = 0.$$

Combining this equation with equation 7 and substituting from equation 5:

$$\frac{c}{V'}\frac{\partial p}{\partial t} - \frac{1}{rV'}\frac{\partial^2 p}{\partial x^2} = 0,$$

$$\text{that is } \frac{\partial^2 p}{\partial x^2} = rc\frac{\partial p}{\partial t}. \quad \ldots\ldots (8)$$

A differential equation of the above type is known as the "equation of heat conduction" (in one dimension) and the solution is similar to that for heat flow in a homogeneous rod with insulated sides.

Steady State Solution

Under steady state conditions all transient phases have decayed $\left(\frac{\partial p}{\partial t} = 0\right)$ and equation 8 simplifies to

$$p = Yx + Z,$$

where Y and Z are constants of integration.

For $x = 0$ at $p = p_1$ and $x = l$ at $p = p_2$ (Fig. 4),

$$\text{then } Z = p_1 \text{ and } Y = \frac{p_2 - p_1}{l},$$

$$\text{whence } p = \frac{p_2 - p_1}{l}\cdot x + p_1,$$

$$\text{or } p = p_1\left(1 - \frac{x}{l}\right) + p_2\cdot\frac{x}{l} \quad \ldots (9)$$

Re-arranging equation (7) yields

$$\rho u V' = -\frac{1}{r}\frac{\partial p}{\partial x},$$

$$\text{that is } \rho u V' = \frac{p_1 - p_2}{rl} \quad \ldots\ldots\ldots\ldots (10)$$

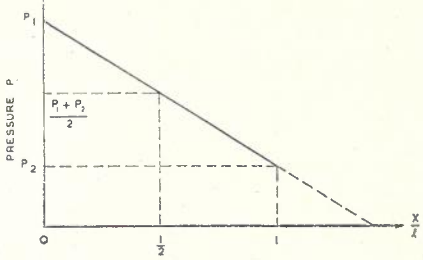

Fig. 5.—Pressure Distribution along the Cable according to the First Lamellar Flow Theory.

This equation is analogous with Ohm's Law for electrical circuits, namely $E = IR$, where

$E = p_1 - p_2$ (applied pressure),
$I = \rho u V'$ (*mass* flow), and
$R = rl$.

Fig. 5 shows the straight line distribution of pressure along the cable length.

Transient State Solution

The solution of equation (8) in the transient state is dependent on the prescribed boundary and initial conditions of flow, and these will be different for continuous and static types of flow.

(i) **Continuous Flow:** The boundary and initial conditions for a fault at distance "s" from the gas source are:

$p(x, o) = p_o$, $o \leq x \leq s$,
p_o = normal cable (gauge) pressure;
$p(o, t) = 0$, $t \geq 0$ (that is the overpressure at the fault is assumed to be zero);
$p(s, t) = p_o$, $t \geq 0$.

It should be noted that x is measured from the fault in the cable.

Subsequent steps in the solution of equation (8) are presented in Appendix 3(i) and result in the formulation of the dimensionless curves shown in Figs. 6-8. Figs. 6 and 7 show the pressure-time and flow rate-time relationships respectively, for various values of x/s, and

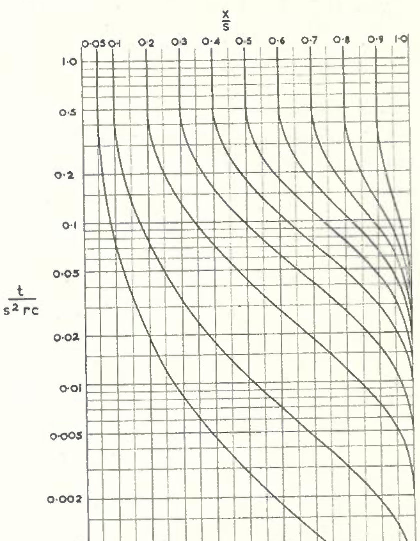

Fig. 6.—Pressure-time Relationships in Continuous Flow Gas-filled Cables.

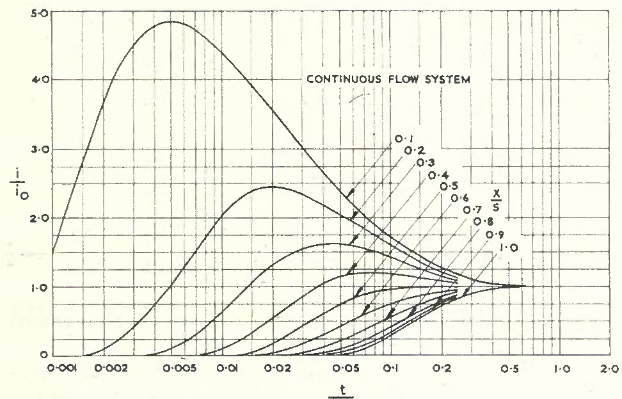

Fig. 7.—Flow-rate Time Relationships in Continuous Flow Gas-filled Cables (Curve for x = o in Fig. 8).

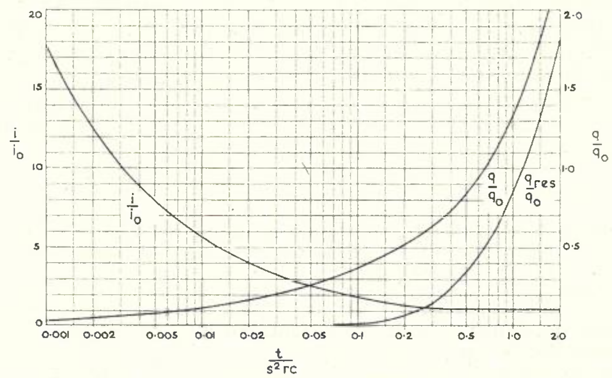

Fig. 8.—Gas Flow at the Leak (i), Quantity of Escaped Gas (q), and the Quantity of Injected Gas (q_{res}) under Continuous Flow Conditions.

provided the cable constants r and c are known together with s and p_0, then the conditions at any instant along the cable can be predicted. "i_0" represents the mass flow to the fault under steady state conditions and (from Appendix 3(i)) is given by

$$i_0 = \frac{p_0}{sr}. \quad \ldots\ldots\ldots (11)$$

Fig. 8 shows the gas flow at the leak (i), the quantity of escaped gas (q) and the quantity of gas injected from the continuous flow reservoir (q res) at any instant. The quantity q_0 represents the mass of gas injected into the cable to achieve the maintenance pressure p_0 above atmospheric pressure.

It is given by (from Appendix 3 (i))

$$q_0 = p_0\, s\, c \quad \ldots\ldots (12)$$

(ii) **Sealed Flow:** The boundary, initial and final conditions for a fault at distance "s" from the sealed end of the cable are:

$p(x, o) = p_0,\ o \leq x \leq s\ (P_0 =$ normal cable gauge pressure);

$p(o, t) = 0\ ,\ t \geq 0$ (no overpressure at fault);

$p(x, \infty) = 0\ ,\ 0 \leq x \leq s$;

$$\frac{dp(s, t)}{dx} = 0\ ,\ t \geq 0\ .$$

Subsequent steps in the solution for equation (8) and given in Appendix 3(ii) result in a dimensionless set of curves to predict sealed system flow behaviour. Figs. 9 and 10 show the pressure-time and flow rate-time relationships respectively for various values of x/s. Although i_0 appears in the dimensionless ratio i/i_0 it has no physical significance as it does in the continuous flow application. Fig. 11 shows the gas flow at the leak (i) and quantity of escaped gas (q) at any instant.

Comparison of Sealed and Continuous Flow Systems. It will be observed from a comparison of Figs. 8 and 11 that the advantage of the continuous flow system over the sealed system becomes of consequence when $\frac{t}{s^2rc} \geqslant 0.1$. From this length of time onwards, the continuous flow system maintains a relatively greater flow of gas from the fault and hence greater protection from the ingress of moisture. If all faults could be repaired within the time interval of their occurrence of $\frac{t}{s^2rc} = 0.1$, then considering only this aspect, there would be no advantage in operating a continuous flow system. However, the costs associated with finding and repairing microleaks to maintain the cable in the gas-tight condition necessary for static flow systems, are greater than for continuous flow systems.

SECOND LAMELLAR FLOW THEORY (9,10)

In the second theory of lamellar flow, no attempt is made to investigate the transient state behaviour, due to the intractibility of the mathematics. Instead it is assumed that

(i) the gas flow in the cable is steady, so $\frac{\partial}{\partial t} = 0$, and

(ii) the fluid in contact with the walls of the tubes is at rest.

Thus the equation of dynamical equilibrium (2) becomes:

$$\frac{dp}{dx} = \mu\left(\frac{\partial^2 u}{\partial a^2} + \frac{1}{a}\frac{\partial u}{\partial a}\right) \quad \ldots\ldots (13)$$

and the continuity equation (1) becomes $\rho u =$ constant (in the x direction).

Thus, for the conditions illustrated in Fig. 4, the mass of gas dF flowing per second between the tubes of radii "a" and "$(a + da)$" is given by:

$$dF = 2\pi a \rho u da \quad \ldots\ldots (14)$$

The solution of equations (13) and (14) in combination with equation (3) is given in Appendix 4, and results in the flow expression

$$F = \frac{p_1^2 - p_2^2}{R'l} \quad \ldots\ldots\ldots (15)$$

where $R' = \frac{16K\mu}{\pi A^4}$, a constant for a particular gas and cable.

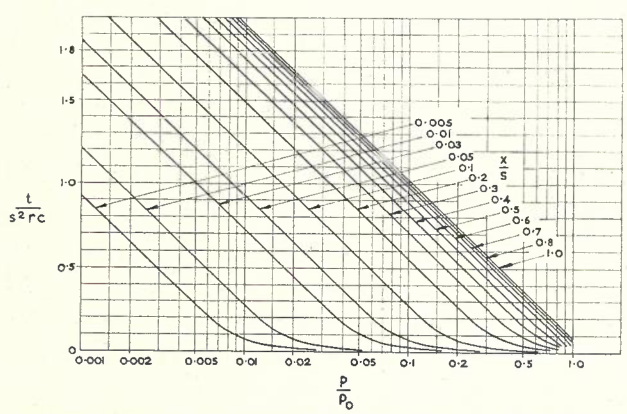

Fig. 9.—Pressure-time Relationships in Static Flow Gas-filled Cables.

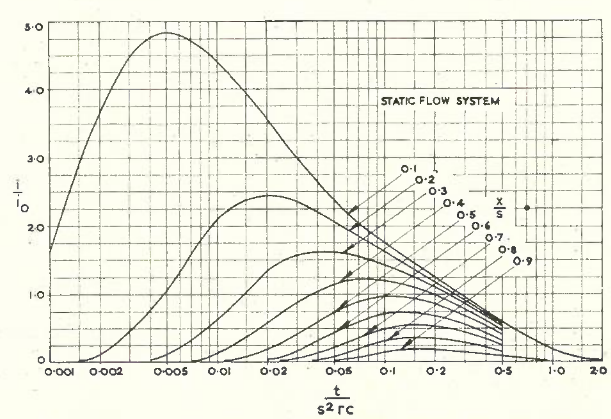

Fig. 10.—Flow-rate Time Relationships in Static Flow Gas-filled Cables. (Curve for x = o in Fig. 11).

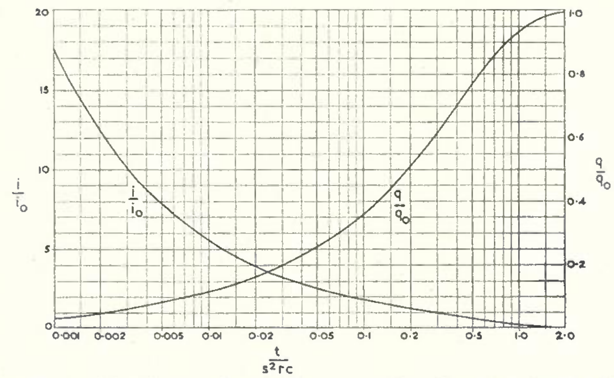

Fig. 11.—Gas Flow at the Leak (i) and Quantity of Escaped Gas (q) under Static Flow Conditions.

The pressure distribution can be determined (Appendix 4) as:

$$p^2 = p_1^2\left(1-\frac{x}{l}\right)+p_2^2\left(\frac{x}{l}\right) \quad \ldots.(16)$$

The gradient lies over portion of a parabola and is illustrated in Fig. 12 (compare with Fig. 5 obtained from first lamellar theory).

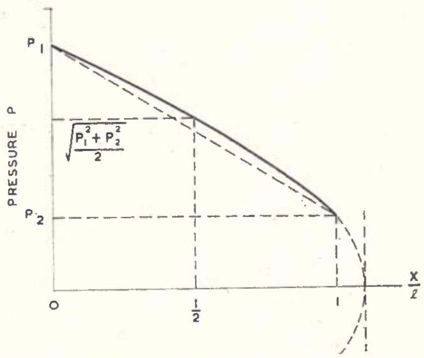

Fig. 12.—Pressure Distribution along the Cable according to the Second Lamellar Flow Theory.

The assumption is now made that this flow takes place in the interstice parallel paths of gas flow, considered as circular tubes of radius A, and that there are "n" such tubes. If the number of conductors is not too small, then the number N and diameter D of the conductors will be proportional to the number and effective diameter of interstice capillary tubes.

$$\text{Thus } R' = \frac{K}{ND^4},$$

where K is a constant for a given gas and for a particular form of cable make-up, for example, star quad, unit twin.

Fig. 13 shows on a log-log scale the constancy of K as determined by Hooker (10) for a selection of cables of star quad construction. The position of the single value for the unit twin type cable at a distance from the straight line representing K, confirms that K varies with constructional make-up.

COMPARISON OF LAMELLAR FLOW THEORIES

The first lamellar theory predicts a simple steady-state linear relationship between pressure and mass flow and pressure distribution along the length of the cable. The steady-state relationships obtained from the second theory are more complex, the mass flow being dependent on the difference in squares of the absolute pressures, and the pressure is parabolically distributed along the cable length.

The relation between cable constants R' and r is obtained from equations (15) and (10) using the expansion

$$p_1^2 - p_2^2 = (p_1 - p_2)(p_1 + p_2).$$

$$\text{Thus } R' = rV'(p_1 + p_2). \quad \ldots.(17)$$

In most applications $p_2 = p_a$ (atmospheric pressure)

and $p_1 = p_{1g} + p_a$ (p_{1g} = gauge pressure),

so that $R' = rV'(p_{1g} + 2p_a)$

TURBULENT FLOW (11)

Whilst it is a little difficult in practice to determine when the transition (if any) from steady to turbulent flow will occur, the transition point is approximately dependent on the value of a dimensionless quantity known as the Reynolds Number

$$N_R = \frac{ud\rho}{\mu}, \quad \ldots\ldots(18)$$

where u is the average velocity across the tube cross-section,
d is the tube diameter,
ρ is the fluid density,
and μ is the fluid viscosity coefficient.

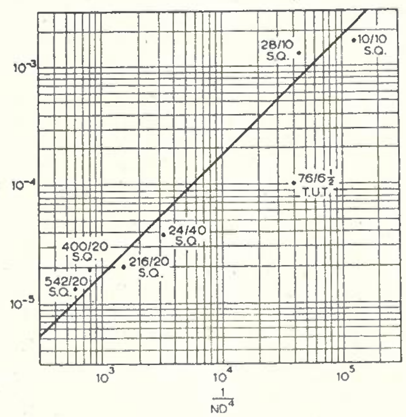

Fig. 13.—The Relationship between the Constant R' and the Factor 1/ND⁴ for a Selection of Cables. (S.Q. = Star Quad, T.U.T. = Twin-unit type.)

For values of N_R above 1,000 there is the possibility of turbulence occurring. Consider a cable under fault conditions with an equivalent cross-sectional air space of 1½ inch diameter ($d = \frac{1}{8}$ ft.) having a flow of 1½ cu. ft. per hour, that is $\frac{3}{2\times3600}$ cu. ft./sec. Then the average velocity u is given by

$$\frac{\text{flow/second}}{\text{cross-sectional area}} = .0335 \text{ ft./sec.}$$

Also $\mu = 0.0377\times10^{-5}$lb.-sec./ft.^{2} at 68°F,

and $\rho = 0.1264$ lb./ft.^{3} at 10 psig and 68°F,

$$\therefore N_R = \frac{.0335\times0.125\times.1264}{.0377\times10^{-5}} \approx 1400.$$

Thus it would appear that turbulent flow is a possibility with medium size fault conditions. In practice the threshold of turbulence depends also on the initial quietness of the fluid, the shape of the entrance, roughness of surfaces and obstructions to flow.

To obtain a theoretical relationship for turbulent flow consider isothermal flow of gas. Experiments of fluid flow in pipes indicate that the frictional stress τ_0 is given by

$$\tau_0 = f\frac{\rho u^2}{4}$$

where f is a constant of proportionality termed the friction factor.

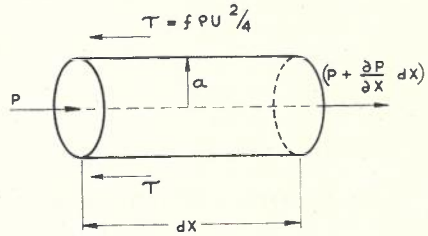

Fig. 14.—Turbulent Forces acting on an Element of Fluid.

From Fig. 14, using this stress in the dynamical equation and neglecting accelerations

$$\frac{\partial p}{\partial x}dx\pi a^2 + f\frac{\rho u^2}{4} \cdot 2\pi a\, dx = 0,$$

$$\text{that is } \frac{dp}{dx}+f\frac{\rho u^2}{2a} = 0,$$

(compare with equation 7).

In the steady state ρu = constant, and for isothermal flow

$$p\, dp + \frac{kf}{2a}(\rho u)^2 dx = 0,$$

$$\therefore \int_{p_1}^{p_2} p\, dp + \frac{kf}{2a}(\rho u)^2\int_0^l dx = 0.$$

$$\text{Thus } p_1^2 - p_2^2 = \frac{kfl}{a}(\rho u)^2,$$

$$\text{that is } F^2 = \frac{p_1^2-p_2^2}{R''l}, \text{ where } R'' = \frac{kf}{\pi^2a^5} \quad \ldots\ldots\ldots.(19)$$

In particular for pressure p at distance x along the cable

$$(p^2-p_1^2)+\frac{fk}{a}(\rho u)^2x = 0,$$

$$\therefore p^2 = p_1^2 - \frac{x}{l}(p_1^2-p_2^2),$$

$$\text{that is } p^2 = p_1^2\left(1-\frac{x}{l}\right)+p_2^2\frac{x}{l} \quad \ldots\ldots.(20)$$

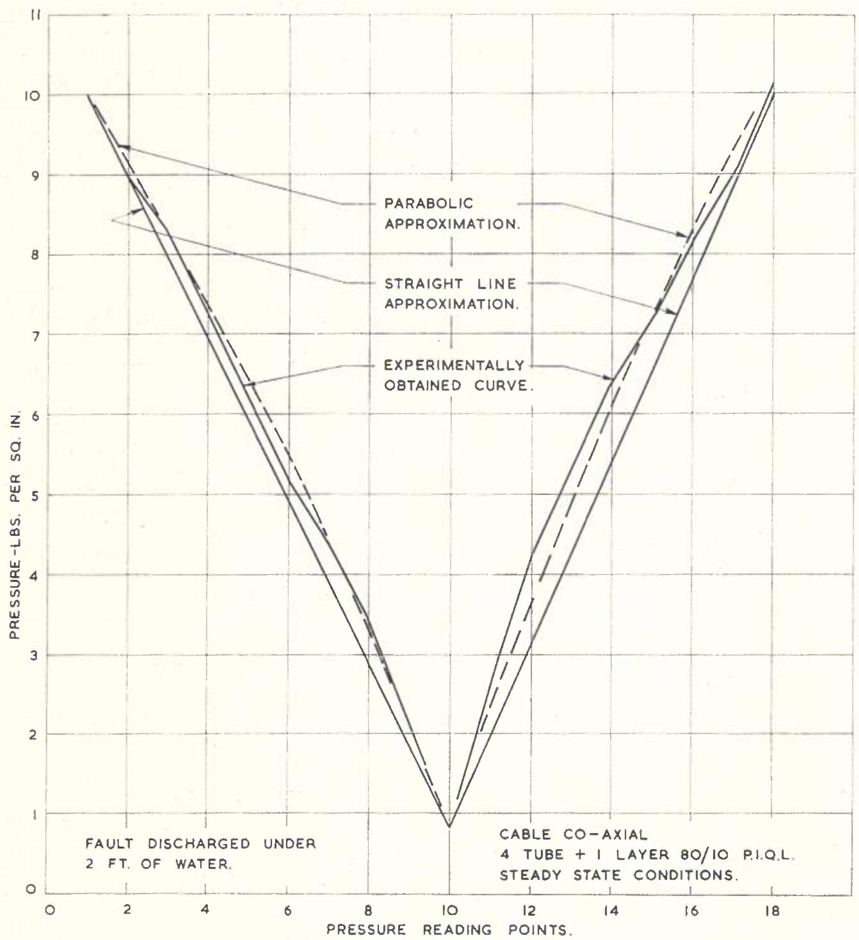

Fig. 15.—Experimental and Theoretically Derived Curves for a Fault on a Coaxial Cable.

Thus the pressure along the cable length follows portion of a parabola (compare equation 16).

INTERPRETATION OF EXPERIMENTAL TESTS

Different basic assumptions have led us to deduce three unrelated equations to represent the pressure gradients in the cable and the pressure-flow relationship in the steady state. Obviously, one set of equations must represent the closest approximation to the conditions actually existing in the cable.

Firstly, consider the pressure gradient. Fig. 15 is typical of the pressure gradient obtained over a coaxial cable after the flow has stabilised; also shown are the predicted straight line and parabolic curves of the theories. The actual gradient is closely approximated by the parabolic curve. The rejection of the straight line theory on observed pressure gradients leaves two theories which purport to predict the pressure-flow, steady-state relationship. If we assume that liquid flow in pipes is analogous to gas flow in telecommunication cables (which it is, apart from a compressibility factor), then Fig. 16 shows how we can reconcile the two theories of turbulent and lamellar flow. Fig. 16 is a log-log plot of friction factor versus Reynold's Number and illustrates the straight line decrease of friction factor with increasing Reynold's Number until a critical point is reached, which represents the transition between steady and turbulent flow. For rough pipes, the friction factor is practically independent of Reynold's Number in the turbulent region.

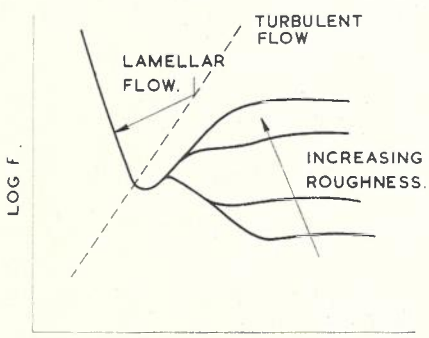

Fig. 16.—The Relationship between Friction Factor and Reynold's Number for Fluid Flow in Pipes.

* A standard cubic foot (SCF) is a cubic foot of air at 62°F and 30 inches barometric pressure. SCFH is standard cubic feet per hour.

Experiments to date on the six coaxial tube Sydney-Melbourne cable (Fig. 2) confirm these observation. From equation 19, f is proportional to R'' for the same gas and cable, and from equation 18, N_R is proportional to mass flow (F) under the same conditions. Hence the log-log plot of F against R'' (Fig. 17) should have the same form as Fig. 16 and the gradient of the straight line portion m is given by

$$R'' = ZF^m \quad \ldots\ldots (21)$$

where Z is a constant.

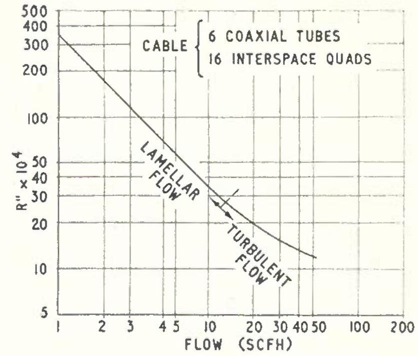

Fig. 17.—Logarithmic Plot of Flow (F) versus Turbulent Pneumatic Resistance (R") for 6-tube Coaxial Cable.

Substituting equation (21) into the pressure-flow relationship of equation 19 gives

$$p_1^2 - p_2^2 = ZF^{2+m} \cdot l \quad \ldots\ldots (22)$$

From Fig. 16, $m \approx -1$.

$$\text{Thus } F = \frac{p_1^2 - p_2^2}{Z.l}, \quad \ldots\ldots (23)$$

and an equation in the form of equation (15) results for flow in the lamellar region.

From Fig. 17 for flows below 13 SCFH* in 6-tube coaxial cable of cross-section as illustrated in Fig. 2, lamellar flow conditions exist in the cable and equation 15 applies. For flows in excess of 13 SCFH, the value of R' does not remain constant. Under normal maintenance pressure, a fault occurring in a minor repeater section on the Sydney-Melbourne coaxial cable will not cause a gas flow in excess of 13 SCFH through both flow-meters situated in adjacent minor repeaters. In any case, the flow-meters with which this system is equipped will not record greater than 5 CFH at 8.8 psig. Therefore, the fact that R' is not constant for flows in excess of 13 SCFH is immaterial in the design of the g.p.a. system for this particular cable.

For each particular cable, then, it is necessary to obtain the relationship of R'' to F, in order to determine if lamellar conditions are normally applicable to the cable. Thence the average value of R' is determined. Different lengths of nominally identical cable will, unfortunately, yield differing values of R', due to the manufacturing inconsistencies inherent in cable production. Thus Hooker found that nominally identical cables manufactured in different batches were as much as 10 per cent different from the mean value; this is of the order of variation found in experimental values of R' obtained for 6-tube coaxial cable.

The transition from lamellar to turbulent flow is by no means clearly defined and will vary for individual cables of the same construction, the flow being lamellar until obstructions and rough surfaces are encountered or changes in the flow cross-section are reached, which raise the Reynold's Number above that for steady flow, and turbulence results. The turbulent effect may occur only in particular sections of the cable, in which case the pressure gradient curve will be steeper in the region of turbulence, due to the greater resistance encountered and the need to maintain the same mass flow. Examination of Fig. 15 shows that the experimentally obtained curve is steepest at the inlet and exit locations, and these are the places where turbulence would be most expected to occur.

DESIGN OF G.P.A. SYSTEMS

Subscribers' Cables

The variation of R' amongst cables of the same size and construction limits the application of the theory to analytical fault-finding under steady-state conditions. However, the usefulness and range of the flow-meter situated at the exchange end of the cable, and the optimum position and range of the "end-point" and any intermediate pressure contactors on subscribers' and trunk cables are factors which can be systematically designed for the pressurised cable network under consideration. This network will usually consist of various sizes and types of cable, in varying lengths. The value of the specific cable resistance R' for any type of cable is determined from equation 15, namely

$$F = \frac{p_1^2 - p_2^2}{R'l}$$

where l is the cable length in yards
p_1 is the inlet pressure in psia
p_2 is the outlet pressure in psia
F is the flow rate in SCFH of air

It is convenient to measure flow rates as a volumetric change rather than a mass change. In equation 15, F must be a mass change, and since the standard cubic foot of air will have a fixed mass, volume flows at a particular pressure must be converted to the appropriate number of standard cubic feet of air.

The total resistance of any length of cable is obtained by multiplying the specific cable resistance by the length of cable. For various cables in series or parallel, the analogy with electrical circuit resistance may be drawn. The overall resistance of the cable network illustrated in Fig. 18 is

$$R_1'l_1 + R_2'l_2 + \left(\frac{R_3'.R_4'}{R_3'+R_4'}\right).l_3$$

Since the **air flow meter** records instantaneous flow rates, a reasonably sized sheath puncture within the monitoring range of the meter will provide a definite indication of a fault condition at the exchange, by indicating a steady-state flow rate sufficiently above average to be discernible. The fixed monitoring range R_f can be measured in terms of pneumatic resistance units so that:

$$R_f = \sum_{x=1}^{n} R_x'l_x$$

A **contactor** may be considered to have two monitoring ranges:

(i) A **definite** monitoring range in **any** direction from the contactor. When a reasonably sized leak occurs within the definite monitoring range, contactor operation will usually occur in eight hours or less.

(ii) An **infinite** monitoring range in a direction towards the gas source, along the cable. This monitoring range will enable contactor operation in a matter of hours or days, depending on the rate of gas flow and the total pneumatic resistance of the cables involved.

If the fixed definite monitoring range is denoted as R_c pneumatic resistance units, then

$$R_c = \sum_{x=1}^{n} R_x'l_x$$

Every point in a subscriber's cable system must fall within the definite monitoring range of a contactor or the monitoring range of the exchange flowmeter. Hence, any reasonably sized fault will give a positive alarm indication within a specified time of the occurrence of the fault.

Fault locating in subscribers' pressurised cable networks may be carried out by graphing flow-rate F against distance, after performing a pressure-gradient run on the faulty cable system. The point of any sharp deviation of the F curve may be considered as a leak-point, since the continuity of mass flow in the cable has been disturbed.

Trunk Cables

Most of the design work associated with placing contactors, gas cylinders and flow meters requires a knowledge of transient state behaviour. Whilst the theory of turbulence and the second theory of lamellar flow provide accurate information on the steady-state conditions, it is necessary to utilise the first theory of lamellar flow for the transient analysis; such an analysis has been found to agree closely with experimental results obtained on the Sydney-Melbourne 6-tube coaxial cable. In order to illustrate the use of the graphs in Figs. 6-11, the design procedure adopted for determining the effectiveness of gas pressure alarm equipment on this particular cable is reproduced in Appendix 5.

The three g.p.a. devices for use on trunk cables are the flowmeter, pressure contactor and gas consumption meter. These three forms of alarm device are compared in Fig. 19 for sensitivity of operation on 6-tube coaxial cable, and the relative sensitivities obtained should be applicable to other forms of coaxial cable make-up. The gas consumption alarm used on the Sydney-Melbourne project is in the form of a gas cylinder high pressure (0-2,000 psi) gauge fitted with adjustable contacts, one contact being carried by the gauge-pointer. Contactors are set to $p/p_o = 0.67$ and located near the $\frac{1}{4}$, $\frac{1}{2}$ and $\frac{3}{4}$ points of minor repeater sections. For a 32,000 foot minor repeater section, a fault between contactors will be detected within $1\frac{1}{2}$-2 hours. To give equivalent protection up to 4,000 feet from the repeater, the cylinder pressure drop alarm should be set to about 75 psi below the "no-fault" setting.

The alarm curves of Fig. 19 serve to emphasise one important fact; the flowmeter as a warning device is vastly superior to the other forms of alarm and, as such, should be utilised on future

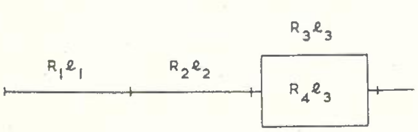

Fig. 18.—Specific Resistances and Lengths for Cables in a Series-parallel Network.

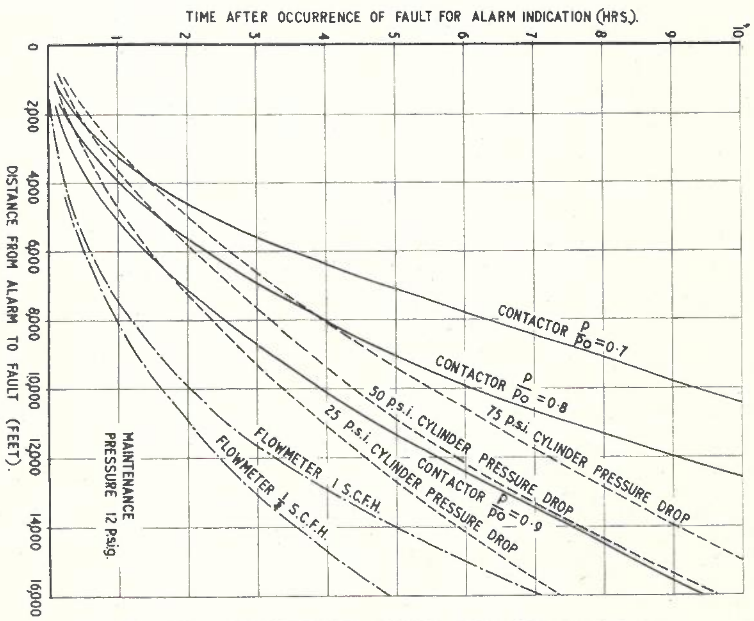

Fig. 19.—Alarm Curves—6-tube Coaxial Cable with 16 Core and Interstice Quads.

systems. The pressure contactor cannot be regarded as a desirable alarm device. It is fairly difficult to calibrate, needs periodic re-adjustment, must be thermally insulated, requires housing in a suitable manhole for access and protection requirements, is prone to gas leakage and low I.R. Thus any scheme which reduces the number of contactors whilst providing the same, if not better, protection is worthy of close consideration. The flow-meter housed in the minor repeater and virtually fault-free in operation will monitor up to 11,000 feet on 6-tube coaxial cable, for an indication of a fault condition within two hours. A manhole in mid-section could house a contactor suitably calibrated, or even better, a flow-meter installation. The manhole would also provide ready access to the cable for closer fault location using radon, emergency gas cylinder supplies, etc.

Practical flow-meter alarms have, as yet, not been considered in detail. Two possible forms are readily apparent. In one case, the metallic ball float rises in the tube and short circuits two probes from the alarm pair projecting into the top of the tube. Its disadvantages are that for an alarm indication with flows of 1 SCFH, then the steady state flow may not be realised (necessary for an approximate localisation of the fault); secondly, the alarm is not readily adjustable. Superior flow-meter alarms would be provided by (i) a photo-electric circuit, whereby the rising opaque float breaks the light path and transmits the alarm, or (ii) the disruption of oscillator frequency by the intrusion of a ferromagnetic float into the magnetic circuit. These latter alarms have none of the disadvantages of the former method.

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APPENDIX 1—EQUATION OF MASS CONTINUITY

Referring to Fig. 3:

Mass entering end (1) $= \rho\pi a^2 u$.

Mass leaving end (2) $= \pi a^2\left\{\rho u + \frac{\partial(\rho u)}{\partial x}dx\right\}$.

Increase in mass of the element dx in time dt is

$$\rho\pi a^2 u - \pi a^2\left\{\rho u + \frac{\partial(\rho u)}{\partial x}dx\right\},$$

$$\text{that is } -\pi a^2 \frac{\partial(\rho u)}{\partial x} dx .$$

As this takes place in time dt, then mass increase of element dx is also given by

$$\frac{\partial\rho}{\partial t}\pi a^2 dx.$$

Equating these results:

$$\frac{\partial\rho}{\partial t} = -\frac{\partial(\rho u)}{\partial x},$$

$$\text{that is } \frac{\partial\rho}{\partial t} + \frac{\partial(\rho u)}{\partial x} = 0.$$

APPENDIX 2—EQUATION OF STATE

For a perfect gas of mass "m" occupying volume "V" at pressure "p" and an absolute temperature "T", then

$$\frac{pV}{mT} = \frac{R}{M} \quad \dots\dots\dots\dots(24)$$

where R is the absolute gas constant, and M is the molecular weight of the gas. Eliminate "m" from (24) by using the expression

$$\rho = \frac{m}{V}.$$

$$\text{Thus } p = \frac{RT}{M}\rho. \quad \dots\dots\dots(25)$$

But the equation of state for isentropic gas behaviour is given by

$$p = k\rho^{\gamma} \quad \dots\dots\dots(26)$$

where γ, k are constants for the particular conditions and gas under consideration.

For isothermal behaviour $\gamma = 1$.

Thus equations (25) and (26) yield:

$$k = \frac{RT}{M}.$$

APPENDIX 3 (i)—SOLUTION OF EQUATION (8) FOR CONTINUOUS FLOW

Boundary and initial conditions are:

$p(x, o) = p_o$, $o \leq x \leq s$;
$p(o, t) = 0$, $t \geq 0$;
$p(s, t) = p_o$, $t \geq o$.

Solution:

$$\frac{p(x, t)}{p_0} = \frac{x}{s} + \frac{2}{\pi}\sum_{n=1}^{\infty}\frac{1}{n}\sin n\pi\frac{x}{s}.e^{\frac{-n^2\pi^2}{s^2rc}.t} \quad ..(27$$

This series is, however, very weakly convergent for small values of the dimensionless expression $\frac{t}{s^2rc}$ and may be replaced **for such values** by the following rapidly convergent series:

$$\frac{p(x, t)}{p_0} = erf\left(\frac{x}{2}\sqrt{\frac{rc}{t}}\right) + \sum_{n=1}^{\infty} erf\left(\frac{2ns+x}{2}\sqrt{\frac{rc}{t}}\right)$$

$$-\sum_{n=1}^{\infty} erf\left(\frac{2ns-x}{2}\sqrt{\frac{rc}{t}}\right) \quad \dots(28)$$

where $erf(\ )$ represents the tabulated error function

$$erf(\epsilon) = \frac{2}{\sqrt{\pi}}\int_0^{\epsilon} e^{-z^2}dz.$$

The pressure curves of $\frac{p}{p_0}$ have been constructed as functions of the dimensionless quantities $\frac{t}{s^2rc}$ and $\frac{x}{s}$, and are shown in Fig. 6.

The gas flow i (mass per unit time) is obtained from equation (27) by partial derivation of the pressure with respect to x, and division by r (equation 7)—

$$\frac{i(x, t)}{i_0} = 1 + 2\sum_{n=1}^{\infty}\cos n\pi\frac{x}{s}.e^{\frac{-n^2\pi^2}{s^2rc}.t}, \quad ..(29)$$

$$\text{where } i_0 = \frac{p_0}{sr}, \quad \dots\dots\dots(30)$$

and represents the mass flow to the fault under steady state conditions.

Gas Flow at the Fault for $\frac{t}{s^2rc} < \frac{1}{4}$:

In the vicinity of the fault it is necessary only to consider the first term in equation (28). By partial differentiation with respect to x and division by r,

$$\frac{i(x, t)}{i_0} = \frac{1}{\sqrt{\pi}}\sqrt{\frac{s^2rc}{t}}.e^{-\frac{x^2}{4s^2}\cdot\frac{s^2rc}{t}} \quad \dots\dots\dots(31)$$

In particular for $x = o$, then

$$\frac{i(o, t)}{i_0} = \sqrt{\frac{s^2rc}{\pi t}}. \quad \dots\dots(32)$$

Figs. (7) and (8) show the gas flow as a function of the parameters $\frac{x}{s}$ and $\frac{t}{s^2rc}$.

Finally, it is necessary to examine the relationship between time and the quantity of gas injected into, and expelled from the cable under fault conditions. Integration of equation (32) with respect to t gives the expelled mass:

$$q(o,t) = \frac{2}{\sqrt{\pi}}\, p_0\, sc \sqrt{\frac{t}{s^2rc}}.$$

The mass of gas in the cable at pressure p_o prior to the fault condition is denoted by Q. From the relationship density = mass/volume then:

$$Q = \rho s V' \quad \ldots\ldots (33)$$

From equations (3) and (5):

$$Q = (p_o + p_a)sc.$$

Put $q_o = p_o sc$ $\ldots\ldots (34)$

where q_o is the mass injected into the cable to achieve the maintenance pressure p_o above atmospheric pressure.

Then $Q = q_o + p_a sc$. $\ldots\ldots (35)$

Then $\frac{q(o,t)}{q_0} = \frac{2}{\sqrt{\pi}}\cdot\sqrt{\frac{t}{s^2rc}}$, where $\frac{t}{s^2rc}<\frac{1}{4}$ $\ldots\ldots\ldots(36)$

If $\frac{t}{s^2rc}>\frac{1}{4}$, then equation (36) should be replaced by the exact equation (37) which is calculated from equation (29)

$$\frac{q(o,t)}{q_0} = \frac{1}{3} + \frac{t}{s^2rc} - \frac{2}{\pi^2}\sum_{n=1}^{\infty} \frac{1}{n^2}\cdot e^{\frac{-n^2\pi^2 t}{s^2rc}} \quad ..(37)$$

The injected mass q_{res} is obtained by integration of equation (29) for $x = s$, from o to t which gives:—

$$\frac{q_{res}}{q_0} = -\frac{1}{6} + \frac{t}{s^2rc} - \frac{2}{\pi^2}\sum_{n=1}^{\infty} \frac{(-1)n}{n^2}.e^{\frac{-n^2\pi^2 t}{s^2rc}} \quad \ldots\ldots\ldots\ldots(38)$$

The variation of $q(o, t)$ and q_{res} with time has been graphed in Fig. 8.

APPENDIX 3 (ii)—SOLUTION OF EQUATION (8) FOR SEALED FLOW

Boundary, initial and final conditions are:

$p(x, 0) = p_o$, $\quad o \leq x \leq s$;

$p(o, t) = 0$, $\quad t \geq o$;

$p(x, \infty) = 0$, $\quad o \leq x \leq s$;

$\frac{dp(s,t)}{dx} = 0$, $\quad t \geq o$.

Solution:

$$\frac{p(x,t)}{p_0} = \frac{2}{\pi}\sum_{n=1}^{\infty} \frac{1}{m_n}.\sin\frac{m_n\pi x}{s}.e^{\frac{-\pi^2 m_n^2}{s^2rc}.t} \quad (39)$$

where $m_n = \frac{2n-1}{2}$, $n = 1, 2, 3$, etc.

Like the series in equation (27), this series converges slowly for small values of u. It may appropriately be replaced by the following series:

$$\frac{p(x,t)}{p_0} = erf\left(\frac{x}{2}\sqrt{\frac{rc}{t}}\right) + \sum_{n=1}^{\infty} (-1)^n\, erf\left[\frac{2ns-x}{2}\sqrt{\frac{rc}{t}}\right] - \sum_{n=1}^{\infty} (-1)^n\, erf\left[\frac{2ns+x}{2}\sqrt{\frac{rc}{t}}\right]. \quad \ldots\ldots(40)$$

The gas flow $i(x, t)$ in this case is also obtained from $\left(\frac{\partial p}{\partial x}\right)_t$ and division by r.

From equation (39):

$$\frac{i(x,t)}{i_0} = 2\sum_{n=1}^{\infty} e^{\frac{-m_n^2\pi^2 t}{s^2rc}}.\cos m_n\pi\frac{x}{s} \quad \ldots.(41)$$

where $m_n = \frac{2n-1}{2}$.

The gas flow at the fault for $\frac{t}{s^2rc}<\frac{1}{4}$ is found by operating on the first term of equation (40) which is identical with the first term in equation (28). Hence equations (31), (32) and (33) are all applicable whether the flow is continuous or static.

If $\frac{t}{s^2rc}>\frac{1}{4}$, then equation (36) should be replaced for static flow by integration of equation (41) for $x = 0$, from o to t which yields:

$$\frac{q(o,t)}{q_0} = 1 - \frac{2}{\pi^2}\sum_{n=1}^{\infty}\frac{1}{m_n^2}.e^{\frac{-m_n^2\pi^2}{s^2rc}.t} \quad \ldots.(42)$$

The ratios $\frac{p}{p_0}$, $\frac{i}{i_0}$, $\frac{q}{q_0}$ in terms of the dimensionless quantities $\frac{x}{s}$ and $\frac{t}{s^2rc}$ have been shown in Figs. 9, 10 and 11.

APPENDIX 4—SOLUTION OF EQUATIONS 13 AND 14

$$\frac{dp}{dx} = \mu\left(\frac{\partial^2u}{\partial a^2} + \frac{1}{a}\frac{\partial u}{\partial a}\right).$$

Since by hypothesis, the left-hand side of the differential equation is independent of "a", and the right-hand side independent of "x", it follows that both sides must be independent of both x and y, and equal to a constant (W), that is:

$$\frac{dp}{dx} = W = \frac{\mu}{a}\left(a\frac{\partial^2 u}{\partial a^2}+\frac{\partial u}{\partial a}\right)$$

$$= \frac{\mu}{a}\frac{\partial}{\partial a}\left(a\frac{\partial u}{\partial a}\right),$$

$$\therefore \frac{\partial}{\partial a}\left(a\frac{\partial u}{\partial a}\right) = \frac{aW}{\mu},$$

$$\therefore a\frac{\partial u}{\partial a} = \frac{1}{2}\frac{a^2W}{\mu}+Y,$$

$$\therefore u = \frac{1}{4}\frac{a^2W}{\mu}+Y\log a+Z,$$

where Y and Z are constants of integration.

Since u is finite when $a = 0$, Y must vanish.

Since $u = 0$ when $a = A$, the radius of the section (Fig. 4) then

$$u = \frac{1}{4}\frac{a^2W}{\mu} - \frac{1}{4}\frac{A^2W}{\mu},$$

$$= \frac{W(a^2-A^2)}{4\mu} \quad \text{(a parabola).}$$

Multiply both sides by ρ and substitute $\frac{dp}{dx}$ for W:

$$\therefore \rho u = \frac{\frac{dp}{dx}\rho}{4\mu}(a^2-A^2).$$

From equation (14)—

$$dF = 2\pi a\frac{\frac{dp}{dx}\rho}{4\mu}(a^2-A^2)da,$$

that is $F = \int_0^A \frac{2\pi a}{4\mu}\frac{dp}{dx}\rho(a^2-A^2)da.$

For a tube of length l with pressure p_1 at the charging end, and p_2 at the other end (Fig. 4):

$$F\int_0^l dx = \int_0^A\int_{p_1}^{p_2}\frac{2\pi a}{4\mu}(a^2-A^2)\frac{p}{k}dp\,da$$

$$\therefore Fl = \int_0^A\frac{2\pi a}{4\mu k}(a^2-A^2)\left(\frac{p_2^2-p_1^2}{2}\right)da,$$

$$= \frac{\pi}{4\mu k}(p_2^2-p_1^2).\frac{A^4}{4}.$$

Whence $F = \frac{p_1^2-p_2^2}{l}.\frac{\pi A^4}{16k\mu}$,

$= \frac{p_1^2-p_2^2}{R'l}$,

where $R' = \frac{16k\mu}{\pi A^4}$.

For any section of length x and pressure p from the charging end:

$$F\int_0^x dx = \int_0^A \frac{2\pi a}{4\mu k}(a^2-A^2)\frac{(p^2-p_1^2)}{2}da,$$

$$\therefore Fx = \frac{\pi A^4}{16\mu k}(p_1^2-p^2).$$

Substituting for F (from equation 15) and rearranging:

$$p^2 = p_1^2\left(1-\frac{x}{l}\right)+p_2^2\left(\frac{x}{l}\right)$$

APPENDIX 5—TRANSIENT ANALYSIS OF PERFORMANCE OF G.P.A. EQUIPMENT ON THE 6-TUBE SYDNEY-MELBOURNE COAXIAL CABLE

(i) Calculation of the Constant r:

The constant r is obtained by experimentally determining the pressure drop across, and flow through known lengths of the coaxial cable, and calculation from equation (11), namely $r = \frac{p_0}{i_0 s}$.

A typical set of such parameters are:

$p_0 = 9.3$ lbs./sq. in. $= 9.3\times32\times144$ poundals/sq. ft.,

$i_0 = 2.4$ $SCFH = \frac{2.4}{3600}$ SCF/sec.

There are 0.0754 lbs. of air in a SCF.

Hence, $i_0 = \frac{2.4\times0.0754}{3600}$ lbs./sec.,

$s = 3764$ yds. $= 3764\times3$ ft.

Thus, $r = \frac{9.3\times32\times3600\times144}{2.4\times0.0754\times3764\times3}$/ft.^{2}/sec.

that is, $r = 7.55\times10^4$/ft.^{2}/sec.

(ii) Calculation of Constant V':

For the 6-tube coaxial cable illustrated in Fig. 2:

Total metallic area of coaxial inner conductors $= 6\times\frac{\pi}{4}(0.104)^2$ in^2.

Total metallic area of coaxial outer conductors $= 6\times\frac{\pi}{4}\times0.04\times0.79$ in^2.

Total metallic area of coaxial quadded conductors $= 64 \times \frac{\pi}{4} \times (0.0355)^2$ in^2.

Total cross-sectional metallic area $= 0.0832\pi$ in^2.

For a disc spacing of 1.3 inch with discs of 0.081 inch thickness, disc volume per one inch length of cable

$$= \frac{\pi}{4} \times 0.081 \times 0.271 \times 0.479 \times \frac{1}{1.3} \text{in}^3,$$

$$= \pi \times 0.002\text{in}^3.$$

Air space volume per inch length of cable, V', is given by

V' = (total volume per inch within sheath) −(total non-air-permeable volume per inch within sheath)

$$= \frac{\pi}{4}(1.4)^2 - (0.0832\pi + 0.002\pi)$$

$$= 0.405\pi \text{ in}^3.$$

(iii) Calculation of the Constant c:

The constant c may be calculated theoretically from equation (6) or equations (33) and (34) of Appendix 3(i).

From equation (6), $c = \frac{M}{RT} \cdot V'$

$R = 8.31 \times 10^7$ erg./degree/gm.

M = 80% of 28 (molecular weight of nitrogen) + 20% of 32 (molecular weight of oxygen)

$= 22.4 + 6.4$

$= 28.8$ gm.

Assume an average temperature of 68°F (20°C), then T = 293°A.

From (ii) $V' = \pi \times 0.405 \times 6.45$ cm^2.

$$\text{Thus } c = \frac{28.8 \times \pi \times 0.405 \times 6.45}{8.31 \times 10^7 \times 293} \text{sec}^2,$$

that is $c = 97.1 \times 10^{-10}$ sec^2.

Alternatively, from equation (33) of Appendix 3(i),

$$Q = \rho s V',$$

and $\rho = \frac{26.7}{14.7} \times .0754 = 0.137$ lb./ft.^{3} at 12 *psig*, the nominal maintenance pressure of the cable.

$$\text{Thus, } Q = \frac{0.137 \times \pi \times 0.405 \times s}{12^2} \text{lb.}$$

From equation (34)—

$$\frac{0.137 \times \pi \times 0.405 \times s}{12^2} = (26.7 \times 32 \times 12^2) s.c.$$

Thus $c = 98.4 \times 10^{-10}$ sec^2.

(iv) Calculation of rc:

Factor $rc = 98 \times 7.55 \times 10^{-6}$sec/ft.^{2},

$= 7.4 \times 10^{-4}$sec./ft.^{2}.

(v) Construction of Pressure-warning Curves

The fault is assumed to be on the far side of the contactor from the nearest pressure source, that is, between contactors if there is more than one contactor in the section, as in Fig. 20. This condition imposes a greater delay time for contactor operation than if the fault were between the nearest pressure source and the contactor.

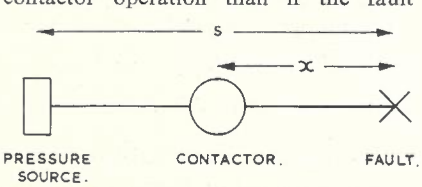

Fig. 20.—Position of Fault with Respect to the Pressure Source and the Contactor.

Assuming an average minor repeater section of 30,000 feet, then

$$15{,}000 \leq s \leq 30{,}000$$
$$0 \leq x \leq 15{,}000$$
$$s = (x + 15{,}000),$$

that is half a repeater section is considered, results being identical for the other half section.

The quantities in Table 1 are computed, and the graphs of time to contactor operation as a function of the contactor's distance from the fault for various values of p/p_o are shown in Fig. 19.

TABLE 1: DATA FOR CONSTRUCTION OF PRESSURE-WARNING CURVES

$\frac{p}{p_o}$	$\frac{x}{s}$	s ft.	s^2rc secs.	$\frac{t}{s^2rc}$ from Fig 6	t
0.7	.05	15,789	18.45×10^4	.0012	3.7 mins.
	.1	16,667	20.56×10^4	.0046	15.8 mins.
	.2	18,750	26.02×10^4	.0185	1 hr. 20 mins.
	.3	21,429	33.98×10^4	.0420	3 hrs. 58 mins.
	.4	25,000	46.25×10^4	.0730	9 hrs. 23 mins.
	.5	30,000	66.60×10^4	.1170	21 hrs. 39 mins.
0.8	.05	15,789	18.45×10^4	—	—
	.1	16,667	20.56×10^4	.0030	10.3 mins.
	.2	18,750	26.02×10^4	.0120	52.0 mins.
	.3	21,429	33.98×10^4	.0275	2 hrs. 36 mins.
	.4	25,000	46.25×10^4	.0480	6 hrs. 10 mins.
	.5	30,000	66.60×10^4	.0750	13 hrs. 53 mins.
0.9	.05	15,789	18.45×10^4	—	—
	.1	16,667	20.56×10^4	.00187	6.4 mins.
	.2	18,750	26.02×10^4	.0073	31.7 mins.
	.3	21,429	33.98×10^4	.0167	1 hr. 35 mins.
	.4	25,000	46.25×10^4	.0300	3 hrs. 51 mins.
	.5	30,000	66.60×10^4	.0460	8 hrs. 31 mins.

(vi) Construction of Flow-warning Curves

Since the flow-meter is situated at the pressure source (minor repeater), then

$$\frac{x}{s} = 1.$$

For the flow-meter at each end of a minor repeater section, the lowest recorded steady state flow will be for a fault at mid-section.

Applying equation (15), that is $F = \frac{p_1^2 - p_2^2}{R'l}$,

where $p_1 = (14.7 + 12)$ psia,
$p_2 = 14.7$ psia,
$R' = 0.044$ units,
$l = 5{,}000$ yards $(=s)$,
then $F = 2.26$ SCFH $(= i_o)$.

However, the flow-meter will **actually** read $\sqrt{\frac{23.52}{26.7}} \times 2.26 = 2.12$ *CFH*, as the flow-meter reads *SCFH* **only** at a pressure of 9.82 psig.

Table 2 has been computed for flow alarms at $i = 1$ SCFH, and $i = 0.5$ SCFH, and the time for the alarm to operate after occurrence of a sheath fault as a function of distance to the fault is shown in Fig. 19.

TABLE 2—DATA FOR CONSTRUCTION OF FLOW-WARNING CURVES

s (ft.)	i_o SCFH From equation (II)	$\frac{i}{i_o}$	s^2rc (sec.)	$\frac{t}{s^2rc}$ From Fig. 7	t
			$i = 1$ *SCFH*		
16,000	2.12	0.472	18.94×10^4	0.134	7 hrs. 3 mins.
15,000	2.26	0.44	16.65×10^4	0.130	6 hrs. 1 min.
13,000	2.61	0.38	12.51×10^4	0.117	4 hrs. 4 mins.
11,000	3.08	0.325	8.95×10^4	0.104	2 hrs. 35 mins.
9,000	3.764	0.266	5.99×10^4	0.0985	1 hr. 38 mins.
7,000	4.85	0.206	3.63×10^4	0.085	51.4 mins.
5,000	6.78	0.1475	1.85×10^4	0.079	24.4 mins.
3,000	11.29	0.0885	0.666×10^4	0.068	7.6 mins.
1,500	22.6	0.0443	0.1665×10^4	0.058	1.6 mins.
			$i = 0.5$ *SCFH*		
16,000	2.12	0.236	18.94×10^4	0.093	4 hrs. 54 mins.
15,000	2.26	0.22	16.65×10^4	0.092	4 hrs. 15 mins.
13,000	2.61	0.19	12.51×10^4	0.085	2 hrs. 57 mins.
11,000	3.08	0.16	8.95×10^4	0.084	2 hrs. 5 mins.
9,000	3.764	0.133	5.99×10^4	0.077	1 hr. 17 mins.
7,000	4.85	0.103	3.63×10^4	0.073	44.2 mins.
5,000	6.78	0.074	1.85×10^4	0.067	20.7 mins.
3,000	11.29	0.044	0.666×10^4	0.061	6.8 mins.

TABLE 3—DATA FOR CONSTRUCTION OF QUANTITY WARNING CURVES

s (ft.)	q_o *SCF* $= \frac{p_o sc}{.0754}$	Gas cylinder pressure drop p psi	q_{res} *SCF* $= \frac{220}{1986} \cdot p$	$\frac{q_{res}}{q_o}$	s^2rc	$\frac{t}{s^2rc}$ from Fig. 8	t
1,000	7.187			1.156	740	1.30	16.0 mins.
2,000	14.37			0.578	2,960	0.74	36.0 mins.
3,000	21.56			0.385	6,660	0.55	1 hr. 1 min.
4,000	28.75			0.289	1.184×10^4	0.45	1 hr. 29 mins.
6,000	43.12	75	8.307	0.193	2.664×10^4	0.355	2 hrs. 38 mins.
8,000	57.5			0.144	4.736×10^4	0.300	3 hrs. 57 mins.
10,000	71.87			0.116	7.40×10^4	0.270	5 hrs. 33 mins.
12,000	86.24			0.096	10.66×10^4	0.245	7 hrs. 15 mins.
14,000	100.6			0.083	14.50×10^4	0.225	9 hrs. 4 mins.
1,000	7.187			0.771	740	0.94	11.6 mins.
2,000	14.37			0.385	2,960	0.55	27.1 mins.
3,000	21.56			0.257	6,660	0.42	46.6 mins.
4,000	28.75			0.193	1.184×10^4	0.355	1 hr. 10 mins.
6,000	43.12	50	5.538	0.128	2.664×10^4	0.287	2 hrs. 7 mins.
8,000	57.50			0.0963	4.736×10^4	0.245	3 hrs. 13 mins.
10,000	71.87			0.077	7.40×10^4	0.215	4 hrs. 25 mins.
12,000	86.24			0.064	10.66×10^4	0.198	5 hrs. 52 mins.
14,000	100.6			0.055	14.50×10^4	0.190	7 hrs. 39 mins.
16,000	115.0			0.0482	18.94×10^4	0.183	9 hrs. 38 mins.
1,000	7.187			0.385	740	0.550	6.8 mins.
2,000	14.37			0.193	2,960	0.355	17.5 mins.
3,000	21.56			0.128	6,660	0.287	31.9 mins.
4,000	28.75			0.0963	1.184×10^4	0.245	48.3 mins.
6,000	43.12	25	2.769	0.0642	2.664×10^4	0.198	1 hr. 28 mins.
8,000	57.50			0.048	4.736×10^4	0.183	2 hrs. 24 mins.
10,000	71.87			0.039	7.40×10^4	0.164	3 hrs. 22 mins.
12,000	86.24			0.032	10.66×10^4	0.154	4 hrs. 34 mins.
14,000	100.6			0.0275	14.50×10^4	0.145	5 hrs. 50 mins.
16,000	115.0			0.0241	18.94×10^4	0.140	7 hrs. 22 mins.

(vii) Quantity of Gas Held by the Cable

From equation (12),

$$q_o = p_o sc \ .$$

Assuming a minor repeater section length of 30,000 feet, and a maintenance pressure of 12 psig,

$$p_0 = 12 \times 32 \times 144 \text{ poundals/ft}^2,$$

$$\text{Thus } q_0 = 12 \times 32 \times 144 \times 30{,}000 \times 98 \times 10^{-10} \text{ lb.},$$

$$= 16.26 \text{ lb.},$$

$$= \frac{16.26}{.0754} = 216 \ SCF \text{ of air.}$$

A standard gas cylinder of air holds 220 SCF at a pressure of 1986 psig. Thus, almost the contents of a gas cylinder are used in filling the unpressurised minor repeater section.

(viii) Construction of Quantity Warning Curves

Under continuous flow conditions, a gas cylinder in the minor repeater is connected to the cable. When a fault occurs gas will flow from the cylinder causing a drop in cylinder pressure. This sudden drop in pressure from the very slowly falling cylinder pressure (due to seepage losses) may be used to provide a warning, particularly for faults closer to the exchange than to a contactor. This form of alarm is more suited to the Sydney-Melbourne coaxial cable than a flow-meter alarm, as a low cylinder contents alarm (which may be easily modified) is provided; in addition, it would be difficult to provide an alarm at a certain flow-rate on the installed flow-meter.

Table 3 has been computed for 220 cubic foot air cylinder pressure drops of 25, 50 and 75 psi and the alarm curves are shown in Fig. 19.

TECHNICAL NEWS ITEM

NEW STANDARDS ASSOCIATION OF AUSTRALIA PUBLICATION—STANDARD TESTS FOR ELECTRONIC COMPONENTS

Standard methods for carrying out climatic and durability testing on electronic and telecommunication equipment components have been established by the Standards Association. Issued as Australian Standard C333, the methods are intended to provide bulk purchasers of components, including the Armed Services, and component manufacturers, importers and exporters with a uniform basis for checking or verifying the durability of components and their reliability in service. AS-C333 is also intended to be the basic document for tests called up by reference in a number of standard specifications for components now in course of preparation by the Association.

The Australian methods closely follow those developed by the International Electrotechnical Commission. The IEC work is intended to facilitate international interchangeability and trading in components, which may have to undergo severe physical stresses and changes in climatic conditions while in storage, transport or service. Australia is one of the first countries in the world to relate its standard methods for testing components to the international recommendations. Australian-made components, in meeting quality requirements on the basis of the tests given in AS-C333, can match components made anywhere else in the world.

Before the IEC methods were adopted for use in Australia they were thoroughly investigated in the field and in the laboratory by the Standards Association's technical committee on which manufacturing and using interests and government departments are represented. As a result of these investigations a number of changes were made in several of the methods and some methods have not yet been adopted.

The methods so far issued cover the following tests: cold (down to −65°C); dry heat (to 200°C); long term exposure to damp heat; accelerated damp heat; fatigue due to vibration, e.g. for components in aircraft and motor vehicles; resistance of components to mould growth; low air pressure, e.g. at high altitudes; rapid change of temperature; air tightness of seals, e.g. gaskets; hermetic sealing of the components; soldering; robustness of terminations. Provision has been made for the addition of other test methods as they are completed.

Copies of AS-C333 are now available from the offices of the Standards Association in the State capital cities and at Newcastle.

EXCHANGE DEMONSTRATION UNIT FOR THE SYDNEY ROYAL EASTER SHOW

*L. R. ASHE**

INTRODUCTION

It has been the practice for many years to have a demonstration unit, showing the operation of automatic switching equipment as used in a typical call in the metropolitan network, demonstrated at the Sydney Royal Easter Show. This has been done in conjunction with the automatic exchange which handles all showground traffic during the period of the show. The exchange itself comprises Pre-2000 type equipment, and the demonstration unit in past years also consisted of Pre-2000 type equipment, designed to simulate equipment in the exchange, and to demonstrate calls originating and terminating in the showground area.

It was felt this year that a new demonstration unit was required. It was decided to use SE.50 equipment and to design the unit merely to enable the demonstrator to give a logical explanation of a call from a local exchange, via a main exchange to another local exchange, incorporating an explanation of metering and alarm conditions, and demonstrating various tones and their meanings. Previous experience had shown that these were the things in which the public was mainly interested. A new unit could also enable more detailed technical descriptions to be given, if required, in answer to questions.

* See page 82

DEMONSTRATION UNIT

Fig. 1 shows the new unit which was designed and used at the last show. It consisted of a two shelf unit, wall mounted, at a height of six feet, enabling the demonstration to be clearly seen. The lower shelf carried, from the left, the calling subscribers' equipment, (handset, L & K relays, uniselector and Subs. register). A repeater completed the local exchange equipment, followed by 1st, 2nd, 3rd selectors simulating main exchange equipment, with a repeater impulsing to 4th and final selectors, and the called subscriber with his associated exchange equipment. SE.50 switches, provided with glass fronted switch covers to allow inspection and to restrict dust, were used. All equipment was designated, with an explanation of its functions.

The top shelf comprised a relay set carrying alarm relays, glass fronted lamp indicators which indicated the number dialled on any selector, a relay set incorporating howler equipment and tone transformer, and a relay set carrying relays required for lamp indication of vertical stepping of final selector. On an adjacent wall an amplifier was mounted to allow demonstration of various tones. These were available via push buttons mounted at left of the equipment, handy to the demonstrator.

In the wiring of the equipment provision was made to allow demonstration of searching over busy outlets. Thus in the successive stages the 6th, 14th, 18th

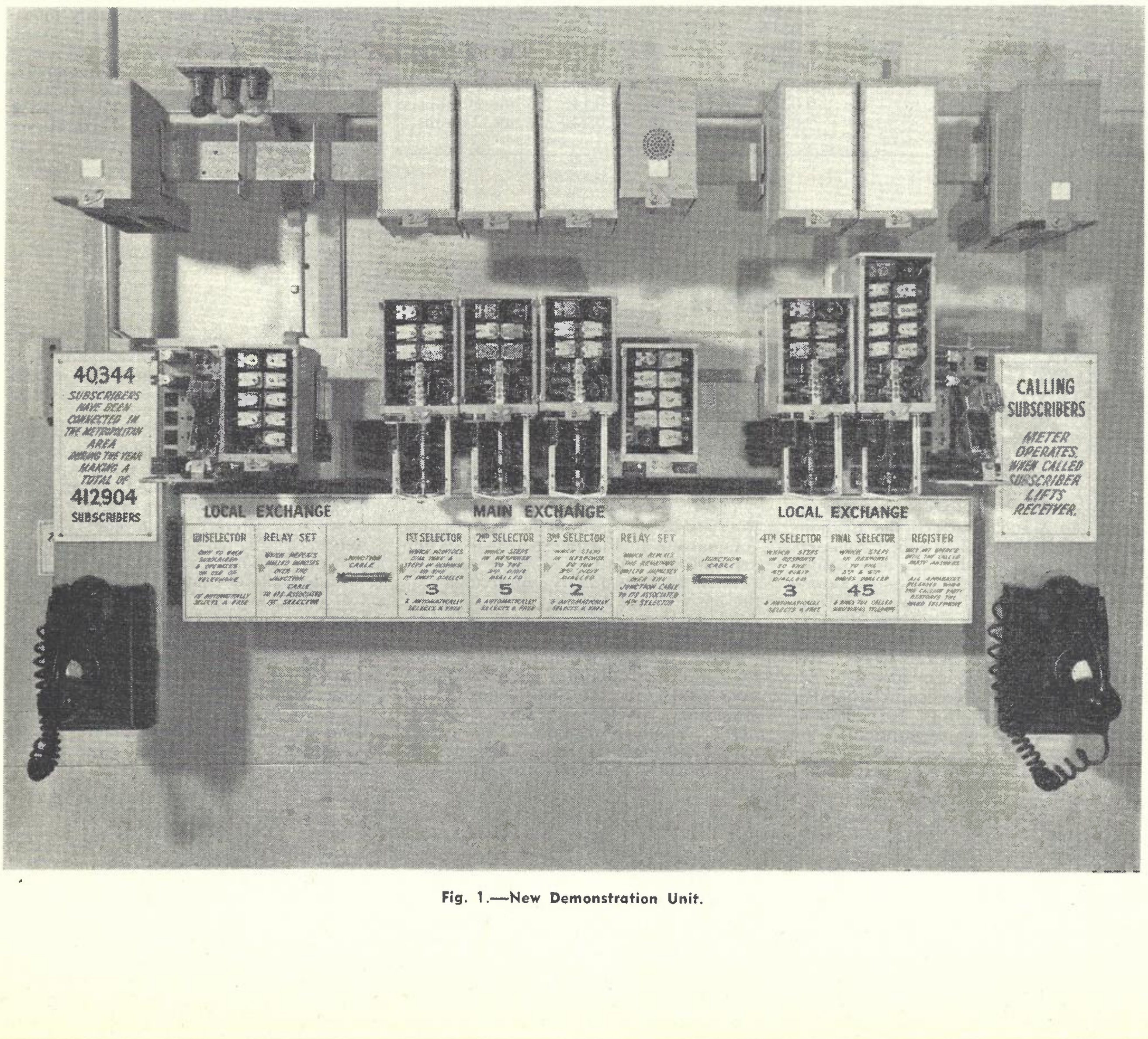

Fig. 1.—New Demonstration Unit.

and 10th trunks were utilised as outlets to the next stage. Previous outlets on all levels were busied, and the appropriate outlet commoned to the next stage, enabling demonstration of switches responding to different sets of impulses. Level 1 on the 1st selector was busied allowing demonstration of all trunks busy. A switching point was incorporated in the called subscriber uniselector to allow demonstration of called sub busy. The graduated howler was demonstrated.

USE OF UNIT

In general the demonstrators were not given a prepared lecture but were allowed to work out their own talk and method of delivery. The general trend of each demonstration commenced with a description of the Metropolitan Telephone Network. This was followed by explanation and practical demonstration of the subscriber's seizure of a free trunk with the successive selectors subdividing the called number into its various digital categories. An explanation was given of the various tones encountered, dial tone, busy tone, ring tone and ring, with the amplified tones being actuated by the demonstrator as required. Particular attention was paid to the registration of the call, emphasis being placed on where and when the call was registered. The howler was demonstrated at the end of the call, and finally, release of all equipment by the calling subscriber. Fuse alarm, release alarm and supervisory alarms were explained.

Exit from the demonstration was through the exchange building where all units of equipment were designated by cards, and identified by the demonstrator with the items of equipment in the demonstration unit.

Public interest in the exhibit was keen. Questions were invited at the end of each demonstration, and some interesting discussions eventuated. Each demonstration was timed to last about ten minutes, which allowed individual questions to be answered while the next show was being handled by a second demonstrator.

Over 800 calls were registered in the unit during the ten days of the show, signifying approximately 800 demonstrations. At an average attendance of 25, a total of approximately 20,000 people passed through the exhibit.

OUR CONTRIBUTORS

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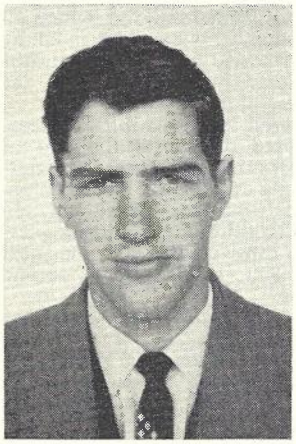
L. R. STEPHENS, author of the article "External Plant Aspects of Coaxial Cable Maintenance", joined the Postmaster-General's Department as a Junior Mechanic in 1940. He enlisted in the R.A.A.F. in 1942 as a Wireless Maintenance Mechanic and served in the South Pacific area. Following his discharge in 1945 he completed his Mechanic's training and was appointed Technician in 1948, Senior Technician in 1949 and commenced Acting Engineer in Telephone Planning, Sydney, later in that year. After qualifying as Engineer in 1951 he was transferred to the Metropolitan Service No. 2 Division, Sydney, and was subsequently appointed Group Engineer, Wagga (his present position) where he took up duty in 1953. Whilst he has been in the Wagga Division he has had temporary service with Nepean Division, and was transferred to Canberra following the Civic fire to take charge of the Internal Plant Maintenance of the temporary Portable Exchanges used there for the restoration of service.

D. B. CLIFF, author of the article "The New Aerial Switching Scheme at Radio Australia, Shepparton — General Design and Performance", joined the Postmaster-General's Department in Victoria as Engineer Grade 1 in 1957, after graduating from the Royal Melbourne Technical College with a Fellowship Diploma in Communication Engineering. He was appointed Group Engineer, in the H.F. Station Division of the Victorian Radio Section in 1961, the position he now occupies. Since joining the Department, he has been associated with the expansion programme at Radio Australia, Shepparton, and has been responsible for the major reconstruction of two 100kW transmitters, the design and installation of monitoring and control systems, the erection of new aerials, and the project described in the paper. He is at present in charge of the operation and maintenance of Lyndhurst Radio Station. Mr. Cliff is a Graduate of the Institution of Engineers, Australia, and an Associate Member of the Institution of Radio Engineers, Australia.

L. C. GEMMELL, co-author of the article "The New Aerial Switching Scheme at Radio Australia, Shepparton —Mechanical and Structural Design", joined the Postmaster-General's Department in 1938 as a clerk in Melbourne. He was appointed a Cadet Draftsman in 1940 and became Sectional Draftsman in 1948 in charge of the Melbourne Workshops, Jigs and Tools Subsection. Mr. Gemmell has played a leading part in the mechanical design, development and erection of major projects for the various divisions of the Engineering Branch. He is now an Assistant Chief Drafting Officer with the Victorian Drafting Section.

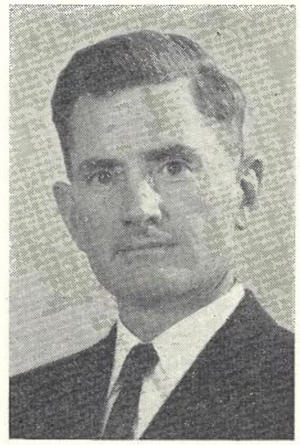
D. L. SHAW, author of the article "Taree Transit Exchange", joined the Postmaster-General's Department as a Cadet Engineer in 1950 while he was undertaking a course in Electrical Engineering at the University of New South Wales. He obtained his B.E. degree with



N. G. ROSS

B. J. CARROLL

P. GLICK



J. M. FULLARTON

2nd Class Honours in 1953 and completed his cadetship in 1954. Since 1954 Mr. Shaw has been employed in the Country Installation Section on the installation of carrier and trunk switching equipment in many areas of New South Wales. During this period he has been associated with the installation of 2VF transit switching equipment at Bathurst, Wagga, Albury, Dubbo and Orange. At present he is a Class II Engineer in the Country Installation No. 5 Division and is currently engaged on the installation of 48-channel carrier equipment in the Newcastle district.

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

N. G. ROSS, author of the article "Theory and Design of Gas Pressure Alarm Systems for Telecommunication Cables", joined the Postmaster-General's Department as a Cadet Engineer in 1956 and completed the B.E.E. course at the University of Melbourne in 1959, obtaining 1st class honors and the Dixson Scholarship. After 18 months' experience in long line equipment and country exchange installation work in Victoria, Mr. Ross was promoted to Headquarters and undertook developmental work on gas pressure alarm systems. During two years at Headquarters, he was also engaged on aspects of coaxial cable project methods and practices, cable procurement and broad-band bearer planning. Mr. Ross currently occupies the position of Engineer Class 2, Frankston District Works Division, Victoria.

B. J. CARROLL, author of the article "Features of the Kew Pentaconta Exchange" joined the Postmaster-General's Department as a Lineman-in-Training in 1941. After serving 4¼ years in the A.I.F. he resumed duty as a Lineman and subsequently qualified as a Technician in 1947 and a Senior Technician in 1948. With nine years' field experience as a Senior and Supervising Technician on Exchange and Substation Maintenance, he was appointed as a Trainee Engineer in 1957 and graduated in Communication Engineering at the Royal Melbourne Technical College in 1959. Since 1960 Mr. Carroll has been attached to the Metropolitan Service Section in the Victorian Administration, and as acting Group Engineer in the Metropolitan Service (Eastern) Division he is responsible for the maintenance of the Kew Pentaconta Exchange.

L. R. ASHE

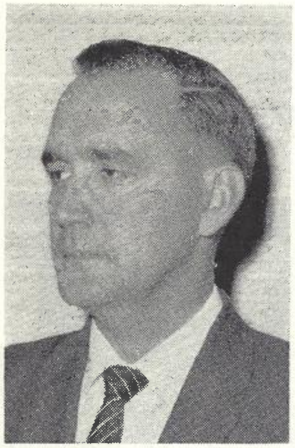
L. R. ASHE, author of the article "Exchange Demonstration Unit for the Sydney Royal Easter Show" is a Supervising Technician on Metropolitan Exchange Installation, Sydney. He joined the Postmaster-General's Department in 1947 and completed the adult Technician-in-Training course in 1952. Since then Mr. Ashe has been engaged on Exchange Installation as Senior Technician and Supervising Technician. He has been responsible for the establishment of new exchanges at French's Forest, North Ryde and Balmain.

P. GLICK, author of the article "An Automatic Howler Connection Circuit and Cable Failure Alarm" is a Class 2 Engineer in the Metropolitan Equipment Service Section in New South Wales. He was born in Grajevo, Poland, in 1923, and came to Australia in 1927. He was educated at Brisbane Grammar School and Sydney University, where he obtained the degrees of B.Sc. in Physics and Mathematics and B.E. in Mechanical and Electrical Engineering. From 1943 to 1946 he was with the R.A.A.F., flying with 101 and 214 Squadrons on Radio Countermeasures duties.

Mr. Glick joined the Postmaster-General's Department in 1951 and worked in telephone planning, exchange installation and exchange maintenance divisions. He designed a number of circuits, including the automatic howler connection circuit described in this article. At present he is engaged on a study of the application of statistical techniques to exchange maintenance problems.

J. M. FULLARTON, co-author of the article "The New Aerial Switching Scheme at Radio Australia, Shepparton —Mechanical and Structural Design", is a Senior Drafting Officer Grade 2 in charge of the Mechanical and Structural Subsection of the Postmaster-General's Department Drafting Section, Melbourne. He joined the Department in 1948 as a draftsman at the Postal Workshops and took up his present position in 1960. Before commencing work on the design of the Shepparton structure, Mr. Fullarton had been engaged on several other telecommunication projects while at the Workshops, including the space frame for the Dunn's Hill Radio Telephone Station and the Lyndhurst Aerial Switch.

Mr. Fullarton, who was educated in Sydney, received his training in the aircraft industry, having worked during the war as a Draftsman and Section Leader with the Commonwealth Aircraft Corporation, Melbourne, and later with the Department of Aircraft Production.



R. D. JOHNSTON

R. D. JOHNSTON, author of the article "Installation of an 1800 Pair Polythene Insulated and Sheathed Cable," joined the Postmaster-General's Department as a Clerk in 1942 and was appointed Cadet Engineer in 1947. He was appointed an Engineer in 1952 and completed the Bachelor of Science degree at the University of Queensland in the same year. His service as an Engineer has been in Brisbane Metropolitan Lines and Lines Planning Divisions, and the Country Divisions of Maryborough, Queensland, and Grafton, New South Wales.

Mr. Johnston is keenly interested in the activities of the Telecommunication Society and for several years has been a member of the Committee of the Queensland Branch. He is an Associate Member of the Institution of Engineers, Australia.

P. G. KRASTEV

P. G. KRASTEV, author of the article "Sydney-Melbourne Coaxial Television Transmission", holds a degree in Electrical Engineering from the Technical University of Stuttgart, Germany. In 1951 he migrated to Australia and that same year joined the laboratory of the Telecommunication Department of Philips Electrical Industries, which later expanded as Telecommunication Company of Australia. There he was engaged in the development of medium and high power radio transmitting equipment.

Mr. Krastev joined the Line Telephony Section of Telecommunication Company of Australia in 1959, when he was sent to Holland and Germany in connection with the Sydney-Melbourne Coaxial Project. While in Holland he was engaged in the development of TV equalization devices. In 1961 he took over as engineer-in-charge of the H.F. line installation and equalization of the Telephony and TV bearer of the Sydney-Melbourne Project, working on this until the beginning of May, 1963. In May 1963 Mr. Krastev was appointed Assistant Chief Engineer of the Line Telephony Department of TCA, Hendon, S.A. He is an Associate Member of the British Institution of Electrical Engineers and an Associate Member of the Institution of Radio Engineers, Australia.

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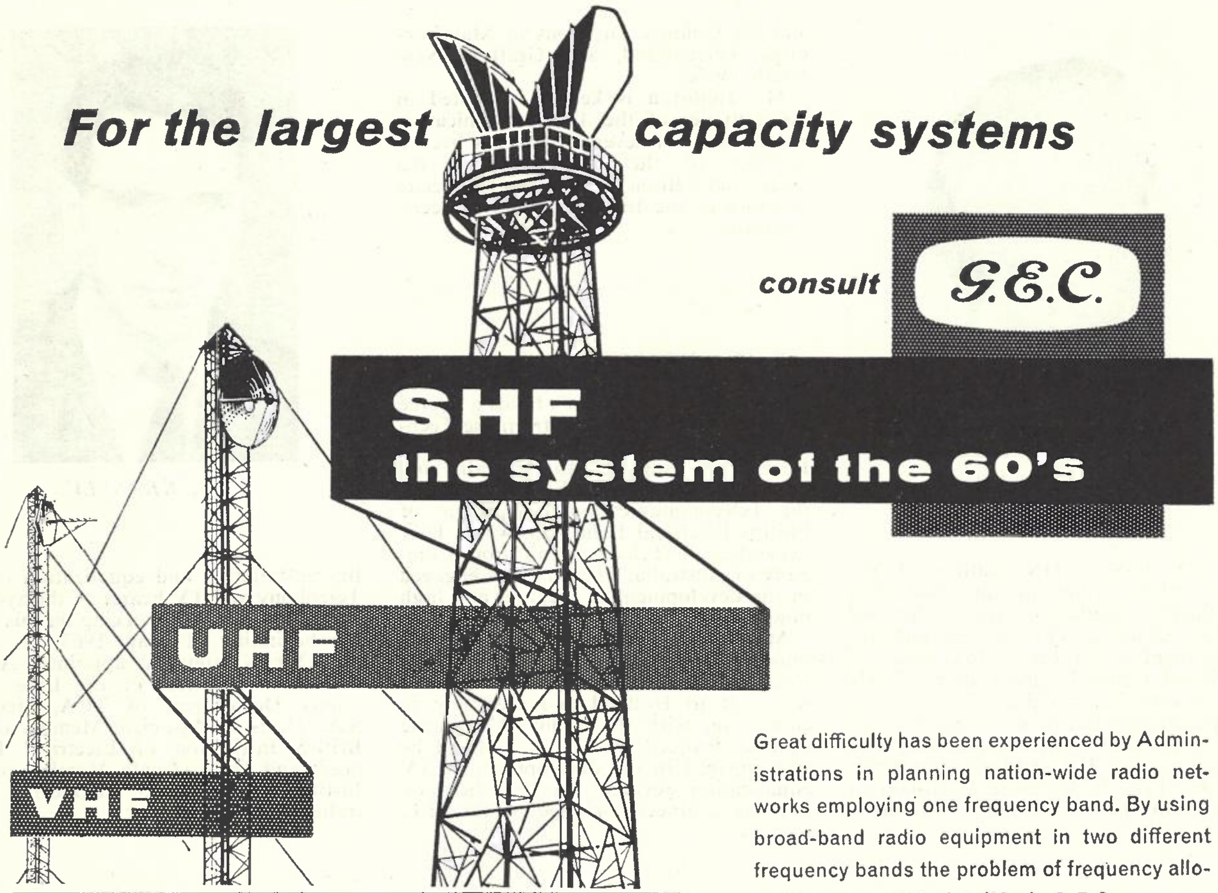

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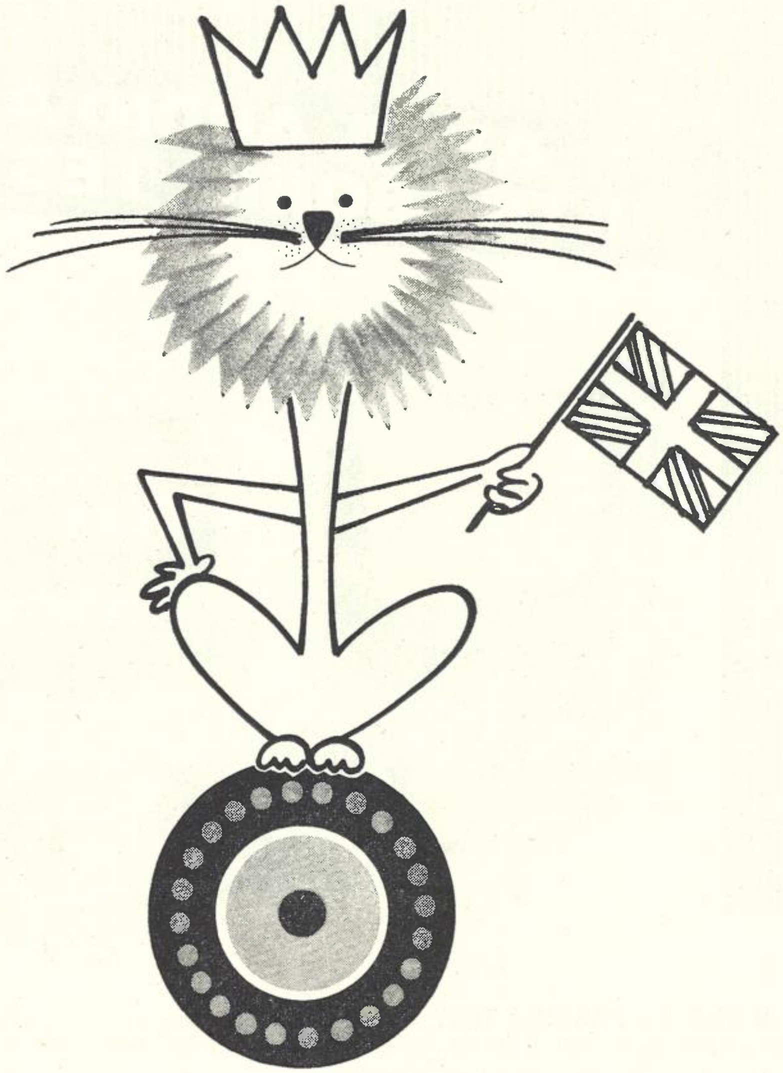

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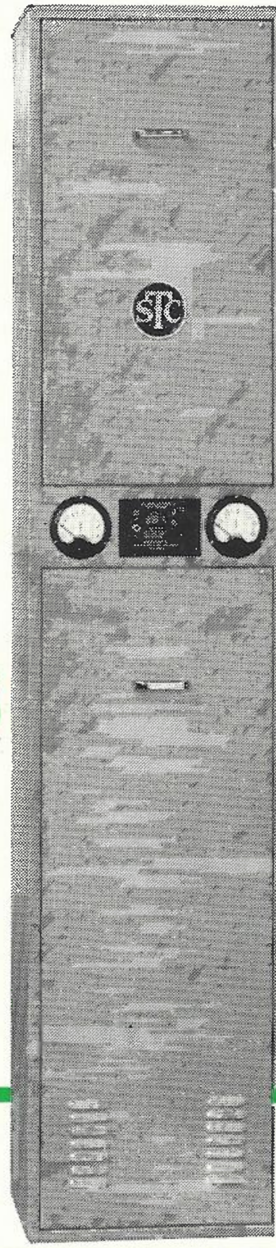

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Printed by The Ruskin Press Pty. Ltd., 39 Leveson Street, North Melbourne.