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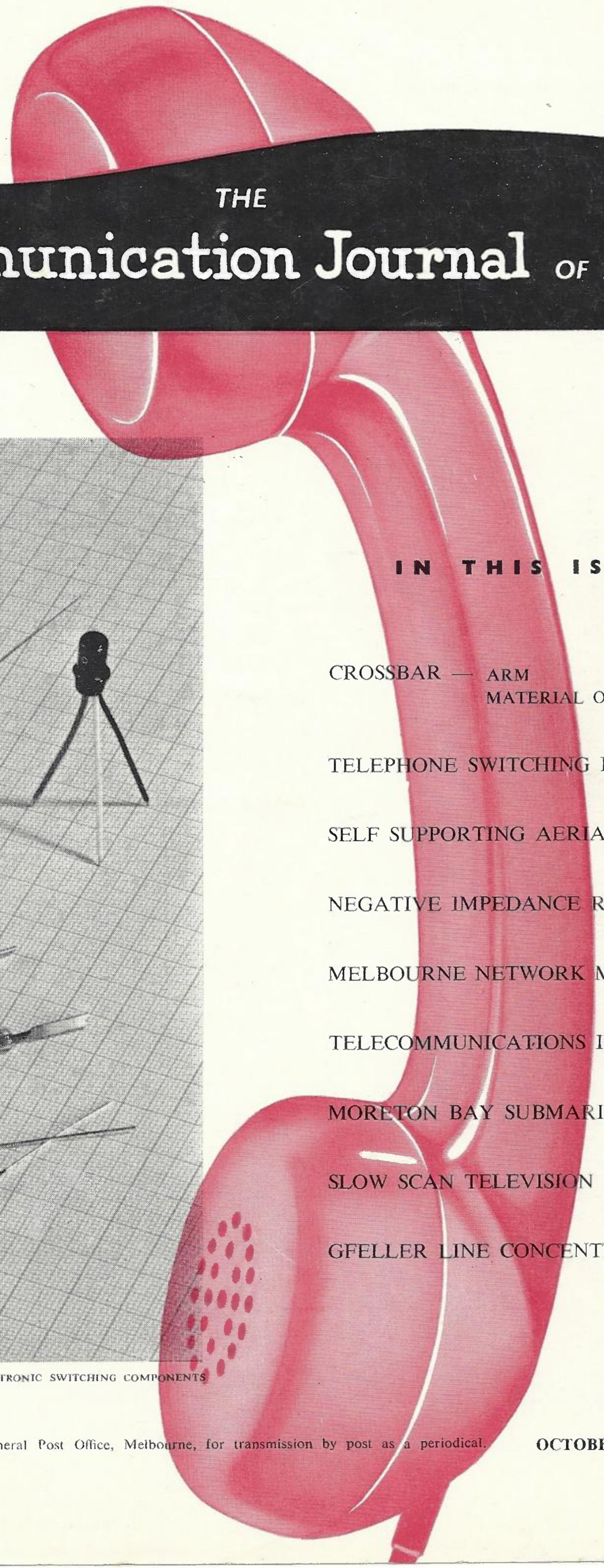

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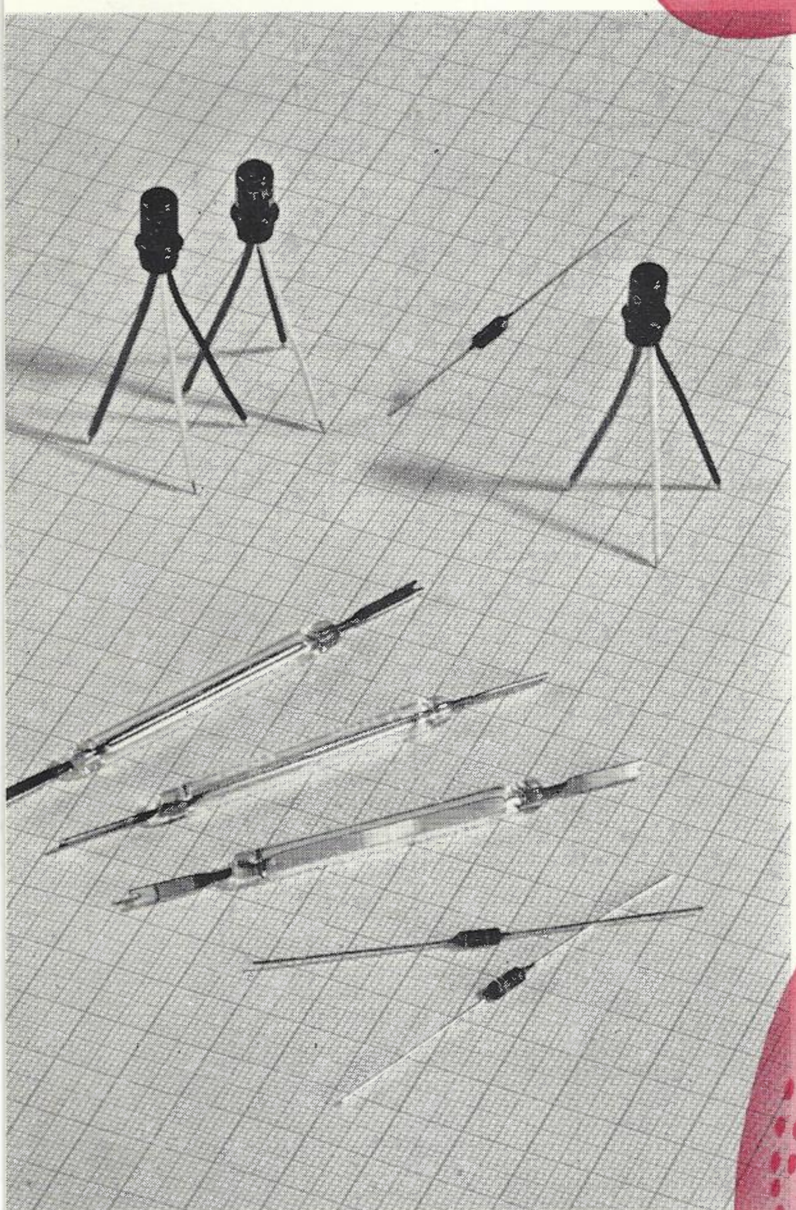

ELECTRONIC SWITCHING COMPONENTS

VOL. 14, No. 5/6 Registered at the General Post Office, Melbourne, for transmission by post as a periodical. OCTOBER, 1964


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The TELECOMMUNICATION JOURNAL *of Australia*

VOL. 14, No. 5/6 — *Registered at the General Post Office, Melbourne, for transmission by post as a periodical.* — OCTOBER, 1964

CONTENTS

The Journal is issued three times a year (in February, June and October) by the Telecommunication Society of Australia. Commencing with Volume 15, Number 1, in February, 1965, each volume will comprise three numbers issued in one calendar year.

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 for Australian subscribers is 10 shillings per year. As from Volume 15, No. 1 (February, 1965) overseas subscriptions will increase to 13 shillings per year (Australian currency) or 5 shillings and 3 pence for single numbers. Remittances should be made payable to the Telecommunication Society of Australia.

*For addresses see page 420.

ACTUAL PROBLEMS OF TELEPHONE SWITCHING

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Editorial Note: Mr. Oden of Standard Elektrik Lorenz delivered the substance of this article as a lecture to the Vienna Institute of Technology in May, 1962. The Editors are indebted to S.E.L. for permission to reprint the English translation of the expanded text of this lecture.

NEW COMPONENTS AND TECHNOLOGIES AS STIMULUS

In the last two decades, scientists and engineers have developed a number of remarkable new technologies and components such as transistors, multistable magnets, reed switches, solar batteries, waveguides, etched circuits, printed components. These new components and technologies not only enhanced the progress in conventional equipment design, e.g., the construction of portable miniature radio sets, but also promoted the development of novel equipment like communication satellites and high-speed computers which could not have been realized by conventional means.

Stimulating influences are exercized by these new technical achievements also on the telephone switching art. Development work aiming at different objectives may be noticed everywhere which can be summed up under the headings: "Electronics in Telephone Switching" or "Electronic Telephone Switching."

This article shall be an attempt to compile systematically and describe the manifold starts which eventually may lead to a gradual or complete structural change in telephone engineering and—as far as it is already possible today—to appraise their advantages and their difficulties. In doing so this investigation is limited to telephone switching although the same applies also to the switching systems for digital information to mention only the electronic buffer store in store and forward systems for teleprinter traffic.

The occasion of a perhaps fundamental structural change in telephone switching should be used for a broad-visioned critical analysis whether the performance characteristics of today's systems are adequate to meet future requirements or whether new services should be provided. In this case it is insignificant if such new services can only be rendered possible by electronic means or if they can also be realized at the present state of the art.

DEFINITIONS, SOLUTIONS, POINTS OF VIEW FOR THE APPRAISAL

When arranging the switching systems in operation or in development according to the basic principle of their switching networks and further subdividing them with respect to the component used, a scheme similar to that illustrated in Table 1 results. All commercially available systems use switching networks operating on the space-division multiplex principle, i.e., a separate transmission path is set up for each connection through the exchange. Solutions using a switching network operating on the time-division multiplex principle associate each connection with an individual instant in a recurrent time cycle on common transmission paths or highways which can carry 25 to 100 connections simultaneously. For the frequency division multiplex systems using a separate carrier frequency for each connection, no details are given because at the present stage of development this system is not interesting from an economic point of view.

Electro-mechanical systems which use space-division switching only because of the inertia of the components are known in a great diversity of systems equipped both with sliding and with pressure contacts. Systems made up largely of electronic components in the control circuits may be classified as semi-electronic. Several systems of this type (1-3) are presently in operation. (Though, strictly speaking, "electronic" components, i.e., components without mechanical movement, have been used in the earliest type telephone systems in the form of resistors, capacitors, glow lamps, etc., these systems should

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TABLE 1: SWITCHING SYSTEMS AND THEIR COMPONENTS

Components	Switching Systems								
	Space-division					Time-division			Frequency-division
	electro-mechanical		semi- electronic	quasi- electronic	fully- electronic	2-wire	4-wire		
	Sliding contacts	Pressure contacts				PAM	PAM	PCM	
Uniselectors, Two-motion selectors, Ericsson selectors...	K		K						
Motor uniselectors	K	K	K						
Crossbar switches		K	K						
Relays with open contacts	S	K S	K S						
Relays with sealed reed contact			K S	K S					
Tubes			S	S	K S	K S	K S	K S	
Semi-conductors			S	S	K S	K S	K S	K S	
Magnetic Components			S	S	K S	K S	K S	K S	

K = Components used for connecting two circuits.
S = Components used in control circuits (in a broad sense).

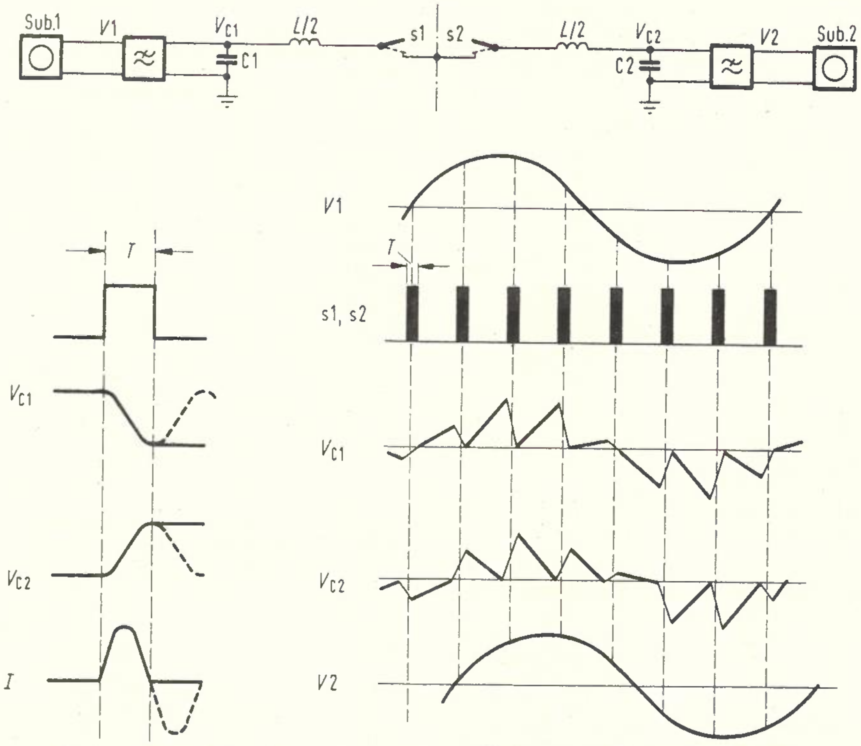


Fig. 1.—Resonant Transfer for Time-Division-Multiplex Systems (according to Svala).

not be classified as semi-electronic. For practical use its seems more appropriate to call a system semi-electronic only when essential switching functions, hitherto accomplished by electro-mechanical means, are performed by electronic means, for instance, replacing a mechanical pulse repeater by multi-stable magnets, converting a relay marker to diode and transistor circuits, substituting a relay chain by a diode-matrix, etc.)

Fully-electronic solutions using exclusively components without mechanical movement are shown on the right side of Table 1. If operating on the space-division multiplex principle, they mostly contain bistable gas-filled tubes or semi-conductor diodes and triodes as cross-point elements. Besides some experimental models set up in laboratories of the telecommunications industry (4-7), exchanges have been built which are still rendering efficient service, e.g., on a French man-of-war (8), or which have been successfully operated, e.g., in Morris, Ill., U.S.A., where an exchange served several hundred subscribers for about one year (9-11). Fully-electronic systems based on the time-division multiplex principle are, apart from their first application for military equipment (12), still in the state of development or laboratory tests. Mention shall be made of the laboratory model Dollis Hills and, derived from it, the experimental exchange Highgate Wood, which both have been developed by the British working group, the Joint Electronic Research Council (JERC), formed by members of the British Post Office and of the telecommunications industry. Highgate Wood will be put in operation before long. The two exchanges work on the 4-wire principle using amplitude modulation and have one highway each for speech and signals in either direction of transmission. Two-wire systems with amplitude modulation to which also the aforementioned military system belongs are being studied at several places.

1	DBP: Syst. 55	German PTT Administration, Local System Type 55.
	SEL: HKS	Standard Elektrik Lorenz AG, Crossbar System HKS 442 (21).
	ATT: No. 5 Cr.	American Telephone & Telegraph Co. Crossbar System No. 5 (22)
	Schw.V.: A 204	Swedish PTT Administration, Crossbar System A 204 (23).
1	CGCT: Pent.	Comp. Generale de Constructions Telephoniques, Crossbar System Pentaconta (3).
	BTM: 7 E	Bell Telephone Manufacturing Co. Rotary-System 7 E (1).
	ATE: 5004	Automatic Telephone & Electric Co. Crossbar System 5004 (24).
3	BTM: 8 A	Bell Telephone Manufacturing Co. Crossbar System 8 A (2).
	NTT: XX	Nippon Telegraph & Telephone Co. Crossbar System (25).
	ATE: XX	Automatic Telephone & Electric Co. Crossbar System (26).
1	SEL: HE 60	Standard Elektrik Lorenz AG, System HE-60 (27).
	S & H: ESM	Siemens & Halske AG, System ESM (28).
3	BTL: ECASS	Bell Telephone Laboratories, Electronically Controlled Automatic Switching System (29).
	BTL: DIAD	Bell Telephone Laboratories, Drum Information Assembler and Dispatcher (30).
	BTL: (ESS)	Bell Telephone Laboratories, Ferreed-Variant of ESSEX (20).
1	LCT: XX	Laboratoire Central de Telecommunication, Marine Telephone Exchange (8).
3	BTL: ESS	Bell Telephone Laboratories, Electronic Switching System (11).
	Phil.: XX	N. V. Phillips' Gloeilampen Fabrieken, see (7).
	LCT: XX	Laboratoire Central de Telecommunication, see (6).
	SEL: XX	Standard Elektrik Lorenz AG, see (5).
4	BTL: ESSEX	Bell Telephone Laboratories, Experimental Solid-State Exchange (17).
	JERC: MK II	Joint Electronic Research Council, Mark II (14).
	BTM: XX	Bell Telephone Manufacturing Co., see (31).
	LME: EMAX	L M Ericsson A. B. Electronic Multiplex Automatic Exchange (15).

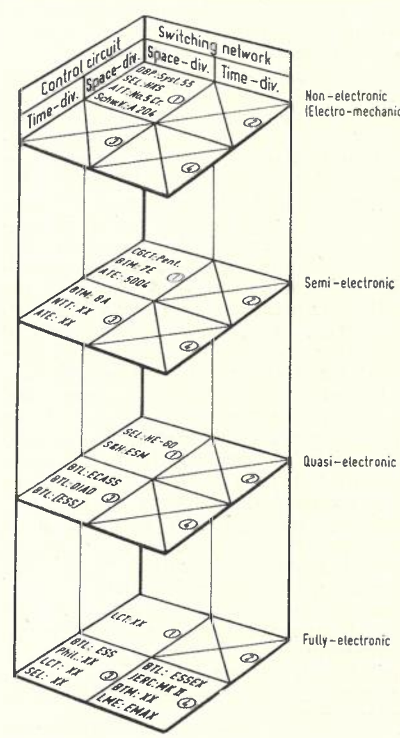


Fig. 2.—Examples for Switching Systems.

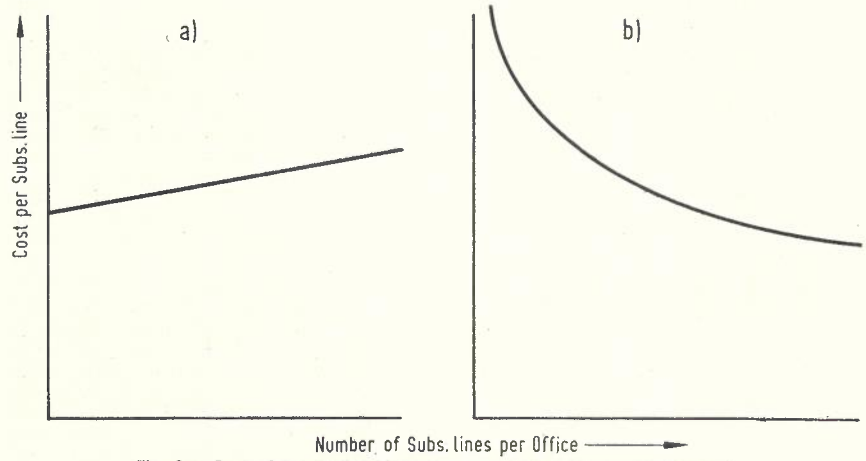


Fig. 3.—Cost of Subscriber Line as a Function of the Office Capacity.
(a) Decentralized Control (Space-Division)
(b) Centralized Control (Space-Division, Time-Division)

Since in time-division systems speech samples from the audio-frequency signal are extracted in recurrent time cycles only, such systems inherently have a considerable insertion loss in the switching network. This disadvantage has been overcome to a large degree by the method of "resonant transfer" described by Svala[1] (15). As illusrated in Fig. 1, the speech energy between two samplings is stored by a capacitor to be transferred instantaneously, at the moment of the connection of the two sections, in a resonant circuit to the opposite side (the contacts in the highway close for the duration of a quarter cycle of the angular resonant frequency). Theoretically, the signal transfer is lossfree. In practice, the insertion loss of several switching stages can be reduced to the order of 2.5 to 4.5 db.

Time-division-multiplex systems with pulse code modulation (16, 17) which are likewise under study at several places show a radical change from conventional systems. They convert the speech signal into digital signals for routing through the exchange. Generally, the analog speech signal is converted into six digital stages so that $2^6 = 64$ amplitude levels (corresponding to irregular amplitude steps of the audio frequency signal) can be distinguished. Often, a seventh signal element per channel is additionally provided for a channel signalling circuit.

The class of exchange systems listed in the column "quasi-electronic" (Table 1) uses, besides the electronic components, also an electro-mechanical component, the reed switch (18-20). This is a mechanical switching contact hermetically sealed in an envelope filled with an inert gas. In this paper, a switching system is called "quasi-electronic" if the switching network uses reed switches exclusively and the control circuits are made up of electronic components and reed switches. Grouping of such systems into a special class[2] appears to be justified on technical grounds and because it is being studied at several places.

For the control circuits of an exchange, too, both the space-division multiplex or the time-division multiplex principle may be applied (completely or partially). Fig. 2 illustrates the classes of systems which may be formed by the application of the different switching principles to the switching and control networks and of the different component groups and shows some examples of solutions and suggestions so far known.

But it is not only the question of the components and the type of switching and control networks to be used which must be considered in the search for the best solution to a new switching system; also in other respects new suggestions will have to be examined and evaluated.

There is, for instance, the remarkable idea to conect all subscribers' lines via "concentrators" (4, 11) to the exchange, i.e., via dependent switching units outside of the exchange. In this case, the exchange proper would only have distributing functions without concentration and expansion stages. Simultaneously it is suggested that such an exchange acting as a central control facility should serve as large a number of subscribers as possible. According

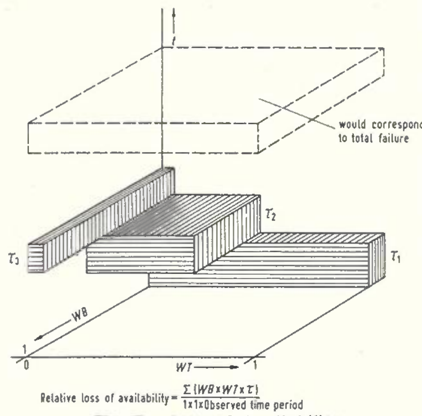


Fig. 5.—Loss of Availability.

to these plans this central control equipment is also to serve a number of offices including the associated concentrators, wideband information channels being provided between the control section on the one hand and the offices and concentrators on the other. Plans of this kind no longer restrict themselves to a rearrangement of an exchange but they may influence the basic structure of the local network. The insertion of such systems into networks of conventional design will create additional problems.

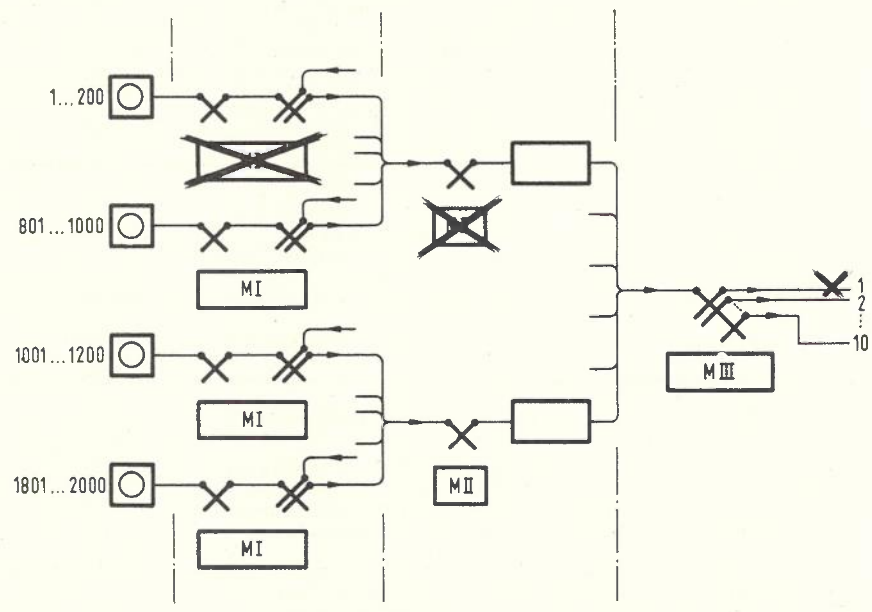


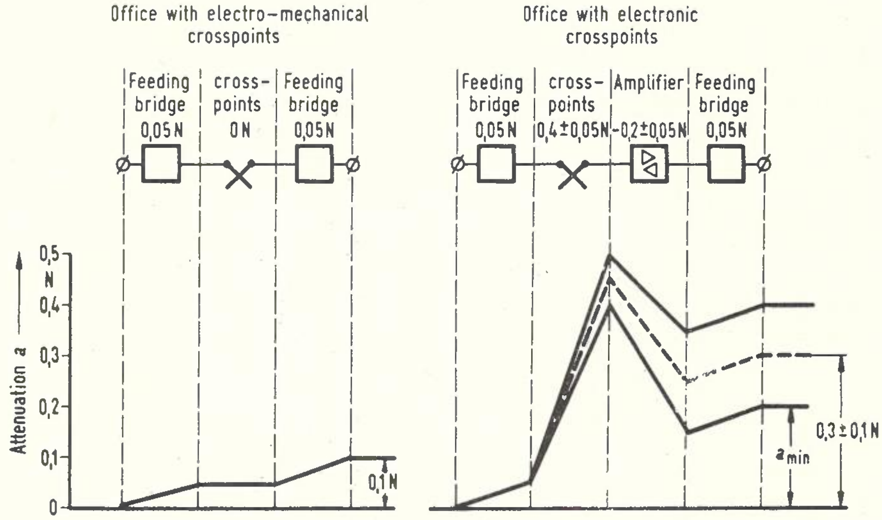
Fig. 4.—Active Width and Depth of Failure.

1. Independently suggested by Cattermole, too.
2. Sometimes this combination is assigned without restriction to the class of fully-electronic systems.

In the appraisal of a proposed system its prospective fields of application should be taken into account. It has to be checked for its adaptability to two-wire local exchanges, two- and four-wire long-distance exchanges, specific wideband data switching networks (if any), PABX systems and, last but not least, for the maximum and minimum exchange capacity which can still be economically justified.

Also the compatibility with existing switching and transmission systems, both from a viewpoint of circuit layout (adaptation expenditure) as well as network structure and attenuation schemes has to be considered. With regard to the attenuation schemes, insertion loss, attenuation distortion, delay distortion (and its variation) as well as stability are of special interest.

Present systems are also suited for transmission of signals outside the speech band in addition to the voice. These outband signals are frequently used for transmission of metering information or for subscriber identification. For systems which enable no outband signalling the cost of substitute solutions has to be regarded.



$a = 0.1$ (0.9 db)

$a_{min} \geqq 0.2$ N (1.7 db) considering the singing margin of the two-wire amplifier as represented by the office

$0.4 > a > 0.2$ N (1.7 db)

$a_{medium} = 0.3$ N (2.6 db)

Fig. 6.—Insertion Loss in an Office. Left: With Electromechanical Crosspoints. Right: With Electronic Crosspoints.

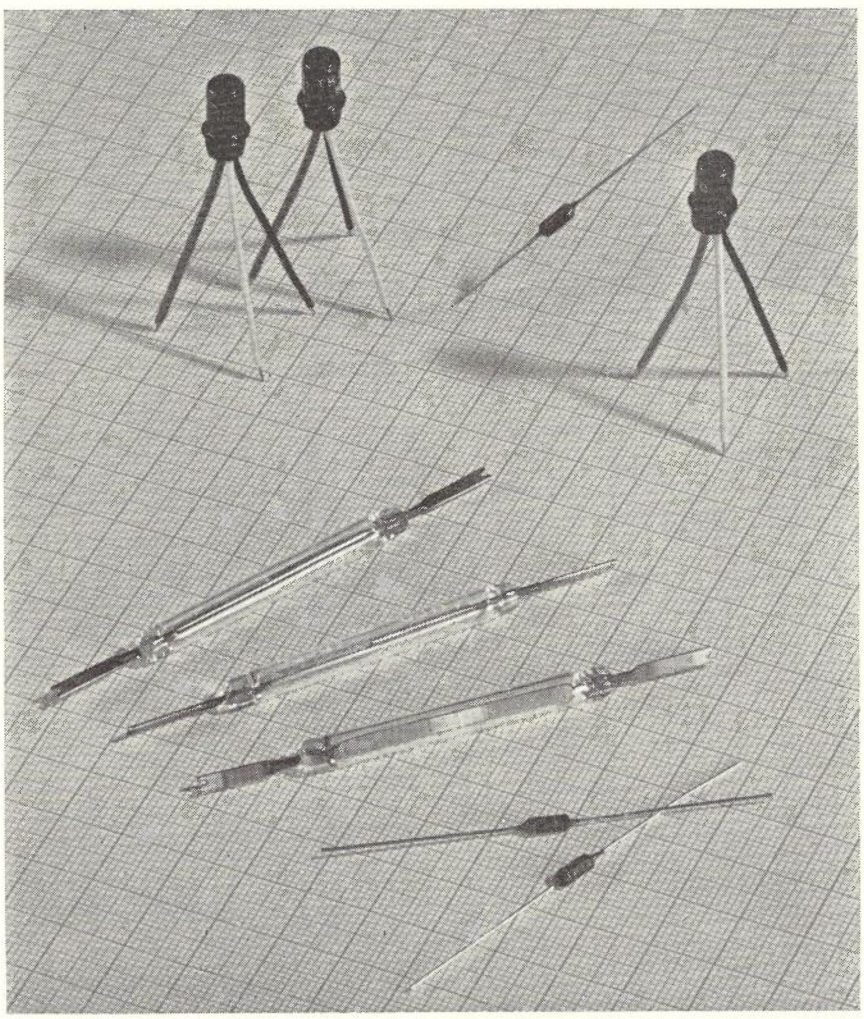


Fig. 7.—Components for Quasi-electronic Systems.

COMPARISON BETWEEN SPACE-DIVISION AND TIME-DIVISION SOLUTIONS

Time-division switching systems basically differ from space-division switching systems (32). The clear circuit lay-out of space-division systems facilitates maintenance works and fault localization. Moreover, since for each conversation the speech connection has to be established but once, cross-point elements of moderate speed, e.g., electro-mechanical components, suffice. In time-division systems, on the other hand, which require several thousands of short-time connections per second to the common transmission path in the course of each conversation, fast operating electronic switching elements are mandatory both in the speech paths as well as in the control circuits. This, in turn, stipulates a high degree of concentration because only a common central control is able to ensure correct timing. Space-division systems in comparison allow any degree of centralization to be used, ranging from the fully decentralized control to the one-at-a-time principle, even for very large offices. Time-division systems require adapting circuits in their inputs and outputs for matching to audio-frequency switching and transmission equipments, as well as to conventional subscriber lines. Their economy, further, depends on the bandwidth of the signal to be transmitted, as a wider frequency band (e.g. for data systems) results in a reduced number of channels on the highway.

From the above explanations which so far are in favour of space-division, no final conclusion must be derived as long as no definite data for a cost and space comparison are available.

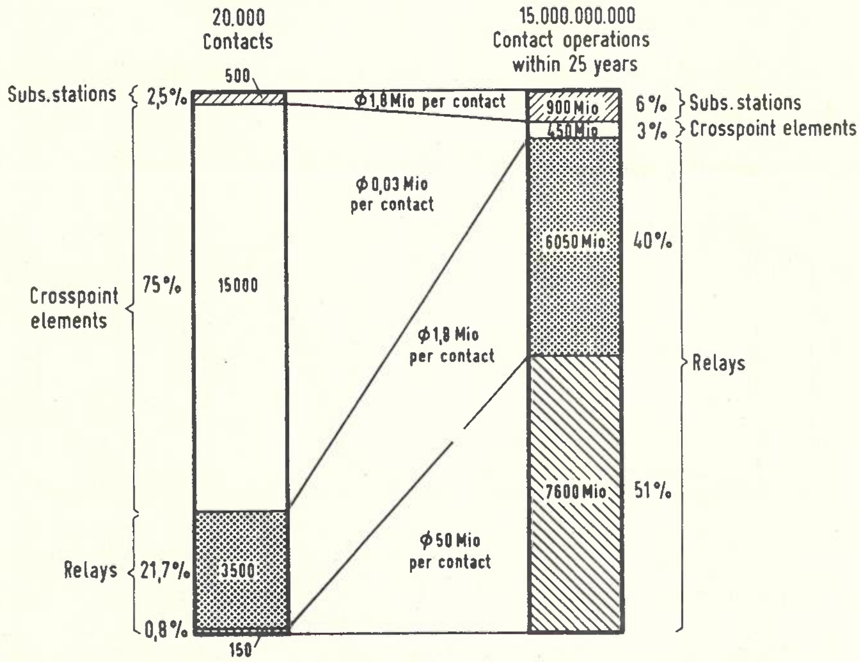


Fig. 8.—Number of Contacts in a PABX for 100 Extensions and Number of Contact Operations during a 25 years Period of Operation (rounded-off values).

CENTRALIZATION OF THE CONTROL ELEMENTS

Solution formulas based on a high centralization of the control elements, which is unavoidable in time-division but often also very attractive in space-division, mainly devote themselves to large and very large exchange systems. However, it should not be forgotten that most offices are of a relatively small capacity. (In 1958, for instance, 98% of all local offices in Western Germany had less than 2,000 lines, or 95% of all subscribers were served by offices with less than 4,000 lines).

The question as to whether and to what extent it is desirable to centralize the control equipment of a switching system is of major importance. High centralization is partly considered a merit and partly a disadvantage of a system, and therefore is applied only hesitatingly.

The degree of centralization of the control equipment exercises a direct influence on the office cost as a function of office capacity. Fig. 3 shows that in decentralized systems the cost per subscriber line starting at an initial value increases steadily with the capacity of the office. In centralized systems, on the other hand, a considerable amount of initial equipment is required which in small offices raises the mean cost per subscriber's line whilst it decreases progressively with increasing office size. Presumably, the two curves will cross at a point showing an office size below which decentralization, and above which centralization will prove more economical. Nobody is able to predict where this point will be.

From the operational point of view a centralized control offers the advantage that modifications in the system's working program can be carried out from one place only, thus permitting easy programming of all system functions (11, 33). It additionally provides a possibility to continuously monitor, by means of the control equipment, proper operation of the system by routine test programs and to localize faults by "diagnostic" programs.

However, the greater the centralization of the control equipment in a switching system, the more thought has to be given to the functional reliability of the control circuits if the system is not to become too vulnerable. Faults occurring in the centralized control equipment are more serious than those in decentralized circuits. Referring to the example illustrated in Fig. 4, a failure of a marker I, which handles the outgoing and incoming traffic of 200 lines of an office serving 2,000 subscribers, would affect 10% of the subscribers by 100% loss of traffic. The marker failure, in this case, has an "active width" WB = 0.1 and an "active depth" WT = 1.0 resulting in an "availability loss" VV = 0.1 × 1.0 × failure duration = 0.1 × failure duration. Failure of a marker II, which serves the entire outgoing traffic (WT = 0.5) of one half of all subscribers (WB = 0.5) will result in availability loss VV = 0.5 × 0.5 × failure duration = 0.25 × failure duration. Finally, if marker III fails in such manner that one tenth of the outgoing traffic (WT = 0.05) of all subscribers (WB = 1.0) is blocked, the availability loss will be VV = 0.05 × 1.0 × failure duration = 0.05 × failure duration. Fig. 5 shows how the weight of a fault can be represented by means of a three-dimensional graph (34)[3]. Failure of a central control facility serving the entire system on the one-at-a-time principle would lead to a total failure of the system (WT = 1.0 and WB = 1.0 and consequently VV = 1.0 × failure duration) graphically represented by a square block with base dimensions 1 × 1. Since an availability loss of the order of 1.0, or in the proximity thereof is not acceptable in a switching system—in contrast to computer systems—serious problems arise for systems with extensive centralized control.

The only way to ensure uninterrupted operation of centralized units is by

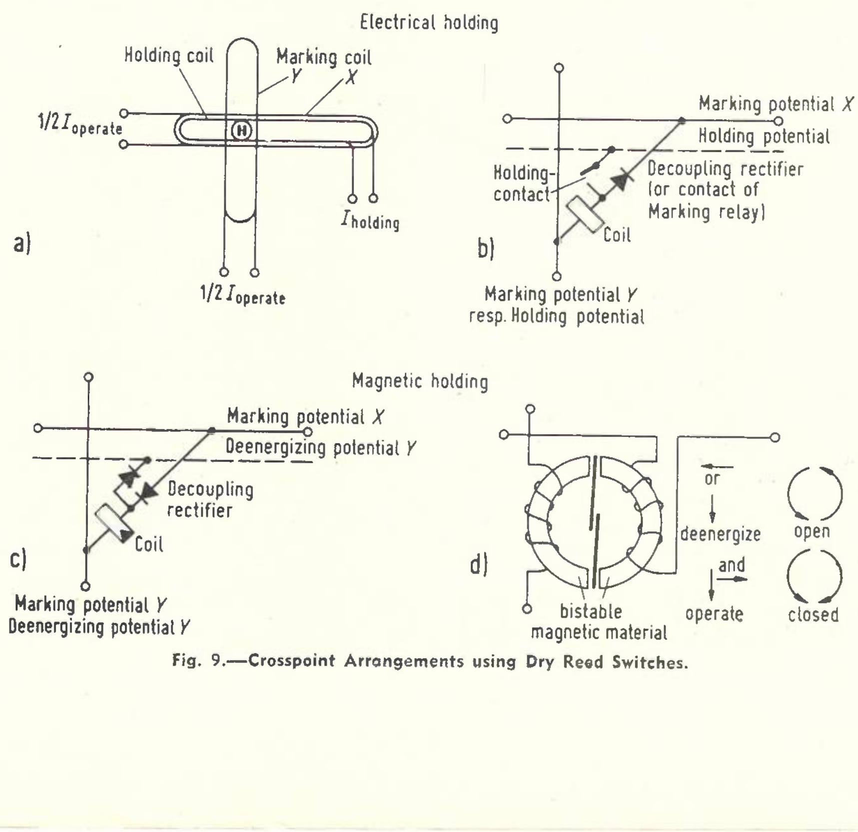


Fig. 9.—Crosspoint Arrangements using Dry Reed Switches.

3. By replacing the linear scale used here for *WB*, *WT* and the time by a more suiting scale (logarithmic scale?) an even better representation of the fault weight might be possible.

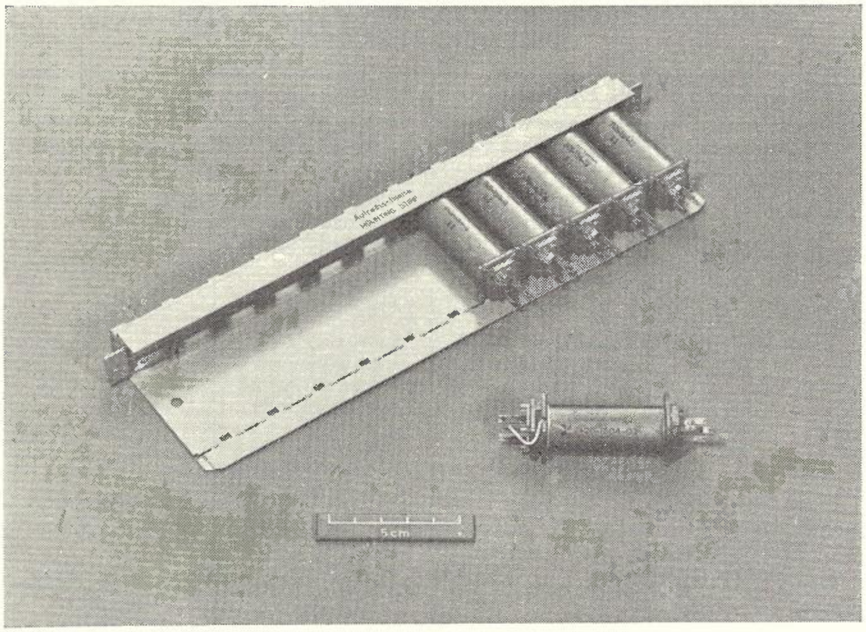


Fig. 10.—Crosspoint Element (right below) and Crosspoint Strip with dry reed switches; at either side of the topmost switch and at right in front of the strip are screening plates.

providing standby equipment, either in the form of complete duplication of the respective switching device (with two variants: firstly the two units are used alternatively or in different parts of the exchange and upon failure of one equipment the other one takes over the whole load; second variant, the standby equipment is available in the event of trouble) or through subdivision of the centralized equipment into smaller operating units, each of which being duplicated. If due to this subdivision a system contains a number of identical central equipments, a smaller number of standby equipments (or even just one) may be provided for several operating units.

Duplication or provision of standbys, however, requires facilities for the initiation of signals indicating fault condition, i.e., the necessity for standby switching. Such signals may be derived from redundant codes, redundant circuits, routine tests or time allowances. Redundancy in switching circuits may be provided on the principle of an error-detecting code in such a way that any irregularity will cause a fault but simultaneously initiate a signal for standby switching. It may also be advanced to conform with an error correcting code so that the switching circuit continues to operate upon appearance of one error. The redundancy loss caused by the error, however, must be signalled at once because the protection provided is lost. Similar considerations apply to complete switching links: If two identical switching links operate in parallel, the presence of differing output information indicates the occurrence of a fault. Special action, however, is required to identify the faulty link (corresponding to an error detecting code). If three switching links operate in parallel, the link with the differing output information can be disconnected on the "majority decision" principle (corresponding to an error correcting code). Again a signal is required to warn of the redundancy loss.

Special attention has also to be paid to the reliability of the information channels discussed in the preceding section, which in many system proposals are provided between the centralized control facility and the remote switching equipment it controls. The vulnerability of such "pilot channels" is increased because interferences are also liable to occur on lines, i.e., outside of operating rooms. Duplication in this case requires a standby channel on another route.

The precautions for safeguarding the operation of centralized control facilities have to be carefully investigated. It should be examined for example, whether the change-over facilities that effect switching from operating to standby equipment and the alarm circuits are sufficiently reliable (duplicated?) and whether they meet redundancy loss signalling requirements. Unfortunately, these additional reliability assurance provisions for centralized control facilities partially reduce their operational and economic advantage resulting from the fact that they have to be provided but once.

FULLY ELECTRONIC SOLUTIONS FOR SWITCHING SYSTEMS

Preliminary to the discussion of fully electronic solutions for switching systems, the question as to the usefulness or necessity of electronic systems has to be dealt with. Undoubtedly, the frequently cited argument "modern" should not be taken too seriously.

Of the advantages attributed to electronics in telephone switching, the attribute "faster" shall be dealt with first. Electronic switching elements operate faster than electro-mechanical ones. The application of electronics is sufficiently justified if time-division switching which cannot be realized by electro-mechanical means should turn out to be the ideal solution. The higher operating speed of electronic switching elements, however, opens still a wider field of application. They permit a high degree of centralization of control equipments in systems of any kind

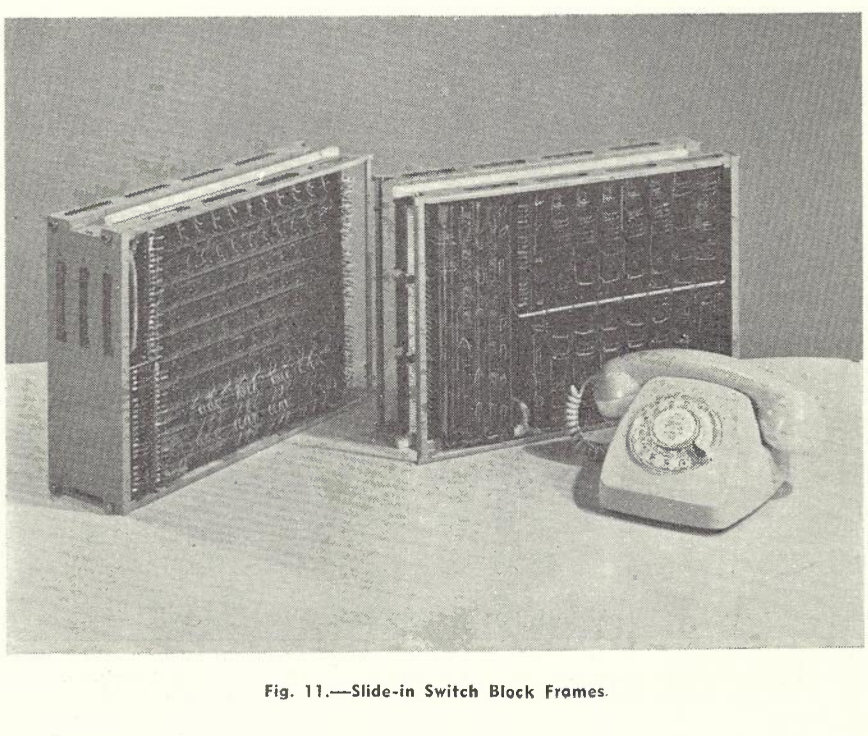


Fig. 11.—Slide-in Switch Block Frames.

because their operation is quick enough to permit control of even the largest exchange systems from one place. The risk of excessive centralization and the necessity to provide measures for limiting the effect of a fault in central equipments have already been pointed out. If quick-operating components are not more expensive than slow-operating ones, but provide the same degree of reliability without raising any additional problems (e.g., because the functions are no longer quasi-stationary), they may eventually lead to a reduction of the number of components and thus of cost. Furthermore, the application of high-speed electronic switches permits an extensive use of traffic routing to be made (with routes of first, second, etc., up to the last choice) with a consequent economy in trunk plant and reduced vulnerability in local and long distance networks. Also "re-arranging switching networks" using recurrent reassignment of the connection paths during a call in order to reduce the internal blocking of the switching network and to enable the setting up of connections which otherwise could not be put through, can only be realized by the speed of operation of electronic components.

Another argument frequently brought forth in favour of electronic switching systems is that they are "lighter" or "smaller". A comparison of the space required for several semiconductor diodes with that required for a single telephone relay shows that it is possible to construct all-electronic exchanges that require less space than conventional exchanges. Whether and to what extent this advantage has to be paid for by higher costs or the need for artificial temperature stabilization cannot yet be foreseen. It should also be taken into consideration that a saving in the bay room floor space when related to the entire exchange would only amount to a factor of 0.4 because an exchange comprises still other equipments such as the main distribution frame, etc., the size of which could not be reduced as yet. Saving of space by greater packing densities of the components (e.g., because they need no longer be accessible for adjustment purposes) may lead to "smaller" but not to "lighter" equipment necessitating adequate heat dissipation (artificial cooling?) and floor loading.

4. Some day, perhaps, "semiconductor integrated networks" (35) will offer a remedy in as much as a functional unit comprising several individual components could be considered one single component.

TABLE 2: COMPARISON OF MECHANICAL AND ELECTRONIC SWITCHING ELEMENTS

Mechanical Switching Elements		Electronic Switching Elements	
Advantages	Disadvantages	Advantages	Disadvantages
	Suitable for space-division only.	Suitable for space and time division.	
	Slow (1ms to 10 ms).	Fast (10 ms to 1 μs)	
	Number of switching operations limited (10^7 to 10^9)	Service life not dependent on number of switching operations.	
	Large space requirements.	Small space requirements.	
Little dependent upon ambient temperature.			Temperature dependent.
Good switching ratio ($\sim 10^{10}$)			Moderate switching ratio (10^5 to 10^7)
High switching capacity (10W)			Low switching capacity (10mW)

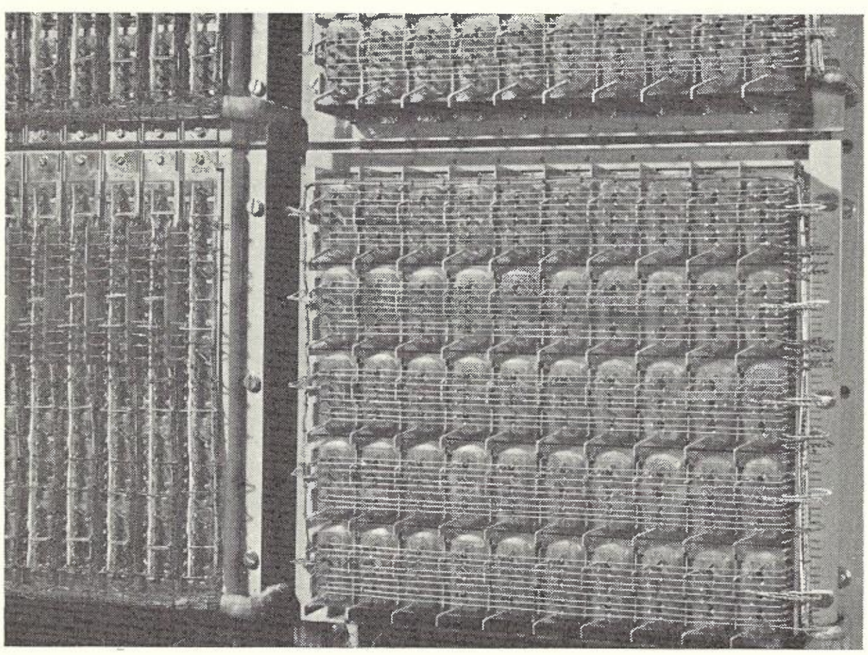


Fig. 12.—Matrix 10 x 5 of an 8-wire Link with Dry Reed Switches for Toll Registers.
Frame dimensions: 320 x 272 mm (12 19/32 x 10 11/16 in.)

Finally, electronics are often claimed to be "more reliable". Undoubtedly, electronic components have the advantage of remaining unimpaired by atmospheric influences (contact corrosion, mechanical disturbances). Apart from e.g. electron tubes, they are not subjected to wear and tear and require no adjustment in the field. They even cannot be re-adjusted, thus excluding any maladjustment. On the other hand, when changing to electronic solutions there is an obvious increase in the number of components required per line[4] which in part cancels the advantage inherent to electronic media as the failure liability increases with the number of components. Present-day modern switching systems—e.g., using crossbar switches—have already attained such a high degree of reliability that it will not be easy to compete with them or even surpass them in the future.

Electronic switching has the advantage of being highly suited for automatic production while electro-mechanical systems always require a large proportion of highly paid manual labour. With continuously rising labour costs, conventional systems may thus become so expensive that the still high-priced electronic systems will then offer real price advantages. This is certainly a positive feature of the electronic solutions. Moreover, changing to electronic systems would include the advantage that identical components, equipment practice, and manufacturing methods

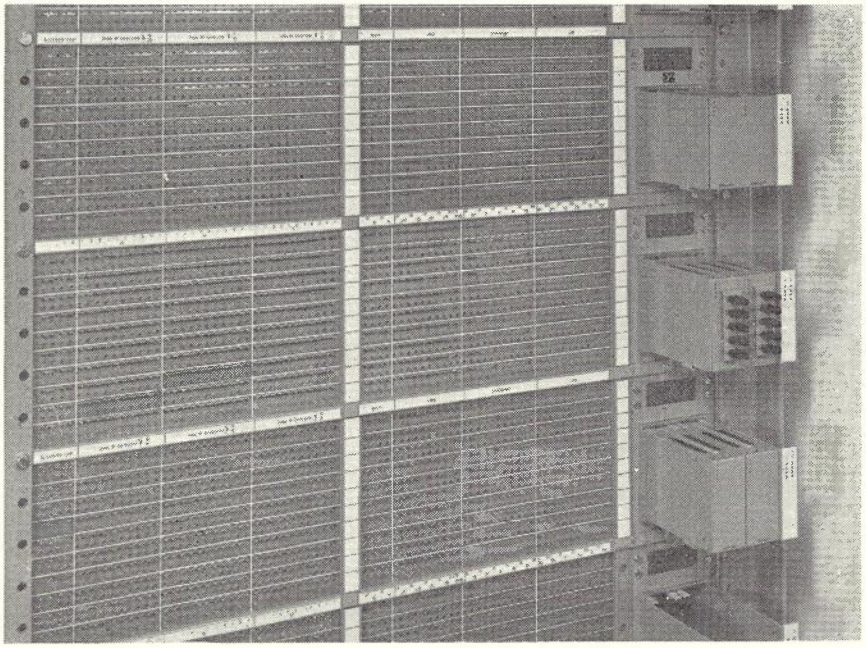


Fig. 13.—Close-up of a Quasi-electronic Central Translator for Subscriber Long Distance Dialling. The Slide-in Panels house the Coincidence Circuits incorporating Dry Reed Switches.
Panel dimensions: 45 x 90 x 126 mm (1 49/64 x 3 35/64 x 4 31/32 in.)

for the three main branches of communication, i.e., switching, transmission and information processing, may be used, which in the long run will have a favourabe influence on costs.

Unfortunately, the fully electronic solutions for telephone switching have also some drawbacks (at least with the presently known components) at the very switching element, i.e., at the point where the speech paths are connected. In Table 2, the advantages of electronic switching elements are compared to these difficulties. The switching ratio of electronic switching elements being poorer by several orders of magnitude introduces considerable cross-talk attenuation or insertion loss problems. Since a decrease of the cross-talk attenuation is not admissible in order not to violate the privacy-of-conversation principle or impair the transmission quality, this handicap usually is overcome by admitting a somewhat greater insertion loss than in electro-mechanical switching systems. Theoretically, this increase of attenuation can be compensated for by amplifiers. Sometimes the switching element itself has a negative differential resistance (36, 37). Unfortunately, each amplification introduces temporary gain variations (due to temperature response, supply voltage fluctuations and ageing of components) so that, on account of the required singing margin, it has not yet been possible up to now to attain the low attenuation values used in electro-mechanical crosspoint elements. Fig. 6 shows the attenuation curves of an electro-mechanical and an electronic exchange. This increased insertion loss may be insignificant for a single exchange; however, conflicts with the internationally accepted attenuation plans are to be expected if in the future several or all exchanges in a connection will have the same increased attenuation values. The required reduction of attenuation could incidentally be effected in the subscriber's station, particularly if the latter has to be equipped with an amplifier because a better but less sensitive microphone is provided. However, the increase of the near-end cross-talk will set a rather close limit to this method of improving the attenuation conditions.

Besides the poorer switching ratio of electronic crosspoint elements, the power handling capacity being likewise poorer by some orders of magnitude is unsatisfying, too. As a result of the lower power handling capacity it is no longer possible to transmit high-power ringing current through the exchange switches. Therefore, voice frequency ringing (38, 39) mostly is provided in fully-electronic systems, i.e., the subscriber is called by means of a voice frequency within the level range of the speech signals. The voice frequency is amplified in the subscriber station and applied to a loud-speaker. This means that the introduction of such systems also requires a new and more expensive subscriber station.

In a developing art such as semiconductor elements, rapid development of new techniques and components with improved characteristics is to be expected, so that an early conclusion should be avoided.

QUASI-ELECTRONIC SOLUTIONS FOR SWITCHING SYSTEMS

The problems arising with full-electronic crosspoint elements as described in the preceding section suggest the idea to examine whether the manifold advantages of electronic switching circuits could be exploited in a system approach using at the critical spot of the crosspoint an electro-mechanical element because of its superior switching ratio and power handling capacity. (Of course, the low switching speed of electro-mechanical components unfortunately then excludes the application of time-division solutions.) This would be a promising solution if there were an

TABLE 3: CHARACTERISTICS OF SWITCHING ELEMENTS

Switching element	Open: Sliding contact	Open: Pressure contact	Sealed reed switch	Gas tube	Semi-conductor element
System	semi-electronic		quasi-electronic	fully-electronic	
Speech transmission	good	good	good	moderate	moderate
Joint use for control circuits	good	good	good	bad	bad
Temperature sensitivity	no	no	no	high	high
Operating speed	slow	medium	high	high	unnecessarily high
Atmospheric influence	great	great	no	no	no
Reliability	medium	high	very high	very high	very high
Working life	medium	long	very long	very long	very long

electro-mechanical crosspoint which also incorporates the advantages of electronic components such as insensitivity to atmospheric conditions, automatic mass production, freedom from adjustment and maintenance.

Such a component is the dry reed switch[5] (18-20) developed by the Bell Laboratories. It combines the good switching performance of a mechanical switch with high reliability and insensitivity to atmospheric conditions, needs no servicing, has a long service life and can also be manufactured in automatic mass productoin. Fig. 7 shows this and other essential components, i.e., transistor and diode, of a quasi-electronic system.

Table 3 shows that the characteristics of the dry reed switch compare very favourably with those of other components used as crosspoint elements in space-division systems. Concerning its working life and switching speed reference is made to Fig. 8 which shows by the example of a crossbar type PABX for 100 extensions that, though 75% of all contacts of the system belong to the switching network, these contacts carry out only 3% of the contact operations within 25 years of service. Since the reed switch is able to perform 10^8 to 10^9 switching operations in a properly dimensioned circuit, it meets the life requirement for this application. The low number of switching operations also shows that no particular requirements need be made regarding the operating speed of the component. Thus, the operating speed of the dry reed switch (switching time 1 to 2 ms) is quite sufficient for this switching function in a space-division system.

The above statcment explains why such switching systems which, due to the reasons cited above, certainly may be classified as "quasi-electronic", are being studied by several laboratories. Among others, German and American telecommunication firms as well as the British Post Office in co-operation with the industry (20, 27, 28, 30, 40) are engaged in these projects. In spite of the use of the same type of components, quite different solutions are obtained. Fig. 9 indicates some possible lines of approach.

Fig. 9a shows the crosspoint elements arranged in a matrix. By simultaneously switching on a vertical and a horizontal coil, each providing half of the required operate ampere-turns, the crosspoint to be operated is marked by magnetic coincidence.

The switching matrices of Fig. 9b and 9c contain individual coils to be controlled, e.g., by means of an access matrix consisting of diodes. An electrical excitation (9b) or a built-in permanent magnet (9c) keep the crosspoint elements in actuated condition. The interconnection can be cancelled by interrupting the holding circuit or by applying a reverse pulse. When the second method is used all crosspoints engaged in the establishment of the connection have to be addressed once more to be restored to normal by a de-marking procedure. This introduces some difficulties when applying the so-called "end-marking technique" (41).

Finally, Fig. 9d shows an arrangement in which the dry reed contacts of the crosspoints are actuated by means of a bistable magnet (20) which is triggered by a current pulse to the desired direction. This principle may be modified in different ways. If the bistable magnet can bc triggered by a very short pulse, then the arrangement simultaneously functions as a "time transformer": A pulse of the order of microseconds triggering the magnet causes the reed contacts to operate after a lapse of time of the order of milliseconds, so that even relatively slow crosspoint elements can be connected to high-speed central control equipments. In this case, too, a de-marking process has to be initiated to release the crosspoints.

Switching relays (42) and crosspoint elements (43) were created by using the aforementioned reed contacts. By simply combining an excitation coil with a permanent magnet a "break relay" is obtained. The reed contacts are held in make-condition under the action of the permanent magnet and are opened, when required, by the cancellation of the permanent magnet field with the aid of an opposing electric excitation. Fig. 10 shows a (four-wire) crosspoint element and a 10-point mounting strip for housing the crosspoint elements. (Screening plates are required only for control duties, but may be omitted in switching grids because two adjacent coils never will be simultaneously energized.) These crosspoint strips are then combined—also together with electronic control media — in plug-in panels to form switch blocks (Fig. 11).

(These components and their arrangement, incidentally, have proven successful in several years of operation in some SEL equipments designed for use in the German subscriber long-distance dialling network. Fig. 12 shows the switching matrix of a register hunter with 8-wire crosspoints and Fig. 13, a close-up of a quasi-electronic central translator (44) for deriving the charging and routing information from the local network code).

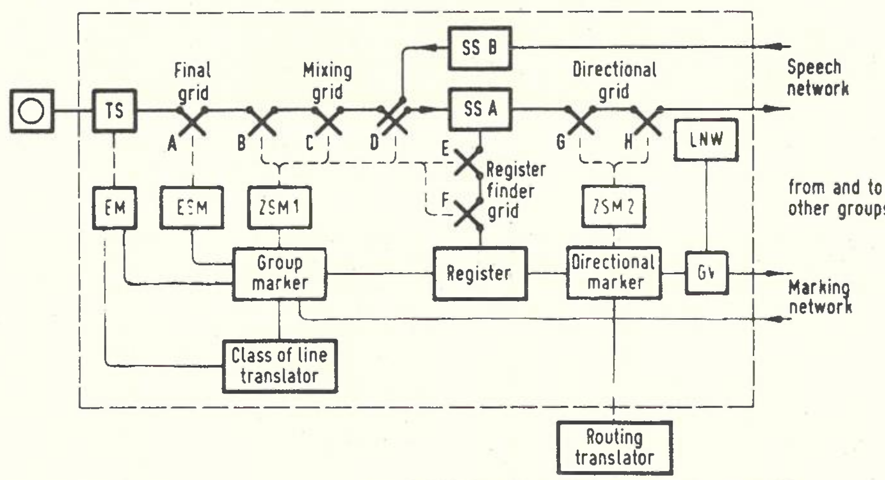


Fig. 14.—Trunking Arrangement of a 2,000-line Group of the Proposed System HE 60.

TS—Subscriber circuit; SSA—Feeding at A; SSB—Feeding at B; EM—Final marker; ESM—Final stage marker; ZSM—Intermediate stage marker; LNW—Guide network filter; GV—Group connector

Fig. 14 shows the layout of a 2,000-line group of the system proposed. This is a register-controlled link system in which no relationship between switching stages and the digits of the directory number exists. Within such a group of 2,000 lines, operations are performed on the one-at-a-time principle. The number of lines of such groups was not limited to 2,000 due to the switching speed of the central control equipment (the mixed use of electronic switching media and dry reed switches in the control circuits permits serving of even larger groups) but solely by the safety requirements. If several 2,000-line groups are provided then it will be possible to establish one incoming and

EXAMPLE OF A QUASI-ELECTRONIC SOLUTION

Some details of the system concept HE-60 of SEL shall be given in the following to facilitate an understanding of quasi-electronic switching systems. An experimental exchange based upon this principle will soon start operation in Stuttgart.[6] It is also planned to install a similar exchange in Vienna.

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5. The dry reed switch manufactured by SEL is sold under the registered name "Herkon" (hermetically sealed contact).

6. The exchange was cut into service in July, 1963, with 500 subscribers connected and following satisfactory performance, is now being extended to 1,500 lines capacity. After more than ten months of operation, neither a total breakdown nor a failure involving a large number of lines has occurred. So far the following troubles have been recorded: 1 wire break (caused during expansion work), 2 diode failures (wrong type diodes installed), 1 short circuit in wiring (manufacturing defect), 1 transistor failure (caused during expansion work), 3 sealed reed switch failures (two of them presumably caused by the above transistor failure in conjunction with a manufacturing defect). The only effect these failures had was that the duplication became effective. The operation of the trial exchange was not affected.

one outgoing connection for each group at the same time.

Incoming connections from other offices are handled in arrival groups which are somewhat simpler in design and comprise separate registers.

A subscriber lifting his handset is connected via the concentration stages A, B, C, D to a feeding circuit A for outgoing calls and via the register finder grid (switching stages E, F) to a register from which he receives dial tone. He dials into this register which, as soon as sufficient information is available, establishes the connection to the desired outgoing direction via the directional grid (switching stages G, H) by means of a directional marker. Incoming connections from other groups are handled with the aid of the directional marker of the originating group and the group marker of the destination group, the group connector GV linking the two markers in the marking circuits.

The establishment of connection through the various switching stages is based on the "conjugated selection principle", i.e., a link to a following switching stage is only seized if completion of the connection up to the destination is ensured. This will be illustrated in Fig. 15 by the example of a three-stage concentration arrangement with 16 inputs and 6 outputs, assuming that the full-line trunks are seized. A connection to any one output is requested from the input marked I.

In case of unconjugated selection (Fig. 15a) the selector of the 1st stage rotates to the first free outlet and seizes the associated link. The connection, however, will be stuck because the selector connected to this link cannot find a free outlet. The routes on which a free outlet might have been reached if the selector of the first stage had not seized the first free line, are shown by dashed lines. Thus unconjugated selection results in high internal blocking which can only be compensated for by a corresponding amount of crosspoints.

The principle of conjugated selection can be realized in different ways. In the system HE 60, use is made of the so-called guide wire. This is an additional marking lead which is run parallel to all links without, however, passing through the crosspoint-elements, i.e., without increasing the number of leads to be switched. To connect the input marked I in Fig. 15b with any one output, an "offering signal" is applied to the guide wire on the input side which is transmitted in fan-like shape via all free links to the outlets. On the output side, any one of the outlets marked free can be selected and marked by a "catching signal". In the example given, the always-the-lowest-route principle is assumed. The catching signal causes a selecting procedure (in this case: "the lowest link marked by an offering signal"), to take place in the marker of the respective switching block of the last switching stage, thus determining one specific return link. The process is repeated up to the input of the switching section so that eventually the "offering signal fan" is reduced to one single route and a connection is established without any negative attempt, provided that a connection possibility was existing at all.

Fig. 16 shows a schematic diagram of a switching block and the function of the guide wire. The offering signal is fed as negative potential from the left to the guide wire m′, regenerated in an offering amplifier and applied in parallel to the guide wires m″ of all links leading towards the right side. Seized links suppress the offering signal by grounding the guide wire. A catching signal of positive potential coming from the right effects connection of the stage marker to the respective switch block of this stage by means of relay B. The marker then selects, if offering signals on several guide wires are available, a specific guide wire and marks it in turn by applying the positive catching signal. The combination of guide wires marked from the right with those marked towards the left determines the crosspoint to be operated. Through-connection of the respective speech and auxiliary wires is then effected by the cross-

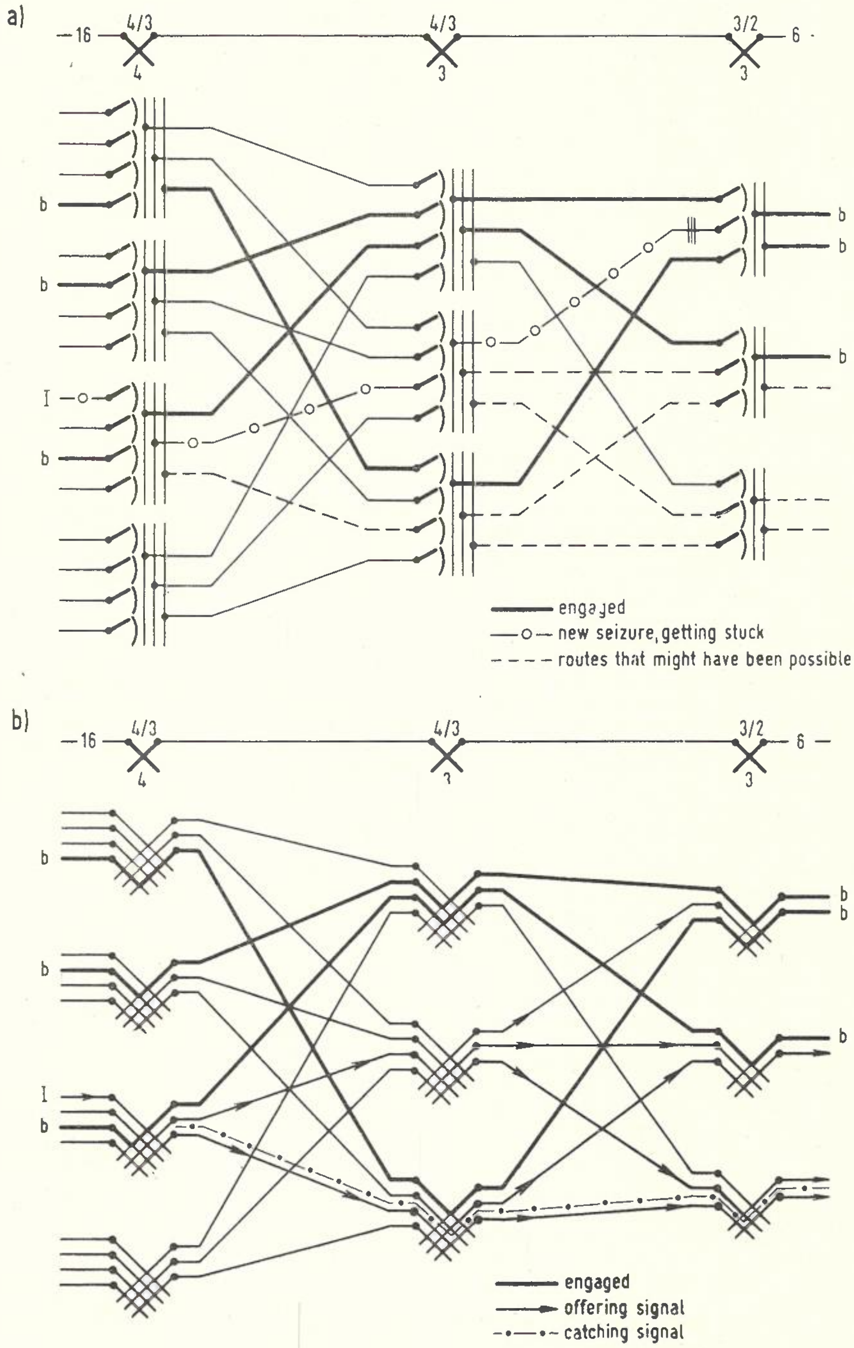

Fig. 15.—Examples (a) for Unconjugated Selection, (b) for Conjugated Selection According to the Guide-Wire Principle.

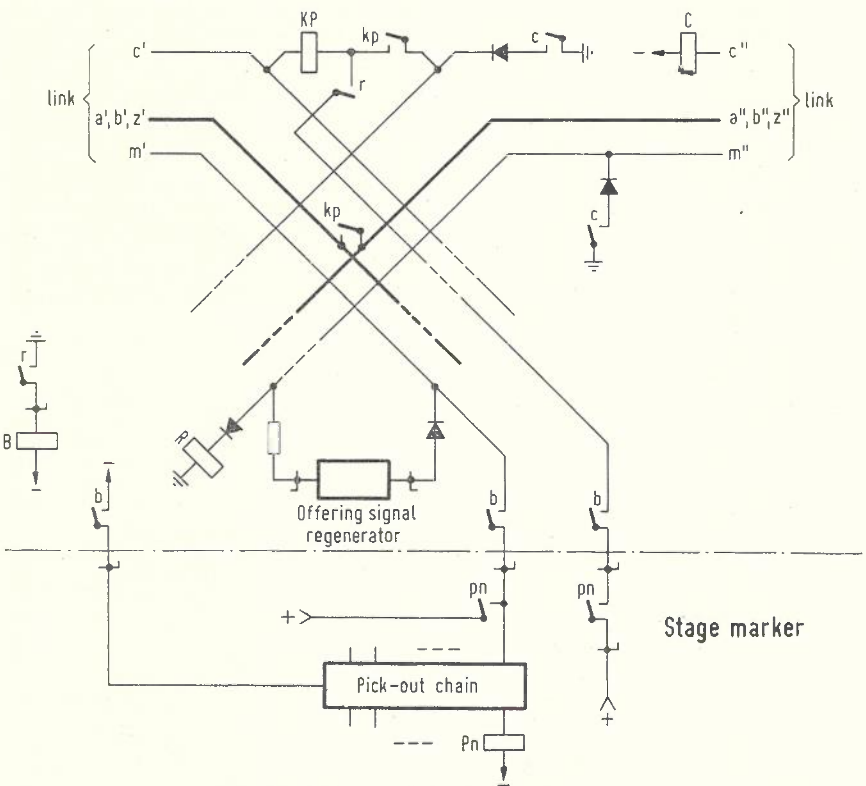

Fig. 16.—Switching Block—Simplified Diagram.

point without pressure of time. The crosspoint holds itself in the c-wire via a holding contact until it is released again by the breaking of the c-wire.

The class-of-line translator provided for each 2,000-line group (Fig. 14) furnishes information relating to particularities of a line (blocking, transfer, classes of authorization, PBX numbers, etc.) while the routing translator derives the desired direction, or an alternative route, from the dialled number and communicates this information to the register.

To ensure reliable operation of a 2,000-line group, among others the following measures are taken:

For the switching stages B, C, D of the concentration grid and E, F of the register finder grid, two common intermediate-stage markers ZSM 1 are provided (Fig. 14) which have access to half of the switch blocks of each switching stage. Failure of one of the markers, which will be signalled, may cause a reduction in traffic capacity but will never result in complete failure of a specific subscriber group. Similiarly, the intermediate-stage marker ZSM 2 serving the directional switching stages G and H is duplicated. In the end stage A two end-stage markers ESM interwork in such a way that one serves the even numbered hundred-line groups and the other the odd groups. In case of failure of one marker the second marker will serve all hundred-line groups.

The group marker which assigns a register to a calling subscriber and directs the incoming traffic to the wanted subscriber, and the directional marker which controls the outgoing (within the calling group, to other groups, or to another office) are duplicated in such a way that even all access contacts and access multiples are available twice. Normally, the marker and its standby operate alternately. In case of a failure in one marker the other marker takes over the whole load without loss of traffic capacity, thereby initiating, of course, an alarm. The fault signals are obtained from the supervision of error detecting codes and by time allowances for the individual switching functions. Moreover, at each establishment of connection, the marker tests whether all leads to be switched through are free of potential up to the last switching stage, and that they carry a specific potential after reaching this stage. If any particular test circuit fails to respond, a fault signal will be initiated.

In case of trouble, the information relating to the switching elements involved in the particular connection is fed into a "data memory" (Fig. 17). As soon as a fault signal appears, the respective switching condition is held for a few milliseconds to permit the numbers of the markers, links, etc., concerned to be recorded in this memory, which then may pass them without hurry to an indicating panel, printer or perforator. It is expected that by means of the information recorded, fault localization will be considerably facilitated.

NEW SERVICES

As has been mentioned above, the expected fundamental change in telephone switching offers an opportunity to examine the list of performance characteristics and to consider whether new telephone services are desirable. In doing so the change as such is essential, but not the expected more or less intensive transition towards electronics. And that all the more so as apparently all conceivable new services for the subscriber can also be realized technologically by the present-day modern systems, e.g., the crossbar systems. (Perhaps in some cases electronic switching systems will offer, however, less expensive solutions.)

From a technological point of view, the dream of a "television telephone" could have been realized long ago. The economic difficulties, however, accruing from the necessary modifications in the exchanges and the required bandwidth on the subscriber, local and long distance lines will prohibit a general introduction for a long time.

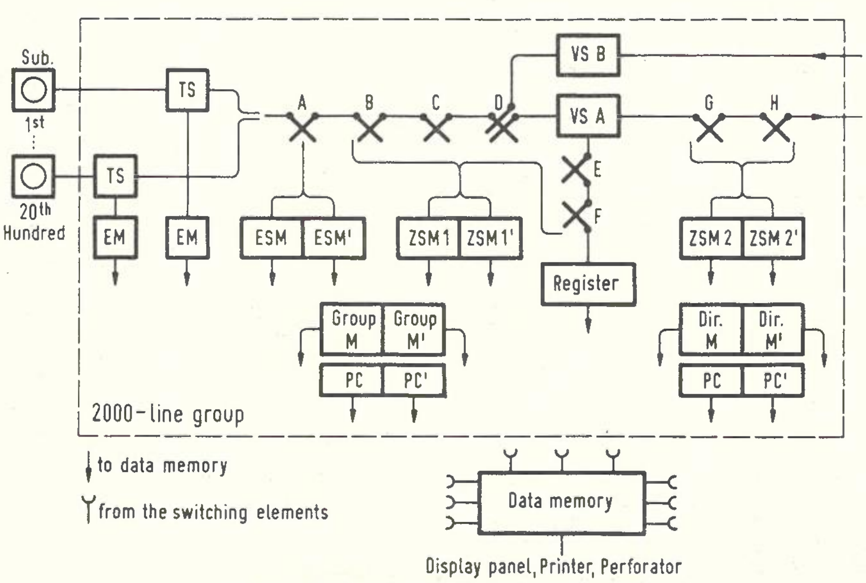

Fig. 17.—Storing of Data for Fault Localization.

The establishment of connections between more than two parties, the "telephone conference" (Fig. 18a), would offer some advantages to the user. Difficulties concerning tariff regulation, message accounting and attenuation conditions are to be expected.

The user should not only be able to freely decide to have a telephone installed, he should also be given an opportunity to put his telephone temporarily out of operation if he does not want to be disturbed. A "telephone pause" (Fig. 18b) could be signalled to the callers by a tone signal, if necessary with the announcement "called subscriber absent" or the calls could be transferred to an information position. The subscriber wanting to initiate a "telephone pause" dials a predetermined code number, for instance, which starts the necessary switching functions, and another code number for cancelling this condition. Since modern switching systems usually include identification of the calling subscriber an abuse of this facility may easily be prevented. Another solution would be to suppress, e.g., the first five rings if the telephone pause feature is effective at the called subscriber.

This condition is signalled to the caller by a distinctive ringing tone who then may replace the handset. However, if he thinks the call important enough to justify a disturbance he permits the ringing condition to continue. The 6th and the following rings actuate the bell of the wanted subscriber while the caller now receives normal ringing tone. The disadvantage of this solution of the telephone pause is that it requires the introduction of a new audible signal while persons not very familiar with the telephone are not even able to distinguish the presently used signals correctly.

Another feature which might be called "visitor's service" (Fig. 18c) (10, 45) effects, after initiation by the subscriber (dialling of a code number and a directory number), that all arriving calls are transferred to that last dialled subscriber's number, e.g., that of a friend to be visited. This feature may also become effective if the called subscriber is busy or if he does not reply after a predetermined lapse of time. Many variants are conceivable. If, however, this visitor's service should be extended beyond the local exchange area of the subscriber concerned, then the attenuation problems will become critical.

Often it is annoying if the called subscriber is found busy again and again although he probably would prefer to interrupt the existing conversation if he knew that a third party was calling. This problem could be solved by a "knocking" feature (Fig. 18d) in such manner that an audible "knocking signal" is transmitted to the conversing parties if a third party has dialled the number of one of them. The caller would receive a special busy tone for a predetermined time (say 10 seconds) giving the conversing parties the possibility to terminate their conversation in favour of the new call. The "new" connection will then be established right away. If the conversing parties do not terminate the conversation within the predetermined time, a change from special to normal busy tone advises the caller to replace the handset. Unfortunately, this service, too, cannot be realized without introducing new audible signals.

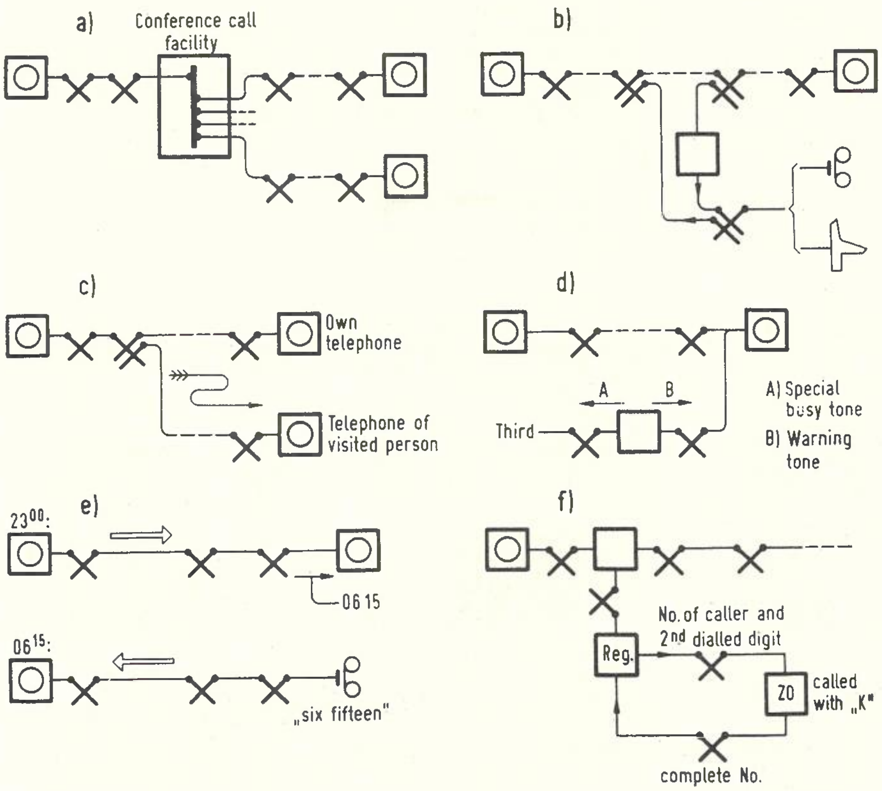

Fig. 18.—Proposed New Services: (a) Telephone conference, (b) Telephone pause, (c) Knocking, (e) Automatic waking, (f) Abbreviated dialling.

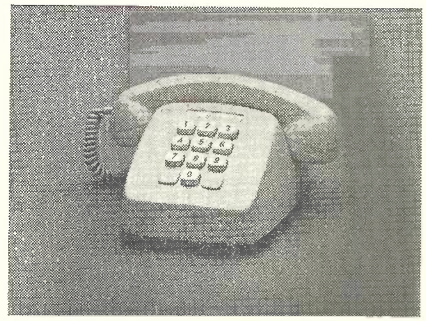

Fig. 19.—Push-Button Telephone Station.

An "automatic call-to-rise feature" (Fig. 18c) could be realized in such manner that the subscriber dials a service number and, after reception of the answer signal, selects hour and minutes he wants to be waked by means of his dial. The facility then takes care that the subscriber — whose calling number had been ascertained by the call-to-rise service—is automatically called at the specified time, e.g., by the speaking clock. In an expanded version, the subscriber could be enabled to record a message or text which will be talked back to him at the desired time.

It would also be possible to create a group of "priority subscribers" whose requests for a connection rank before normal subscriber calls. If a priority subscriber encounters a busy trunk group or subscriber, a waiting condition is set up for a limited period of time. As soon as a trunk or the wanted subscriber becomes free, the waiting priority subscriber is handled with preference. This type of service requires the identification of the origin (class of authorization) over the whole connection path. As variants, permanent and temporary priority (push-button operation in response to busy tone) could be conceived. The problem of charging priority subscribers could be solved by a special fixed fee, or better still—as it becomes effective only during the time this facility is used—by means of a higher metering pulse rate, e.g., doubling the pulse periodicity. The provision of a priority facility might also contribute to compensate, to a certain degree, the need of authorities, etc., for special networks.

Of special interest is the problem of "push-button selection" (46), which will replace the slow-operating dial by a keyboard (Fig. 19). The progress consists not only of a more convenient and quicker input of dial information but also and primarily, when used in conjunction with high-speed switching elements, of a considerable speeding-up of the establishment of connection. It may be expected that the conversion from dial to push-button selection will entail an improvement ratio of 1 : 4 for short numbers, and still of 1 : 2 for long numbers, with respect to dialling time and — in conjunction with high-speed switching media—also to switching-through time (Fig. 20). The telephone user would not benefit from the high operating speed of the proposed new switching systems if the duration of establishment of connection continued to be dependent on the slow-operating dial. Besides the advantages for the subscriber, push button selection also contributes to reduce the holding time of the lines and exchange equipment, particularly of the registers.

Another interesting feature might be the "abbreviated dialling" (9, 10). It enables any telephone user given this class of service to fix several frequently used subscriber's numbers (local or long distance) which he then may reach by two-digit numbers. Lest no directory numbers will be lost in the local network it is recommended to give the criterion for abbreviated dialling either by a train of eleven pulses (dial selection) or by an eleventh key (push-button selection) (Fig. 21). When marking the eleventh hole of the dial or the eleventh key by the letter K, the eleven calling numbers K1, K2 to K9, KO, KK are available for such short numbers. Operational studies showed that by means of eleven numbers a considerable portion of the telephone traffic can be covered. In addition to a simpler dialling procedure, abbreviated dialling provides in conjunction with modern and fast operating exchanges the additional advantage[7] of substantially reducing the time required for the establishment of a connection, which not only conveys more comfort to the subscriber but also results in reduced holding times for registers and subscriber lines.

The abbreviated dialling feature may be realized according to Fig. 18 f: After identification of the abbreviated dialling criterion (1st digit = K), the register calls in a translator which determines, from the calling subscriber's number and the 2nd digit, the complete number of the required subscriber and conveys it to the register.

7. Also compared with so-called auto-dials installed at the subscriber's premises.

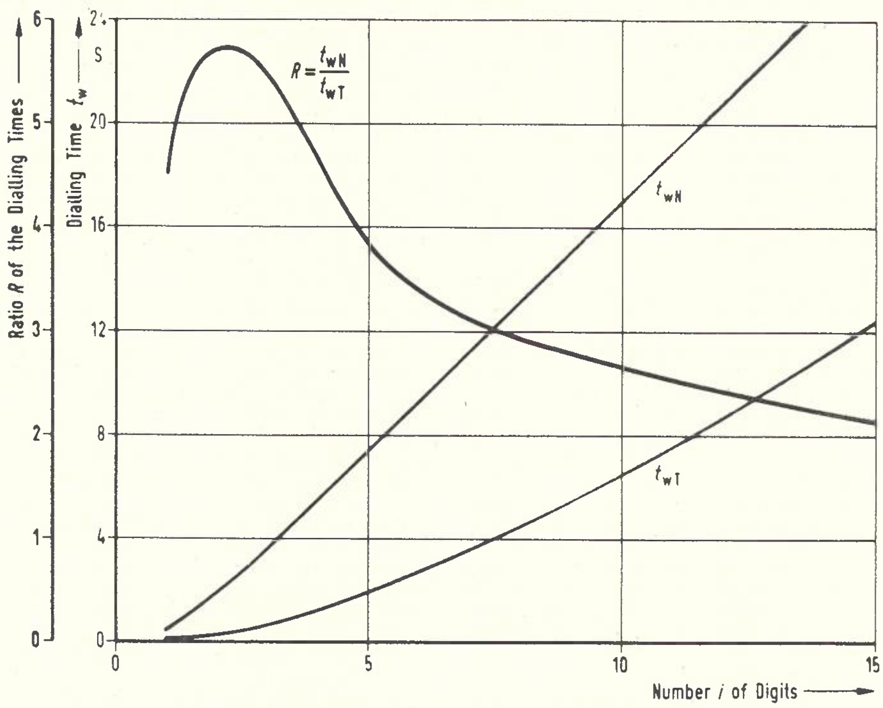

Fig. 20.—Increase of Operating Speed by Push-Button Selection.

OUTLOOK

Obviously it is still too early to try to find an answer to the question what the switching system of the future will be. The variety of development work under way at different places shows that up to now no specific system has established a clear superiority. For this reason the alternatives: space- or time-division and quasi- or fully-electronic solution, have been compared in this paper, and attention has been drawn to some points of particular interest for the appraisal of systems, as they are not directly obvious in a comparison of cost, space requirements, efficiency and reliability.

It is to be welcomed that in the near future a number of experimental exchanges using different techniques will be built. This will offer a possibility of studying the various concepts and comparing them. These comparisons, however, must not be restricted to clearly measureable values (cost, current consumption, space and maintenance requirements) but should also cover those properties which cannot be expressed by figures (differing performance characteristics, complexity of system). Fortunately, there are telephone switching systems available today (e.g., crossbar switching systems) of such a high quality that there is no need to expedite the development. Designers all over the world appreciate the opportunity of letting their plans mature quietly.

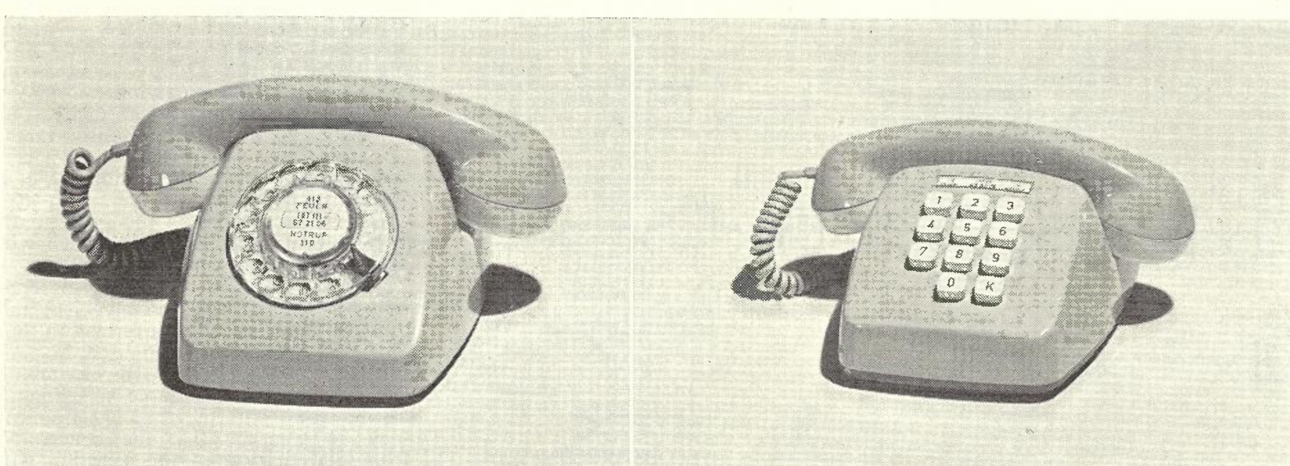

Fig. 21.—Dial and Push-Button Keyboard for Station with Abbreviated Dialling Facility.

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CROSSBAR TRUNK EXCHANGES FOR THE AUSTRALIAN NETWORK—PART 1.

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Editorial Note: Part II of this article will appear in the February, 1965 issue and will deal with Charging Requirements, Traffic Characteristics, Registers, Line Relay Sets, Special Facilities and other aspects.

INTRODUCTION

The use of crossbar trunk exchanges in the Australian telephone network is a natural outcome of several decisions which were made a few years ago. These included the decision to adopt a common control system for the switching of telephone traffic, the decision to push on with and accelerate the move towards nation-wide subscriber trunk dialling, the decision to adopt a crossbar switching system, and later, after consideration of the equipment available at that time, the decision to use and manufacture in Australia the L M Ericsson types of exchange. References 1 to 9 cover the reasons for these various decisions in much more detail.

Initially the emphasis was on the development of local switching systems. One of the most urgent problems confronting the Department at that time was the need to meet the situation in the Sydney and Melbourne metropolitan networks where 7 digit working using conventional step-by-step exchanges was increasing and where the whole local switching system was becoming increasingly inflexible and costly. It was decided to use L M Ericsson ARF 102 type crossbar for the larger automatic exchanges in Australia both for new exchanges and for extensions of step-by-step exchanges. Because the policy of the Australian Government is to manufacture in Australia as much as possible of the switching equipment we require, it was also decided to manufacture the ARK 51 and ARK 52 exchanges in Australia for use as small terminal exchanges and to discontinue the production of bi-motional switching equipment.

It was always envisaged that crossbar trunk switching equipment would also be introduced to permit nation-wide subscriber dialling with a nation-wide unique numbering scheme, and the equipment covered by Australian Post Office Specification No. 959 (10) and described in this article will meet this need.

Since 1938 motor uni-selector exchanges together with 2 VF signalling equipment have been used to provide single operator dialling in the trunk network, particularly in the period from 1950 onwards. During the decade following 1950 trunk traffic approximately trebled without a very significant increase in the number of trunk operators.

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The use of ARM equipment of L M Ericsson design is now proposed, and growth in the trunk system will be catered for by circuits and switching equipment over which the subscribers may establish their trunk calls directly to the maximum extent possible. Although some subscriber trunk dialling equipment is already in use, the rate of introduction of subscriber trunk dialling will now be greatly increased, and the current target is for 66% of all trunk calls to be subscriber dialled by 1975. Although this will involve a considerable outlay in capital, it is expected that this can be achieved without substantially greater investment either in trunk or trunk switching plant and with a very great saving in the number of operators required to handle calls. This is in line with the estimates and experience of all other major Administrations in the world.

In particular, it is estimated that the capital investment required in trunk switching equipment during the next 10 years will be of the order of £43,000,000 to provide subscriber trunk dialling. To continue with present equipment would cost approximately £31,000,000, but by 1975 there would be an additional 13,500 operators (there are approximately 9,000 at present) and assuming steady growth over the 10-year period, the additional operator wage costs would be of the order of £65,000,000 to £70,000,000. The expected savings, coupled with the fact that Australia is growing in the economic sense at a very rapid rate and has for some years enjoyed full employment conditions make it imperative to proceed with this trunk mechanisation in order to assist in a national objective of using mechanisation to the maximum extent possible to permit the best use of our limited labour resources.

EQUIPMENT SELECTED

Although variations in detail in these exchanges have been negotiated, the basic design of the two types used is that of the L M Ericsson ARM 20 and ARM 50 exchanges. (A block diagram of the ARM 20 Trunk Exchange is shown in Fig. 1.) Generally speaking the ARM 50 exchange will be suitable in Australia for exchanges requiring not more than about 1,000 trunk terminations in the 20-year period. The current trunk growth rate is as high as 10-12% per annum so that unless we are prepared to replace the switching equipment within the 20-year period, the ARM 50 exchange can only be considered for exchanges with an initial capacity of the order of 100-120 trunk lines. The ARM 20 exchange on the other hand can cater for exchanges having of the order of 4,000 to 8,000 trunk terminations depending on the proportion of both way circuits used. On this basis the ARM 20 will be used at main and primary switching centres and the majority of secondary switching centres also. At some of the smaller secondary centres the ARM 50 exchange will find application and also at some of the minor switching centres. It is proposed that some of the minor switching centres should use ARF 102 equipment slightly modified to provide 2 wire transit switching facilities, but if charge determination requirements are at all complex then an ARM 50 will be provided. Alternatively, the trunk traffic will be switched via the next higher order switching centre.

Because of the relative complexity of the task performed by the ARM exchange the switching cost tends to be high. It has been found economic in many cases to convert exchanges which previously had minor switching centre status to terminal exchanges, particularly where the centre concerned is connected by a V.F. trunk cable to the next higher order switching centre. This trend is a logical outcome of the general tendency in recent years for the bearer costs to decrease relative to the switching costs.

SWITCHING REQUIREMENTS

The ARM switching system as supplied for the Australian network will provide for the following:—

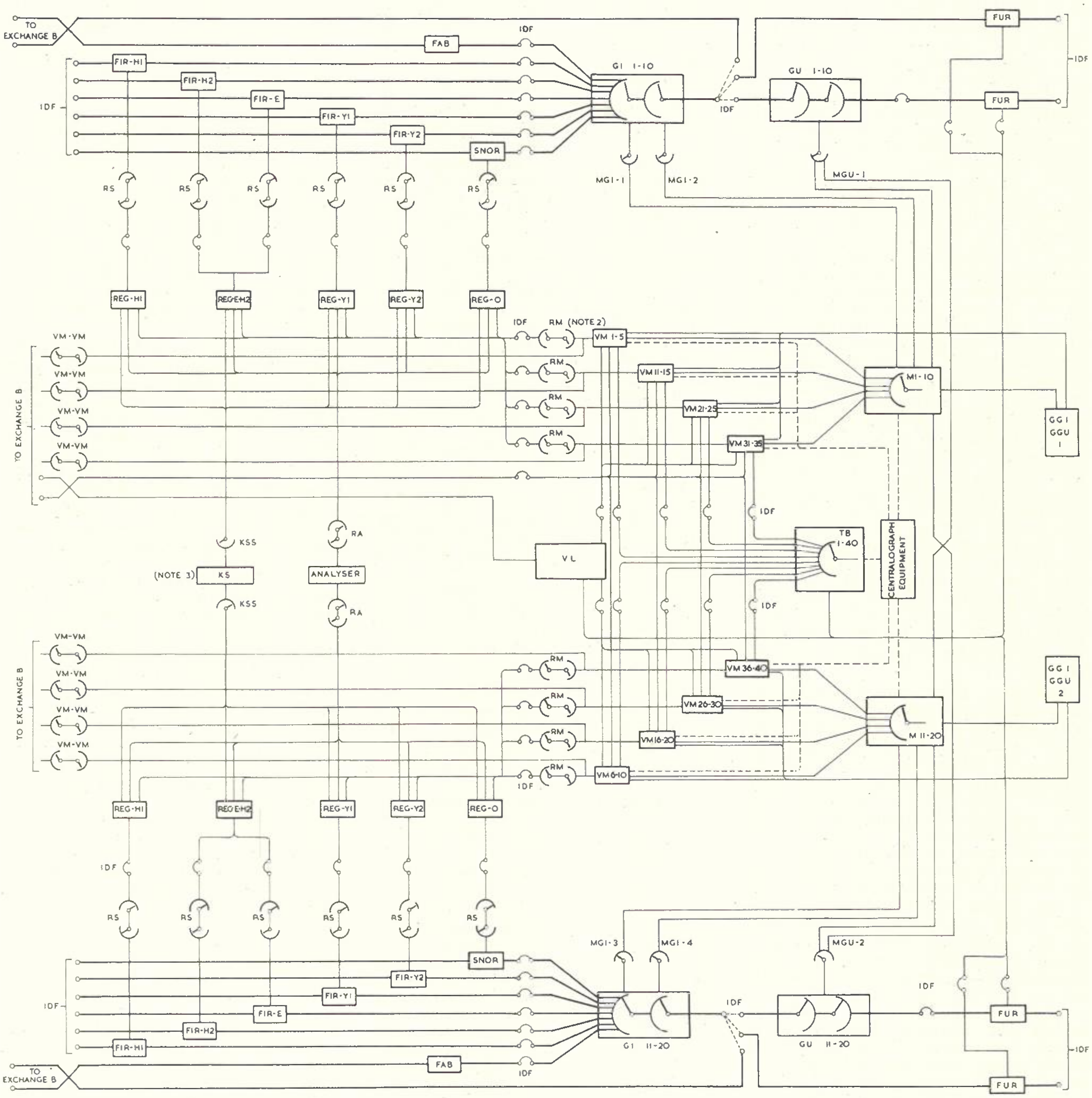
4-wire Switching: The present operator dialling network employs 4-wire switching but of the tail-eating type which was appropriate because of the higher proportion of 2-wire lines existing at the time of its adoption. In the ARM equipped network directional 4-wire switching, sometimes called true 4-wire switching will be provided.

Bothway Circuits: In the Australian network there are many routes on which a relatively small number of trunks will be provided and economic bearer provision dictates the use of bothway circuits. In addition, the use of bothway circuits as well as unidirectional circuits on the larger routes gives a reduction in the total number of circuits required and has an additional advantage in those cases where the traffic peaks in the two directions do not coincide.

Provision for Variable Availability: Although the numbers of trunks on some of the major routes will be such that full availability cannot economically be provided, there are many other routes on which a relatively small number of circuits will be provided. The equipment, therefore, provides for many increments in availability on outgoing routes, from as low as 4 up to as high as 90 outlets per route.

Alternate Routing: To provide for economical use of bearers and a minimal use of switching equipment, direct routing will be used to the maximum extent possible. High usage routes will be provided where there is sufficient traffic to justify this, and the ultimate grade of service will be provided on the backbone route structure. The normal rules governing a hierarchical switching system will be used.

Provision for both Local and National Numbers: The National Telephone Plan for Australia envisages the use of local numbers of 7, 6 or 5 digits, trunk area codes consisting of zero plus 1, 2 or 3 digits, respectively, and national numbers made up of the local number prefixed by the area code, giving a maximum number length of 9 digits. The local number is used within a defined numbering area and the national number is used for calls beyond this area. In general, the whole of the number dialled will be forwarded through the trunk network at least to the point of entry to the closed numbering area of the called subscriber. From this point the trunk prefix may be omitted, and the local area number will be handled in the same way as if it had been dialled within the terminating area.



NOTES:-

1. SHOWS TRUNKING AND COMMON EQUIPMENT REQUIREMENTS FOR AN EXCHANGE OF MAXIMUM CAPACITY 4000 INLETS AND 4000 OUTLETS.
2. EACH GROUP OF RM's IS CAPABLE OF CONNECTING 50 REGISTERS TO 5 ROUTE MARKERS.
3. THE CODE SENDERS KS MAY FORM A COMMON GROUP WITH THOSE IN AN ASSOCIATED ARF EXCHANGE.

ABBREVIATIONS.

GI INCOMING GROUP SELECTOR STAGE
GU OUTGOING " " "
M MARKER
VM ROUTE MARKER
TB TEST BLOCK
VL FREE MARKING RELAYS FOR ROUTES
GGI/GGU COMMON GROUPS.
FAB JUNCTOR FOR CONNECTING EXCHANGE A - EXCHANGE B

Fig. 1.—Block Diagram of the ARM 20 Automatic Trunk Exchange.

Digit Re-insertion: Where access to the trunk exchange has been gained via step-by-step equipment, some digits will already have been absorbed in gaining access to the trunk exchange. To avoid ambiguity in switching it is necessary for the incoming register in the trunk exchange to re-insert the digits already dialled, and provision has been made for this by marking from the incoming relay set to the register.

In some other cases it is necessary to switch from one exchange to another in the same closed numbering area via a third exchange which is outside that numbering area. A particular case would be one in which 2 secondary centres are included in the same closed numbering area, but for which the final route between them is via a primary centre common to both, but outside their closed numbering area. The subscriber will have dialled only the local number, and if it is necessary to proceed via the primary centre in the example quoted, the area code must be inserted before the number is forwarded to the primary centre to avoid confusion with a subscriber in the primary exchange's area who may have the same local number as the called number.

Echo Suppressor Switching: Because of the long transmission circuits in Australia, provision must be made for the insertion of echo suppressors. Although it would be possible to include echo suppressors on all long circuits, it is preferable to have only one far end operated differential half echo suppressor at each end of the 4-wire section of the circuit. The signalling scheme provides for the insertion of an originating end and a terminating end half echo suppressor only on those calls which require echo suppressors, these to be at points less than 500 miles from the end of the 4-wire section of the circuit.

Switching Overload: Switching systems which use high occupancy routes with overflow on to a common backbone route are highly efficient, but because of this efficiency, they are also quite sensitive to overload. When congestion occurs in one part of the system, repeated call attempts give rise to increased demands on the common control equipment at that point and also at preceding switching points. Further, the holding of trunks through other parts of the system whilst a delay occurs in associating common control equipment at the congested point can cause a spread of congestion through the whole network, even when serious overload occurs initially in a relatively small portion of the network. Deliberate action has therefore been taken to restrict the number of calls entering the trunk system from the originating network when excessive delays are encountered, and the general philosophy is that those calls which have already been set up through part of the trunk network should be given preference over locally generated calls and completed if possible with a minimum of delay. The registers serving the local area will feed recorded announcements to the calling subscribers if an excessive delay is encountered when calling for the ARM marker. Depending on the conditions existing at the time, the recorded announcement will request the caller to call back in say 20 minutes, or it may make an announcement that it is estimated a particular route will be out of service until some particular time. Initially it is proposed that this action will be taken if the delay in obtaining the marker exceeds one second, but this will be reviewed in the light of experience.

TRANSMISSION REQUIREMENTS

The connections effected through the trunk switching equipment may possibly extend as far as National networks in other countries via international circuits of extreme length. Even within Australia it is possible that 9 transmission links will be connected in tandem. For these reasons the transmission performance of the exchange has been given particular attention, and the following characteristics have been considered in detail:—

(a) Loss through the exchange.
(b) Loss/frequency characteristics.
(c) Linearity, harmonic distortion and intermodulation.
(d) Crosstalk.
(e) Phase distortion.
(f) Speech path impedance.
(g) Balance to earth of transmission paths.
(h) Noise.
(j) Transmission levels.
(k) Circuit terminations.
(l) Hybrid characteristics.
(m) MFC injection and pick off effects.
(n) Echo suppressor performance.

Appendix 1 sets out the detailed specification of these various transmission parameters and characteristics.

SIGNALLING REQUIREMENTS

The trunk exchange must co-exist with the equipment already in service and must also be compatible with the new crossbar exchange equipment coming into service in the terminal areas. The signalling system provides the means of communication between the trunk exchange and both old and new equipment and must therefore be capable of meeting any of the interface conditions encountered. In the case of the older equipment the normal loop disconnect type DC signalling is used. The operator dialled network, whilst differing in detail, uses the same basic decadic signalling pattern. Since the signalling speed of this system is at least an order of magnitude slower than the MFC compelled sequence signalling system there is usually no point in using high speed either to or from the lower speed system. Generally speaking then, the loop disconnect mode is used in signalling between the ARM and any step-by-step equipment.

For future development of the Australian network an MFC end-to-end compelled sequence signalling system has been adopted for information signalling with provision for both forward and backward signals. Banks (9) has given further details of the reasons for adopting this system. Although end-to-end signalling is a desirable objective, it is convenient to depart from this concept at the point of entry to the terminal closed numbering area. One of the reasons for this is that the actual series of signals used in large ARF equipped metropolitan networks is different in detail from that used in smaller networks employing ARF, and the series of signals used for revertive MFC control of ARK exchanges is different again. Furthermore, in the trunk system there is a requirement for some additional signals, mainly those connected with echo suppressor switching. Although at first sight this appears to present considerable difficulties, much of the signalling scheme is common to all these applications and there are only very few calls on which echo suppressors for example will be required. For the majority of calls therefore it would be possible to signal right through from the originating register to the terminating code receiver if the call were established entirely through crossbar exchanges.

The major reason dictating the retention of a register at the point of entry to a terminal network is that number length analysis is necessary at some point in the call to avoid holding code receivers unnecessarily, particularly in SL stages of the terminating exchange. In addition, our networks will generally be mixed step-by-step and crossbar networks, and therefore it is desirable to analyse in the incoming network not only for number length but also to identify the type of terminating equipment in order to minimise post dialling delay on calls to step-by-step terminals. If the register were not retained at the point of entry to the closed numbering area, changes of exchange type or number length in that area would require corresponding changes in the analysing equipment throughout the whole of Australia, and this is clearly impracticable.

The MFC signalling equipment on order and already in use has been designed to be reasonably frequency selective and also to check that the two frequencies received as components of a legitimate signal are approximately equal in level. If significant amounts of frequency shift occur, or if the two frequencies undergo differential attenuation in the transmission path, rejection of the signal could occur. The two main offenders in this regard are likely to be the older type of carrier system where a significant amount of asychronism could occur, and loaded cables where the loss/frequency characteristic can be quite irregular. Provision has been made for the registers to be retained by the incoming line relay set if a particular circuit is known to be subject to one or other of these troubles.

The line signalling techniques which will be used will vary according to the type of transmission path. Because of its basic simplicity and reliability normal DC loop disconnect line signalling will generally be used to and from step-by-step equipment, including some cases in which the phantom path of 4-wire amplified junctions is used for conveying line signals. Where carrier equipment is used and, in some cases, where VF amplified circuits are used, A.C. signalling methods will be necessary. If no provision is made in the carrier system for an out-of-band signalling channel, then a single frequency VF system will be used. Later carrier systems are equipped with an out-of-band signalling channel which will be used for line signalling.

Many A.C. line signalling schemes are possible, but a pulse system using two different pulse lengths, viz., 600 m/s and 150 m/s has been adopted. This system is essentially that recommended by L M Ericsson and Appendix II gives more detail of the actual signals passed backward and forward. An important factor in its selection was its provision for the recognition of dual seizure on both way lines. It is foreseen that the number of both way lines used in the Australian system will rise, and it is desired to avoid dual seizure problems by clearly recognizing the condition when it occurs. It is true that other systems could also provide for this but it was considered that the particular pulse system recommended was likely to give the best performance in practice in this regard.

Generally speaking pulses of tone will be used in preference to pulses of absence of tone since it is much more difficult for fault conditions such as dry joints or human interference to simulate pulses of tone as compared with pulses of no tone. The penalty involved in this decision however is that there is no tone on the line in the idle condition. Failure of the circuit is not immediately detected and one call will be lost before the line is busied against further traffic. In this regard there are other measures which can be taken, e.g., the circuits concerned may be automatically busied when the group pilot fails, but generally it is reasonable to tolerate the loss of the first call connected over a faulty channel, provided the circuit is busied subsequently.

The rural carrier systems which were purchased some years ago provide a special problem so far as signalling is concerned. Their use is confined to terminal links only but, for this reason, they are likely to be used for both way circuits and also they must transmit multi-metering pulses from the parent centre to the terminal centre. These carrier systems use transmitted carrier and 2 sidebands, and signalling is effected by interrupting the carrier. Interruption of the carrier also interrupts the speech while the carrier is off, and since multi-metering pulses must be passed during conversation, provision must be made for another out of band path for multi-metering. Equipment operating at 83 c/s had already been developed for signalling over rural carrier systems and it was decided to use the 83 c/s channel in the parent to terminal direction only. This path although established for multi-metering has also been used for other purposes.

The other major difficulty with carrier signalling of this type is that the carrier must be present during speech and also during the set-up of the call to allow transmission of progress supervision tones, and in some cases speech is required before an answer signal has been received, e.g., in booking a call with a trunk operator or in talking to a non-metering service. This therefore forces one in the direction of having pulses of carrier off, rather than pulses of carrier on. This in turn leads to the necessity for guarding against breaks of carrier caused by fault conditions. The rural carrier signalling scheme, also included in Appendix II, is rather more elaborate therefore than the signalling scheme used with conventional out-of-band signalling channels, and hence, although the carrier system itself is much cheaper, the signalling system which must be provided with it becomes more expensive.

Finally, provision must be made for working towards international circuits. The Overseas Telecommunications Commission (Australia) has responsibility for the establishment and operation of circuits external to Australia. The information and line signalling used on the COMPAC cable and which will be used on the SEACOM cable are essentially the C.C.I.T.T. No. 5 Signalling System. It is envisaged that the main ARM exchange in Sydney (Haymarket ARM Exchange) will be equipped with registers to send and receive the C.C.I.T.T. No. 5 signals, although it would be possible to meet the situation equally if the OTC gateway exchange for international calls in Sydney were equipped with registers to send and receive the Australian network signals.

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APPENDIX I

Transmission

General: The connections effected will normally be part of a multi-link connection possibly extending to intercontinental circuits. The following transmission requirements have been framed in this context, and apply to any path through the 4 wire exchange after the necessary signalling and switching operations to establish the desired path have been completed.

For the purpose of this specification the required path is defined as incorporating all exchange equipment and wiring between and including the incoming and outgoing signalling sets associated with the switched line. The signalling sets referred to include any line and/or information signalling relay sets remaining in the desired path after it has been established. The term "path" shall be taken as applying to either the "go" or "return" direction unless either the "go path" or the "return path" is specifically referred to. Where the above definition of a path through a 4-wire exchange includes such items of line transmission equipment as echo suppressors or compandors, these items shall be excluded from the path for the purpose of meeting the path characteristics specified.

The transmission path through the exchange must be bi-directional to cater for the interconnection of two 2-wire lines. This type of interconnection also imposes a requirement for correct poling of all connections through the exchange.

DC potentials should not be fed to line except those deliberately inserted for line and information signalling or for contact wetting purposes. In particular, D.C. currents should not be fed transversely through line transmission equipment, and any contact wetting currents should not exceed 1mA and should flow longitudinally.

Transmission Loss: The path loss through the exchange will vary with time. The mean loss of a particular path shall not vary over any period of time from the nominal loss at 800 c/s of that path by more than $\pm$ 0.2 db with a standard deviation of 0.2 db. The nominal loss of a particular path will be dependent upon the equipment employed on the incoming and outgoing circuits, and may vary for paths interconnecting different incoming and outgoing circuits. The nominal losses are included in Fig. 2.

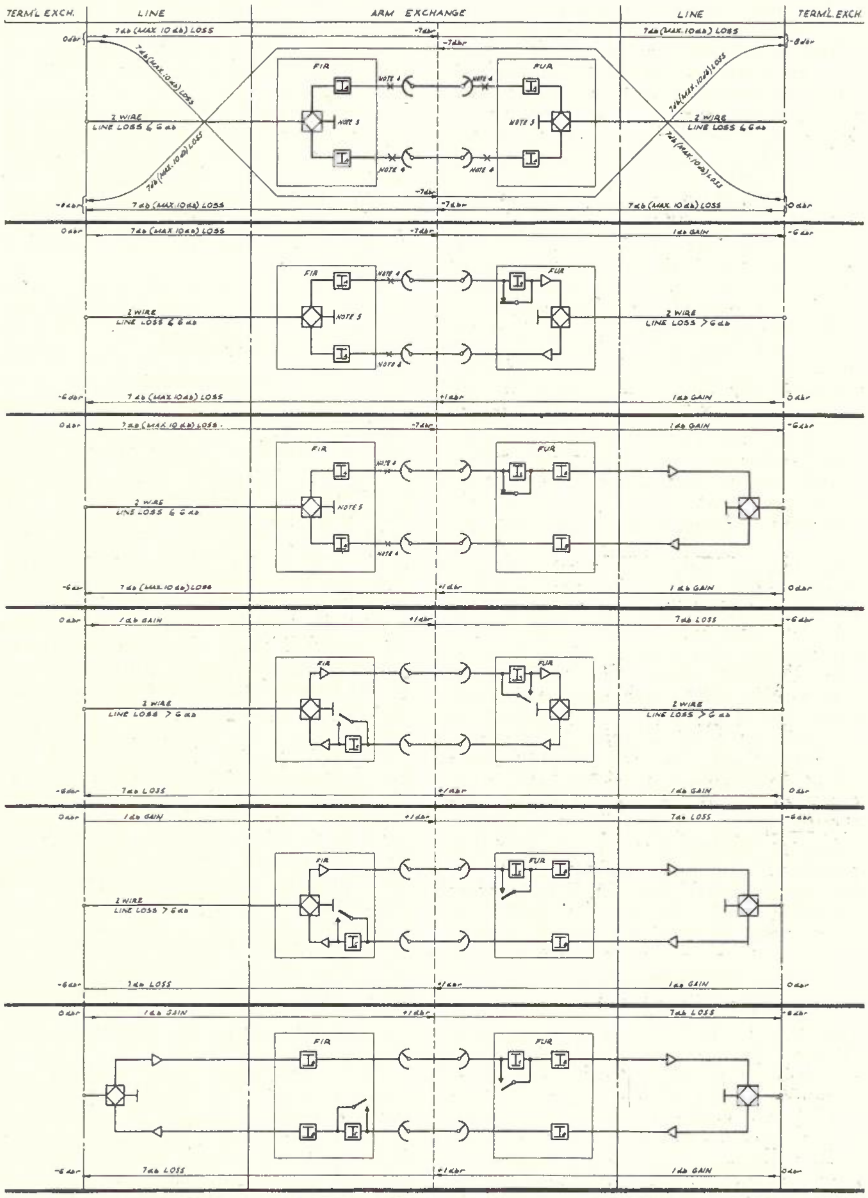


Fig. 2 (a).—Transmission Level Diagrams for ARM Exchanges—Terminal to Terminal Exchange. (For key to notes see Fig. 2 (b).)

Loss/Frequency Characteristic: The permissible variation of the loss/frequency characteristic of any path measured between nominal impedances at any frequency between 300 c/s and 3,400 c/s is ± 0.2 db relative to the loss at 800 c/s. The manufacturer should state the loss/frequency characteristic down to 200 c/s.

Linearity, Harmonic Distortion and Intermodulation: Over the frequency range 300 c/s to 3,400 c/s the path shall be linear to within 0.1 db for levels up to + 5dbm0, and to within 1.0db for levels up to + 12dbm0.

The total harmonic distortion of any fundamental frequency in the same range at any level up to + 5dbm0 shall be at least 26db below the fundamental.

When the equipment is loaded with any two frequencies f_1 and f_2 which lie in the range 540 c/s to 1980 c/s, any 3rd order intermodulation products (i.e., $2 f_1 \pm f_2$ or $2 f_2 \pm f_1$) which lie in the frequency range 540 c/s to 1980 c/s shall be at least 40 db below the fundamentals in level, when these fundamentals are of equal level in the range —5dbm0 to —38dbm0.

Correspondingly, the second order intermodulation products ($f_1 \pm f_2$) measured under the same conditions shall be not less than 30db below the level of the fundamentals.

Crosstalk: Between the two paths of the same 4-wire circuit the crosstalk ratio shall be not less than 55db at any frequency between 300 c/s and 3,400 c/s.

Between any two paths in different 4-wire circuits the crosstalk ratio at any frequency between 300 c/s and 3,400 c/s shall be not less than 70 db in the worst case, with 90% of combinations in a large number of measurements being better than 80 db.

Phase Distortion (Group delay): The group delay distortion, defined as the time difference between the maximum and minimum group delays in the frequency range 500 c/s to 3,000 c/s shall not exceed 100 microseconds.

Impedance: The nominal impedance of speech path connections to relay sets is 600 ohms (balanced), except that on the line (2W) side of 2W/4W and 4W/2W relay sets there shall be an option for either 1,200 ohms or 600 ohms impedance (balanced).

The balance return loss of any input or output port measured against its nominal impedance with the relay set in its through-switched condition and with all other relevant input or output ports terminated in their nominal impedances, shall be not less than 20 db between 300 c/s and 3,400 c/s, and not less than 15 db between 200 c/s and 300 c/s.

Balance to Earth: The impedance balance ratio at the input (or output) of each path when the output (or input) is terminated in its nominal impedance shall be not less than 40 db over the frequency range 600 to 4,000 c/s, 26 db over the range 200 to 600 c/s and 15 db over the range 50 c/s to 50 Kc/s. The impedance balance shall be measured in accordance with the method outlined in C.C.I.T.T. COM. XVI, No. 18.

Noise: By the choice of a suitable weighting network and indicating meter the disturbing effect of the four following types of noise may be ascertained by a single measurement:—

(i) Very low frequency (e.g., power supply) noise,
(ii) High frequency noise,
(iii) Audio frequency noise,
(iv) Impulsive noise.

The measuring instrument shall be a peak reading voltmeter similar to the U.K. Peak Programme meter (C.C.I.T.T. Red Book, Vol. 3 Annex 49 p. 429) having a charging time constant of 0.25 milliseconds (in lieu of 2.5 milliseconds) and used in conjunction with the following weighting:—

0 to 150 c/s, 29.0 db (C.C.I.T.T. 1951 weighting figure at 150 c/s).

150 c/s to 4,700 c/s in accordance with the table of weights for the C.C.I.T.T. 1951 psophometer.

Above 4,700 c/s, 29.4 db (C.C.I.T.T. 1951 weighting figure at 4,700 c/s).

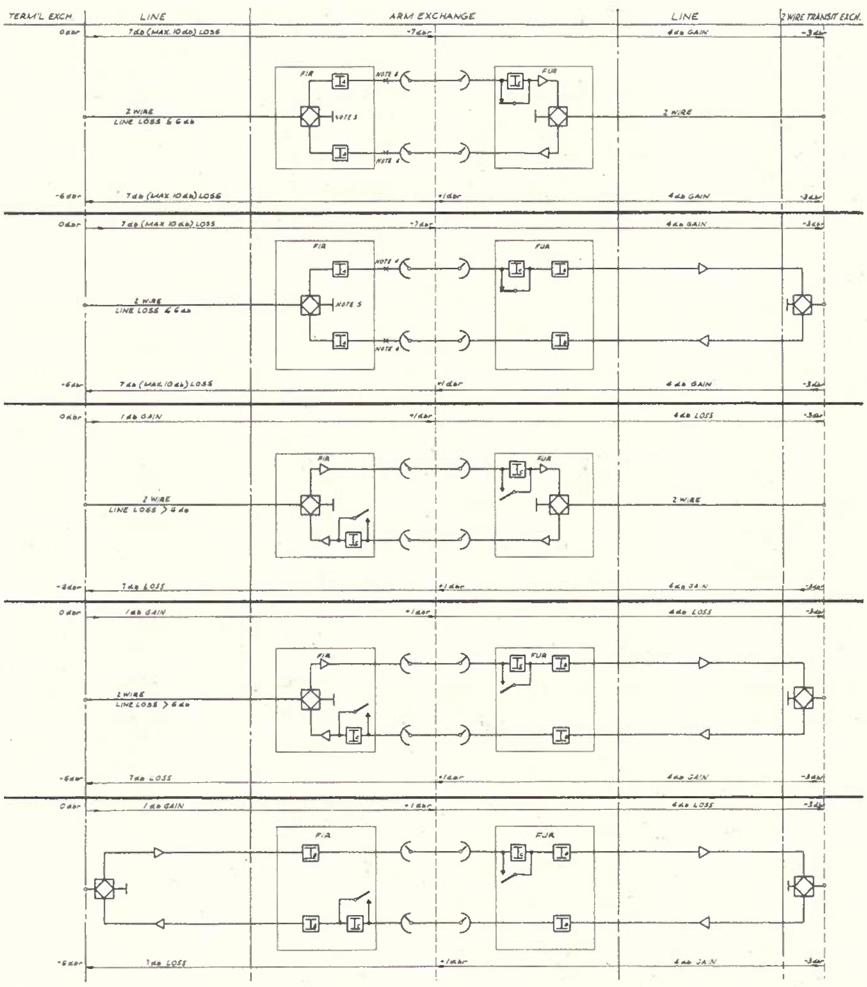
The mean noise introduced into any path during any hour when measured on an instrument as described above shall not exceed a level of —70dbm0 (weighted). Occasional peaks up to —40dbm0 will be permissible.

Transmission Levels: The nominal transmission levels through the 4-wire exchange for a particular arrangement of level adjusting pads are shown in Fig. 2. Switching out of the pads is only required for level adjustment on other than a connection between two 4-wire lines. No pad switching is required for stability control.

Switchable Level Adjusting Pads: Level adjusting pads are required to introduce a nominal loss of 8 db into the transmission paths on a 4-wire to 4-wire connection on the assumption that the loss in the exchange equipment and wiring is 1 db. The positions of the level adjusting pads (see Fig. 2) were chosen to give the most favourable conditions from a consideration of crosstalk and noise, but alternative positioning of these pads in the transmission path will be considered provided that all the requirements of this specification are met, particularly those relating to crosstalk and noise.

Stability Pads: Stability pads must be provided in the go and return paths of 2W/4W relay sets as shown in Fig. 2 to meet echo and stability requirements when switching to 2-wire circuits of low loss (less than 3 db).

Line Building-out Pads: The normal levels at channel modulator and demodulator points in the Australian network are —13dbm0 and +4dbm0 respectively, although some rural carrier equipments have corresponding levels of —11dbm0 and +5dbm0 respectively. Building-out pads shall be associated with 4-wire relay sets on the line side and these will be strapped at the time of installation to give the correct levels at the ARM exchange taking account also of any losses involved in the physical extension of the circuits between the ARM exchange and the line transmission equipment. These pads should be on the line side of the line side test access jacks to achieve uniformity of test levels at these jacks.



NOTES:

1. Building out pad 'A' (0.5 + 1.0 + 2.0) db is inserted when the line loss is less than 3 db such that line loss and pad loss lies between 3 and 3.5 db (to give the required loss of 7 db between the terminal exchange and the switch bank).
2. Building out pad 'B' (0.5 + 1.0 + 2.0 + 4.0) db is inserted to adjust the loss between the transmission equipment and the switch banks.
3. Level adjusting pad 'C' (nominal value 8 db) is switched as shown for a particular connection.
4. Amplifiers may be required at future date. Level adjusting pads will not be required.
5. When amplifiers are fitted, as in note 4, precision balance network is required.

Fig. 2 (b).—Transmission Level Diagrams for ARM Exchanges—Terminal to 2-Wire Transit Exchange.

Terminations: Two wire lines shall be terminated at all times, i.e., either connected through to another circuit or terminated locally. All speech circuits should be terminated at all times between seizure and release, and it is desirable that 4-wire lines be terminated at all times.

Hybrids: Hybrids shall be provided in signalling relay sets as appropriate for association with 2-wire lines to enable these to be switched on a 4-wire basis.

A strapping arrangement permitting a nominal line side impedance of 600 ohms + 2 microfarads or 1,200 ohms + 1 microfarad is required. The hybrid will be permanently associated with the 2-wire line, and these lines will be individually balanced. The types of 2-wire lines most frequently encountered are:—

(i) Loaded cable, paper insulation, mostly 10 lb. per mile, but isolated instances of 6½ and 20 lb. per mile, loaded with 88mH at intervals of 6,000 feet (midsection terminated).

(ii) Unloaded cable as above.

(iii) Open wire lines (in the case of a limited number of lines at country exchanges).

Standard balance networks will meet all normal conditions, but provision for special networks to be mounted either within or external to the relay set would have marginal advantage.

MFC Injection and Pickoff; Multi-frequency code signalling equipment should be connected to the line relay sets on a 4-wire basis whether the particular lines are 2-wire or 4-wire lines.

Echo Suppressors: It is proposed to use far end operated differential half echo suppressors on the longer distance trunk calls and on international calls. Echo suppressors will be provided at strategic points in the 4-wire trunk network in such a manner that the distance from the echo suppressor to its most remote associated terminal exchange will not in general exceed 500 miles. In practice this will mean that echo suppressors will be required at all main switching centres, many primary centres, and at a few lower order centres such as Darwin, Alice Springs, Cloncurry, Carnarvon and Derby.

APPENDIX II

AUSTRALIAN NETWORK LINE SIGNALLING

General

Line signalling in the trunk network will be as follows:—

(i) D.C. circuits—conventional loop disconnect signals.

(ii) Standard out-of-band carrier—pulse line signals.

(iii) Standard carrier not incorporating out of band facilities — pulse line signals, using V.F. signalling.

(iv) Rural carrier systems—special pulse and compelled line signals using carrier signalling and an 83 c/s path.

The pulse type line signalling scheme is designed to allow both-way circuit operation to be applicable to in-band, out-of-band or separate path signalling arrangements.

The line signalling is link-by-link in a multi-link connection, and the signals are transferred through transit switching exchanges on a D.C. basis. When the same basic code is used on different types of signalling media, no code conversion is necessary and, for this reason, the maximum use will be made of pulse line signals. All the line signalling schemes cater for decadic information signalling also, and details of this are included below where appropriate.

Signalling Codes (Pulse)

Pulse Lengths: The code is composed of two signal elements, one short and one long, with nominal lengths of 150mS and 600mS respectively. In addition, decadic impulsing may be passed forward with 65mS pulses.

Signal	Forward	Backward
	duration (mS)	duration (mS)
Seizure	150	
Decadic Impulses	65	
Forced release		600
Answer		150
Clear back		600
Clear forward	600	
Release guard		600
Blocking		Continuous
Forward transfer	150 operator in next 150 operator out	
Metering		150

Seizure Signal: The seizure signal consists of a short signal element which is sent from an outgoing junction relay set to the far end of the circuit where it initiates action in that exchange.

Forced Release Signal: The forced release signal consists of a long signal element. It is sent from the incoming end of a circuit if the register or code receiver times out because of non-receipt of digits after seizure. The receipt of the forced release signal initiates clear forward from the outgoing end.

Answer (and re-answer) Signal: The answer signal consists of a short signal element. The signal is sent from the incoming relay set to indicate that the called party has answered. The signal has a supervisory function, and on a subscriber dialled call will be used to start metering.

Clear Back Signal: The clear back signal consists of a long signal element. It is sent from the incoming relay set to indicate that the called party has cleared. The signal has a supervisory function.

Clear Forward Signal: The clear forward signal consists of a long signal element. It is sent from the outgoing relay set when it is desired to release the connection. It is the only long signal in the forward direction and is easily distinguished, thus giving positive release of the call at any time.

Release Guard Signal: The release guard signal consists of a long signal

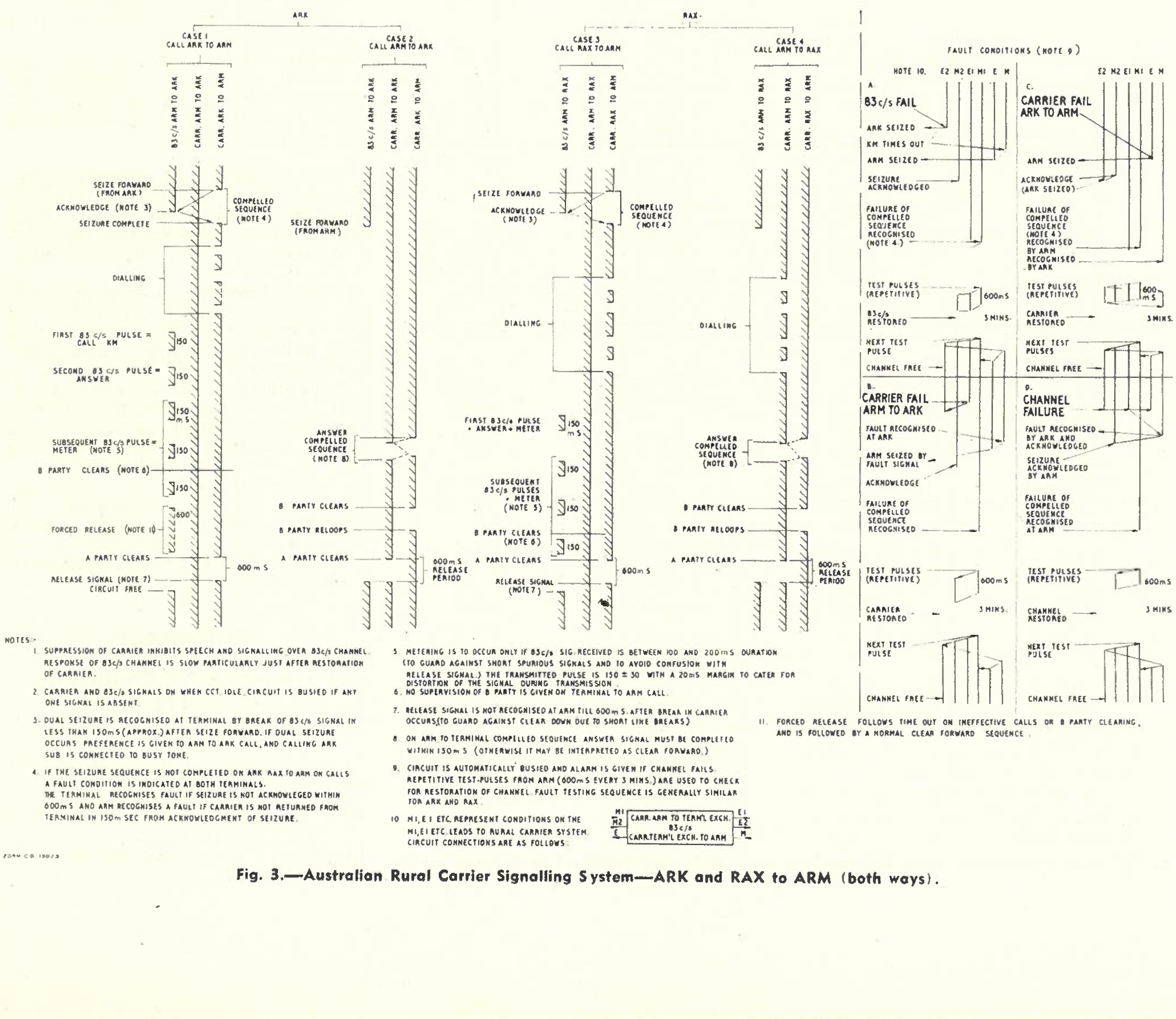


Fig. 3.—Australian Rural Carrier Signalling System—ARK and RAX to ARM (both ways).

element. It is transmitted in the backward direction in response to the clear forward signal and indicates that release of the connection has been effected at the incoming end of the circuit.

The release guard, forced release and clear back signals are identical. If any is received in the outgoing relay set a time supervision period of 90 seconds is started. If the connection through the exchange is not released in this period an alarm is given; this is particularly important where the call is connected via a transit exchange.

The release guard signal is sent only when the clear forward has been preceded by a seizure signal with the correct signal length.

When no release guard signal is received, e.g., because of a line fault, the outgoing relay set is busied, and the outgoing relay set transmits repeated seizure and clear forward signals. When a release guard is received, the outgoing relay set busy condition will be removed.

Blocking Signal: The blocking signal is continuous and busies the outgoing relay set against seizure.

Forward Transfer Signal: This signal will only be required by operators and is a re-ring signal. In an international connection it will be used to obtain operator assistance in the country of destination of the call.

Metering Signal: The short signal element is used for sending metering impulses during conversation. Because these impulses should not be heard by the subscriber the metering signals can only be sent over out-of-band signalling channels.

Signalling Codes (Loop Disconnect)

General: Conventional loop disconnect signalling when used will be in accordance with the summary of signals below:—

(i) *Seizure.* Loop forward.

(ii) *Impulsing.* Loop disconnect impulses forward.

(iii) *Clear forward.* Open loop forward for at least 400mS. After a period of say 600mS minimum, the back busying relay will be connected to line.

(iv) *Called subscriber answer.* Reversal of battery feed in backward direcion.

(v) *Multi-metering pulses.* Slow restoration of normal polarity followed by slow return to reverse polarity (slow or silent reversal).

(vi) *Clear back.* Restoration of normal battery feed polarity in the backward direction.

(vii) *Back-busy.* Open or reverse battery feed in backward direction.

(viii) *Trunk Code Dialled.* Reverse battery feed for 100-150mS followed by restoration of normal potential.

Signalling Codes (Australian Rural Carrier Signalling)

This signalling scheme has been developed specifically for use with the rural carrier systems used in Australia which employ carrier signalling in both directions, and an 83 c/s out-of-band signalling channel in the main station to terminal direction only. Both-way working is possible with this signalling scheme which is also arranged for operation over trunk lines subject to interruptions of short duration. Further detail of the signalling scheme is given in Fig. 3.

AUSTRALIAN TELECOMMUNICATION MONOGRAPHS

Until the introduction of Australian Telecommunication Monographs, the Telecommunication Journal of Australia was the only Australian technical journal specializing in telecommunications, and therefore had an obligation to publish all types of papers on telecommunication subjects, including highly-specialized papers of limited interest.

At the same time, the Journal had (and still has) an obligation to give a well-balanced coverage of all important developments in telecommunications, with emphasis on topics of the greatest interest.

These objectives sometimes clashed, and the Board of Editors was obliged at times to reject otherwise excellent "Journal" articles because of their great length or narrow field of interest.

The Telecommunication Society of Australia is therefore grateful to the Australian Post Office for sponsoring the production of a separate technical publication: Australian Telecommunication Monographs. Monographs will be published from time to time, as suitable material is offered, with printing arranged by the Australian Post Office, editorial arrangements in the hands of the "Journal" editors, and sale and distribution by the Telecommunication Society of Australia (as for the "Journal").

The Society can now supply, on demand, copies of the first two Monographs as described below at a cost of 10/- (ten shillings, Australian currency) each.

Australian Telecommunication Monograph No. 1: Calculation of Overflow Traffic from Crossbar Group Selectors. N. M. H. Smith.

Australian Telecommunication Monograph No. 2: Symposium on Preservation of Wooden Poles. Melbourne, 1963.

Applications should be addressed to the General Secretary, Telecommunication Society of Australia, Box 4050, G.P.O. Melbourne, Vic., Australia.

CHANGE IN BOARD OF EDITORS

The Board of Editors is pleased to announce the appointment of Mr. H. S. Wragge, B.E.E., M.Eng.Sc., A.M.I.E.E., A.M.I.E.Aust., as an Editor of the *Journal.* Mr. Wragge is Engineer Class 4, Principles and Standards in the Systems, Principles and Standards Section, Research Branch. His main interest at present is electronic switching and in 1962 he spent three months overseas studying developments in this field. Mr. Wragge has been a Sub-Editor of the *Journal* since 1955 and is currently Chairman of the Papers Committee for Research Branch. This experience should enable him to make a substantial contribution to the Board's task of recording major advances in telecommunications in Australia.

ORDERING MATERIAL FOR THE CROSSBAR INSTALLATION PROGRAMME

*G. A. DOBBINS, A.M.I.E.E., A.M.I.E.Aust.**

INTRODUCTION

General

The Australian Post Office (A.P.O.), like any other Administration providing a telephone service, has several ways open to it of obtaining automatic exchange equipment and bringing it into service. It can:—

(a) specify to the manufacturer the traffic to be handled, its distribution and the basic facility requirements for particular exchanges and leave the detailed engineering — equipment quantities, mechanical design, circuit design, cabling plans and floor layout—to the manufacturer, who would also install the equipment;
(b) use method (a) but install the equipment itself;
(c) specify to the manufacturer the traffic and trunking requirements and full engineering detail, including circuitry, for each individual exchange it proposes to purchase and have the equipment installed by the manufacturer;
(d) use method (c) but install the equipment itself;
(e) specify to the manufacturer a standardised engineering design for each part of the automatic system and make purchases in bulk for installation by the administration as required;
(f) use method (e) but have the equipment installed by the manufacturer.

The choice of method is dependent upon both technical and commercial factors and demands a critical appraisal of facility requirements, the advantages to be gained by a standardised design, the availability of experienced technical staff, the availability of equipment from a commercially suitable source and overall economic considerations.

Methods of Purchasing Used by A.P.O.

All of these methods have been used to some extent by the A.P.O. since the first automatic exchange in Australia was purchased from U.S.A. and installed at Geelong, Victoria, in 1912. The earliest exchanges were obtained and installed by method (a) but later, as the engineering strength of the A.P.O. grew, installation was carried out by its own staff. This led inevitably to a better understanding of system and circuit design which enabled the A.P.O. to specify its requirements in more engineering detail and adopt method (c). Several exchanges were purchased in this way but difficulties brought about by changes in development plans and delays in the completion of exchange buildings caused the A.P.O. to adopt the policy of having all equipment installed by its own staff. This proved to be a more flexible and economic method and, coupled with the advantages of system standardisation, resulted in the adoption of bulk buying—method (e). This method has now been in operation for some twenty years.

No exchanges had been installed under contract from equipment obtained by bulk purchasing until 1963/64 when a contract for this method (f) was placed for Cronulla crossbar exchange, N.S.W. This was a special case resulting from contracts with L M Ericsson, Sweden, to supply 8,000 lines on the Haymarket contract and install 4,000 lines at Haymarket and a further 4,000 lines at another exchange in the Sydney metropolitan area. Cronulla was nominated by the A.P.O. as equipment for this exchange had been delivered previous to this decision and was held in Stores together with bulk supplies delivered by Standard Telephones & Cables Pty. Ltd. (S.T.C.), Telephone & Electrical Industries Pty. Ltd. (T.E.I.) and L.M.E., Sweden. Thus equipment withdrawn from Stores for Cronulla was not necessarily of L.M.E. manufacture. This is characteristic of all A.P.O. exchanges installed since bulk buying was adopted and in the case of 2,000 type step-by-step equipment an exchange could contain racks and relay sets manufactured by two Australian and four British companies. Such a combination of supplies well illustrates that the need for standardisation is fundamental to satisfactory operation of the system.

History

In the period 1912 to 1935, about 171,000 lines of automatic equipment were purchased for the Australian network of which 101,000 came from U.S.A. and 70,000 from England. This equipment was of the Keith Plunger and Strowger (pre-2000) types. In 1935, the first purchases of 2,000 type equipment were made from England, and from then until 1950 about 441,000 lines were obtained. Of this, 216,000 lines were engineered for specified exchanges and 225,000 lines were purchased under the bulk buying scheme which began in the 1944/45 financial year.

After the introduction of 2,000 type equipment, further purchases of pre-2,000 type were limited to extensions for established exchanges. No exchanges were purchased as complete units after 1950 except for special trial exchanges which did not employ bimotional switches. These are listed in Table 1 which shows their sizes and types. However, the volume of bulk supplies was increased and from 1950/51 to 1962/63 inclusive a further 900,000 lines of 2,000 type equipment were purchased.

All supplies of 2,000 type equipment were obtained from England until 1948 when the two Australian factories in Sydney, S.T.C. and T.E.I., began production of this type of equipment. Approximately 800,000 lines were purchased from these two companies in the fifteen years to June, 1963.

PURCHASE OF CROSSBAR EQUIPMENT

Manufacture of Crossbar in Australia

The A.P.O. made the decision to adopt a register controlled crossbar system in April, 1959 (1) and in July, 1959, it was decided to standardise on the L.M.E. system (2). One of the factors which influenced these decisions was the necessity to have supplies of automatic equipment manufactured in Australia (3). Previous experience had shown the disadvantages of being fully dependent upon imported supplies. There had been a steady flow of 2,000 type equipment from the Sydney factories in recent years, and close co-operation with the

TABLE 1: PURCHASES OF COMPLETE EXCHANGES SINCE 1950

† Exchange and Type	Delivery Year for Initial Purchase	Size of Initial Installation	Extensions Installed and/or Orders Placed for Extensions
North Essendon (Vic.)—Siemens 17	1950/51	3,600	4,400
Botany (N.S.W.) ,,	1958/59	2,000	400
Gepps Cross (S.A.) ,,	1959/60	2,400	1,600
Elizabeth (S.A.) ,,	,,	1,000	1,000
Matraville (N.S.W.)—Siemens & Halske EMD	1960/61	2,000	—
Maribyrnong (Vic.) ,,	1959/60	2,000	1,000
Kew (Vic.)—S.T.C. Pentaconta	1960/61	3,900	1,100
Sefton (N.S.W.)—L.M.E. Crossbar, ARF50*	1956/57	600	400
Templestowe (Vic.) ,, *	,,	600	400
Toowoomba (Qld.)—L.M.E. Crossbar, ARF101*	1959/60	6,300	1,000
Newtown (Qld.)	1964/65	200	—

† The list excludes the standard crossbar exchanges for Petersham, Haymarket, Cooma and Flinders.

* These crossbar exchanges are of different types from those standardised for use in Australia.

*Mr. Dobbins is Engineer Class 3, Exchange Equipment Section, Headquarters. See page 422.

manufacturers, in both supply and design matters, made possible by having a domestic industry, had been of great assistance to the A.P.O. There are, too, obvious reasons for supporting a local industry in a rapidly expanding country like Australia and it was fundamental to foster their growth. The political and commercial implications of the decision are too involved for treatment in this article but it is pertinent to record that both S.T.C. and T.E.I. were licensed by L.M.E. to manufacture crossbar equipment in Australia and that L.M.E. themselves established a new factory in Melbourne from which ARF, ARK and ARM equipment started to flow in the 1963/64 financial year. S.T.C. and T.E.I. commenced production of ARF and ARK equipment in 1961 and made the first deliveries in the 1961/62 financial year (4).

Initial Crossbar Orders

The first order for ARF equipment was placed on 5th June, 1959, for the supply by L.M.E., Sweden, of a 2,800 line exchange for Petersham, N.S.W. (5). It had been established in preliminary negotiations with L.M.E. that some modifications to the standard L.M.E. system would be necessary to make it suitable for integration into the A.P.O. network. Petersham was therefore treated as the "pilot" installation and detailed technical discussions were held with L.M.E. engineers to determine what facilities must be incorporated and what design changes were necessary. This work was not completed before manufacture of the equipment began but was considered during manufacture. Meanwhile, a further order was placed with L.M.E. on 14th July, 1960, for the supply of complete and fully engineered exchanges for Haymarket (N.S.W.), Cooma (N.S.W.) and Flinders (S.A.), and also for First Stage Switching equipment for specified exchanges. As already mentioned, it was decided that Haymarket would be installed by L.M.E.

On 17th October, 1960, the first bulk orders were placed with S.T.C. and T.E.I. for a total of 39,860 lines including ARK equipment. All the equipment quantities in these orders were calculated by Engineers in Headquarters from trunking diagrams based on step-by-step principles provided by State Engineering Divisions and engineering information then available from L.M.E. (6). At this stage, certain items were not being manufactured by S.T.C. and T.E.I. and orders for these were placed with L.M.E. All this equipment was for delivery in the 1961/62 year.

The first bulk supply order with L.M.E., Sweden, was placed on 17th January, 1962, and covered 11,230 lines including ARK equipment. For this order, L.M.E. were given trunking details of selected exchanges and were requested to provide all the necessary equipment, including miscellaneous items such as installation ironwork, to enable the A.P.O. to complete installation. Further orders placed with L.M.E. were for manufacture in their Australian plant and covered bulk supplies for 1963/64 in quantities specified on an item-by-item basis by the A.P.O.

These supply arrangements are shown in Fig. 1 which indicates how purchases of 2,000 type equipment from S.T.C. and T.E.I. were also being made during the changeover from 2,000 type to crossbar equipment. The final purchase of 2,000 type equipment was made for delivery in 1962/63; thus, the changeover was made, so far as bulk purchases from the local factories were concerned, in two years. Fig. 1 also indicates that a relatively large purchase of 2,000 type equipment was made for 1961/62. This was done to provide a buffer stock to meet any disruption to the supply of crossbar equipment in the early stages of local manufacture.

Factors on which Ordering is Based

The true need for new, and extensions to existing, automatic exchanges is indicated by the applications for telephone service combined with the necessity to replace manual services and old automatic exchanges, and to develop the trunking in existing exchanges to cater for increased traffic and subscriber trunk dialling. This represents the work that ought to be done, and is known as the Needs Programme. However, this programme must be restricted to fit within the limits of funds granted by the Treasury for A.P.O. capital works, which cover not only telecommunications but also mail services, broadcasting and television. Therefore, when it becomes known what funds can be expected for telecommunication services, a realistic programme is drafted which must provide for a balance of purchases as between automatic equipment, cable, telephone instruments, equipment for trunk services, etc., and take into account available resources such as buildings and staff. A detailed examination of proposed expenditure on purchases of automatic equipment to ensure that supplies will be adequate but not result in

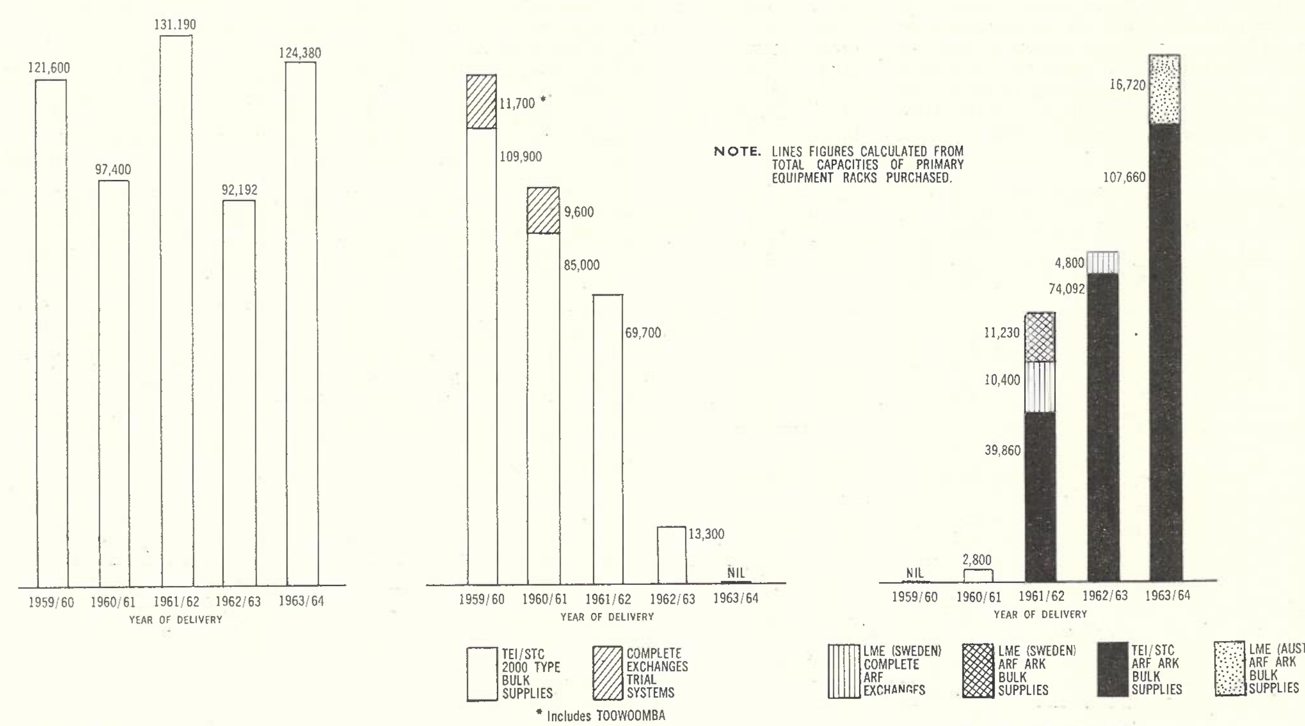


Fig. 1.—Supply Arrangements, 1959/60 to 1963/64.

unusable stocks because of labour shortages, etc., is a prerequisite of material ordering.

Purchasing funds are made available in two categories — Forward Ordering funds and Short Term funds. The first is for those items of plant which must be ordered before the financial year in which delivery is required and the second is for those items which can be ordered in the same financial year as that in which delivery is required. To satisfy short term contracts, manufacturers must carry stocks of those raw materials and components obtainable only on long lead times. For some materials, lead times from overseas can be as long as 12 to 15 months and manufacturers naturally are not prepared to invest in large stocks of specialised material, which can be used only in equipment for which there is no outlet other than the A.P.O., without some assurance of orders. Forward orders therefore form the larger portion of annual purchases so that manufacturers can organise their supplies and plan production programmes that will be economic to them and meet the A.P.O. delivery requirements. Economic production means, in turn, lower prices to the A.P.O.

Material held in stock by the A.P.O. is considered before a purchase is made. Stocks must be kept within predetermined limits because all material held is a charge on a Stores Trust Account from which funds to make further purchases are made available. Thus, excessive stocks restrict purchasing power. The present value of Stores stocks of all types of equipment used by the Post Office is nearly £26 million. This includes £3.33 million of automatic equipment and with annual purchases at about £7 million it is necessary to maintain an average turnover rate of two. Provided that material purchased is used strictly according to the programme of works planned at the time of purchase, a smaller stock can be maintained and orders can be confidently placed far enough ahead of needs to ensure deliveries on time.

Assessing the Annual Requirements

The programme of exchange works is drawn up by the Engineering Divisions in each State in the form of a three-year project programme and in July each year, the six States present to Headquarters a detailed estimate of the automatic equipment requirements for the three-years' programme. For example, the States submitted, in July, 1963, their requirements for the three years 1963/64, 1964/65 and 1965/66. In preparing this information, every exchange in the three-year programme is listed and the quantities of individual items of equipment (as described later) for each exchange are shown. Special forms are used for this purpose on which the total annual requirement of every individual item is shown. These totals are carried forward to a summary on which is entered current stores stocks, deliveries still to be made and recoveries which are expected to be made that will be suitable for re-use in the year under consideration. An extract of the summary form used is shown in Fig. 2. Any changes in the usage pattern resulting from changes in design, standards, trunking or policy are taken into account.

When the returns from each State are received in Headquarters, they are examined in relation to the project programme and in the light of any developments in the extent of the overall programme which may have become known during preparation of the information. At this stage an estimate of the cost of satisfying the needs is made and if this is within the budget for automatic equipment purchases, material ordering proceeds. If the cost of meeting the stated requirement is too high adjustments are made in such a way that the most urgent works can proceed and the less urgent works are carried over into the following financial year. Usually, the stocks of some items in some States are in excess of immediate requirements and the transfer of these items from one State to another is taken into account before purchases are made. (The actual physical movement of the material is not arranged until it is actually required.)

There were many problems associated with the assessment of quantities for the initial bulk supplies of crossbar equipment owing to unfamiliarity with this equipment and it was not practical to adhere to the established procedures outlined above for the orders placed during the first year. Equipment quantities were therefore estimated by Headquarters staff as already mentioned. In assessing these quantities frequent consultation with L.M.E. was necessary to gain knowledge of the breakdown of major equipment units such as SL markers and to determine the relativity between certain items, such as parts 1 and 2 of the incoming register. This information was consolidated into a Schedule of Items making up the ARF and ARK systems which was circulated to all engineers concerned with installation and material ordering and also to the manufacturing companies. It gave details of usage rates, and rack and relay set capacities to enable the States to assess quantities for orders in the following years.

Although the Schedule of Items covered all racks and relay sets for the two systems, it did not provide for the wide variety of miscellaneous items such as installation ironwork, IDF strips, suite control equipment and plugs for inter-rack cabling that also had to be purchased. Estimates of the quantities of these items required for the first bulk order were made on the basis of recommendations from L.M.E., Sweden. Shortages of some items occurred by doing this owing to the different methods of installation employed by L.M.E. but these were overcome by the placing of urgent supplementary orders and delivery by air from Sweden in some cases. As

CATALOGUE ITEM NO.		SERIAL & ITEM		ACTUAL STOCKS 30-6-63			OUTSTANDING DELIVERIES		COMING FORWARD ON 1963/64 CONTRACT		TRANSFERS		TOTAL AVAILABLE FOR 1963/64	WITH-DRAWALS FROM STOCK FOR 1963/64 WORKS	STOCK 30-6-64		COMING FORWARD ON 1964/65 ORDERS	RECOVERIES IN 1964/65	TOTAL AVAILABLE FOR 1964/65	WITH-DRAWALS FROM STOCK FOR 1964/65 WORKS	
				MAIN STORE	ENG. STORE	ON HOLDING AUTH'Y	1961/62	1962/63	BULK ORDERS	LOCAL (STATE) ORDERS	FROM OTHER STATES	TO OTHER STATES			SURPLUS	DEFIC-IENCY					
1	RACK, SLA/B-LR, M = 6	251/1																			
2	" " ", M = 8	251/2																			
3	" " ", M = 10	251/3																			
4	", SLB	251/4																			
5	" "	251/5																			
6	", SLB/PBX	251/6																			
7	", PBX EQUIPMENT	251/7																			
		251/8																			
		251/9																			
213	ROA																				
214	RACK, FUR-PABX	251/191																			
215	RELAY SET, FUR-PABX	251/192																			
216	ROA	251/193																			
217	ROA	251/194																			
218	ROA	251/195																			
219	ROA	251/196																			
220	RELAY SET, ALARM & BLOCKED ROUTE	251/197																			
221	RACK, SLA/B, M = 8	251/198																			
222	" ", M = 6	251/199																			
223	RELAY SET, OPERATORS CCT	49/65																			

Fig. 2.—Example of Summary Form for showing Annual State Requirements.

more information on the assembly of equipment became available, including that from experience by installers dealing with the first installation, estimating guides were compiled and circulated so that future ordering could be handled by routine procedures for quantities assessed by State user divisions.

ORDERING PROCEDURE

General

The first stage in the placing of orders is to give each manufacturer a broad estimate of the probable extent of orders at least 12 months ahead of the delivery year so that he can arrange for the ordering of raw materials and imported components, especially those with long lead times, in sufficient time to ensure delivery of complete equipment according to schedule. This advice is given in the form of the number of lines of equipment required together with some indication of the product mix. About a month later, a detailed list of the items and quantities required is sent to the manufacturers who are then asked to confirm that they can supply the items at times suited to the A.P.O. programme.

Because of the limitation on funds for forward ordering at this stage not more than about 70% of the annual needs can be placed on contract but this equipment must be ordered before final details of the programme are known. For example, about 70% of the equipment required for 1963/64 was ordered before July, 1963, when the three-years' estimates for 1963/64 to 1965/66 were received from the States; therefore, the previous year's estimate (July, 1962), which showed 1963/64 as the second year of the three-year programme, was used to assess quantities. The placing of the short term order is left until the beginning of the year in which delivery is required and before this order is placed the quantities shown in the latest estimates from the States (July, 1963, in the example quoted) are examined and if these differ considerably from those indicated earlier the manufacturers are asked if they can accommodate the changes in their production programme.

The content of orders, whilst being based on the annual three-years' programme, is influenced by other factors including periodic reviews of available funds, an annual programming and planning conference, and a four-monthly conference to examine the adequacy of supplies coming forward. In the special case of the first bulk supply contracts with S.T.C. and T.E.I. for crossbar equipment, the timing of orders was different because of the decision to embark on local manufacture in parallel with development of the system in Sweden. This is explained in a previous article (6).

Preparation of Contracts

Once the details of equipment requirements have been settled, a technical report is prepared by the Engineering Division which gives an item by item distribution of the equipment among the States. Usually, a quantity of each item is ordered from each manufacturer to safeguard supplies in the event of a breakdown in any one factory and against the possibility of a particular manufacturer being unable to schedule production at times suited to A.P.O. needs. This report also shows the prices, obtained from the manufacturers by the Stores and Contracts Branch, applicable to every item, and the total expenditure involved in the proposed contract. For the first crossbar orders, quotations were obtained from L.M.E. and the prices were related to labour rates ruling in Sweden at a specified date. Further orders placed in Sweden used these same prices, subject to the application of a specified escalation clause, and it was not therefore necessary to seek fresh quotations for subsequent orders. For the purpose of writing the initial contracts with S.T.C. and T.E.I., Swedish prices, adjusted to provide for Australian labour rates, were used. The A.P.O. Finance Branch played an important part in establishing these rates in co-operation with the local companies and consulted the International Labour Organisation to assess the relativity of material and labour costs in Sweden and in Australia. After S.T.C. and T.E.I. had produced equipment in Australia, they were able to determine actual production costs and, in conjunction with an A.P.O. cost investigation team, fixed a revised set of prices which were acceptable to all parties.

The technical report is submitted to the Stores Branch where it is checked for prices and commercial aspects of the agreement with the suppliers and is then forwarded under cover of a recommendation to the Tender Board. The Tender Board is an independent body comprising representatives of the Engineering, Stores and Finance Divisions and approves of all purchases made by the A.P.O. If approval to purchase is given—based on the estimated expenditure being within the limits of available funds and the proposal being in accordance with general purchasing policies—the Stores Branch proceeds with the preparation of formal contracts. These are issued in the form of Letters of Acceptance which contain all relevant commercial clauses such as cost variation, delivery, payments terms and conditions of supply, and relate the technical aspects of the contract to the Catalogue discussed later in this article. The whole ordering pattern is shown in Fig 3.

SPECIFICATION OF MATERIAL

General

All telephone equipment used in the A.P.O. is specified in a series of drawings under the prefix "CE". No such drawings existed at the introduction of crossbar equipment and it became necessary to determine how the new equipment could best be specified. The most important considerations were the use by L.M.E. of the metric system in dimensioning mechanical drawings and the use of the semi-attached contact method in circuit drawings. S.T.C. and T.E.I. decided to convert all metric measurements into British equivalents, mainly because their established factory metrological facilities were based on British standards. An exception to this is screw threads for which the metric system has been retained. L.M.E., on the other hand, were faced with equipping a new factory in Australia and chose to adopt metric measure. A.P.O. mechanical drawings are dimensioned in metric measure, usually with overall dimensions shown in British equiva-

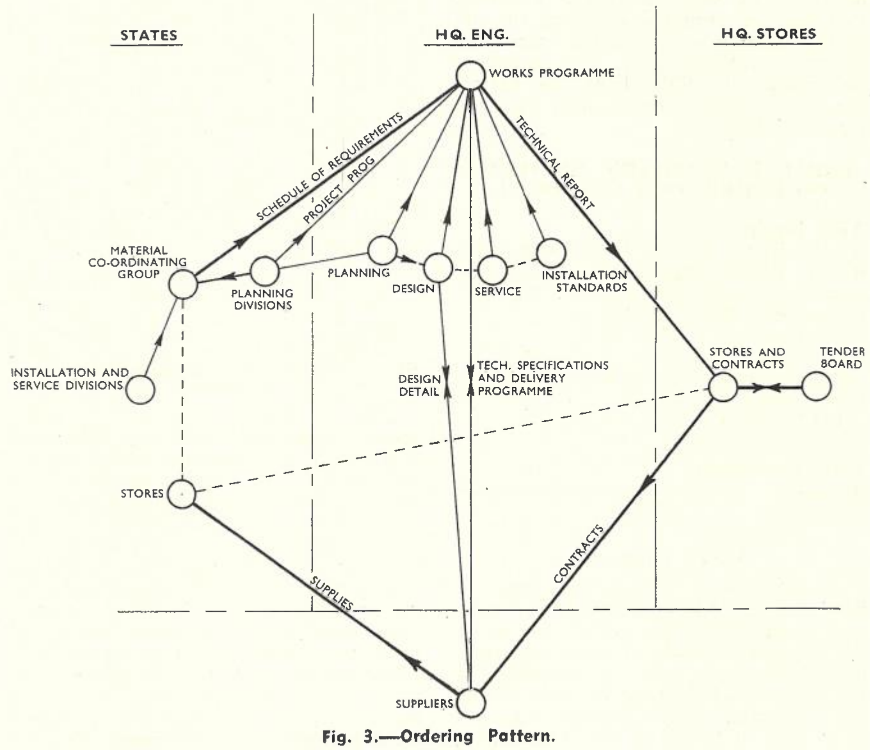


Fig. 3.—Ordering Pattern.

lents to give a quick appreciation of sizes.

The task of converting L.M.E. circuit drawings into drawings using the detached contact method was considered too large to undertake for the doubtful advantages to be gained. Moreover, A.P.O. technicians who installed the first crossbar exchanges (Sefton, Templestowe and Toowoomba) had reported little difficulty in using the L.M.E. drawings and it was decided to adopt the Swedish method. L.M.E. co-operated by having English translations of all Swedish terminology added to their drawings and providing lists of the more commonly used terms. It was also decided to retain the L.M.E. equipment designations and coding of individual parts both in the local factories and in the A.P.O.

The production of A.P.O. drawings for each item of equipment was necessary so that the Post Office would have control of the specification of items and be able to order the same equipment from all manufacturers. There is now a complete range of "CE" drawings covering ARF and ARK equipment.

L.M.E. provided the local manufacturers with detailed design data and copies were passed to the A.P.O. which used this to determine what breakdown of the plant should be set as an objective. Bearing in mind the bulk method of supply, which involves the storage of material in units best suited to installers' needs and the invoicing of each unit at its true price, it was clear that a breakdown similar to that used for 2,000 type equipment should continue. Consequently racks are ordered and delivered as units complete with wiring and miscellaneous items but not fitted with relay sets, and relay sets are ordered and delivered as separate items. Crossbar switches are supplied mounted on the racks. Certain other items are also purchased as separate units, such as testing equipment and IDF strips. A list of the items bought on a unit basis is given in Table 2.

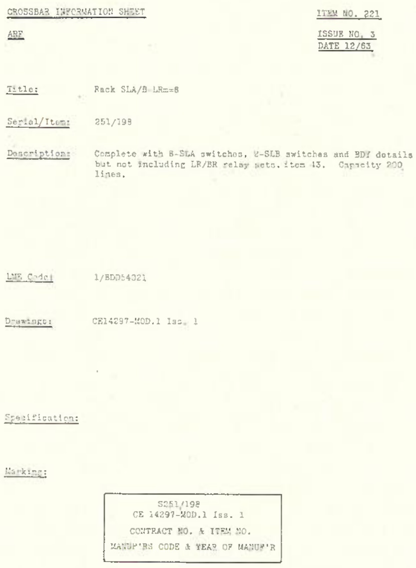
TABLE 2: SUMMARY OF ITEMS INCLUDED IN CATALOGUE

ARF Equipment		
Racks, BDD types	14	different types
Racks, BDH types	18	,, ,,
Racks, special types	4	,, ,,
Relay sets, BCH	84	,, ,,
ROA Boards	35	,, ,,
Relay Sets, other types	14	,, ,,
Other items, e.g. I.D.F. strips, Test Equipment	15	,, ,,
ARK Equipment		
Racks	10	different types
Relay sets	36	,, ,,

A.P.O. Catalogue

As the design information came to hand from L.M.E., a Catalogue of items was produced by the A.P.O. based on the original Schedule of Items but omitting explanatory notes on the usage of the items which had by this time served their purpose. This Catalogue specifies each item in terms of Post Office item numbers, L.M.E. codes, and L.M.E. drawing numbers. Later, as the designs became more stabilised, each item was further specified by a CE drawing number which became the standard reference. The CE drawings are, in general, reproductions of the L.M.E. drawings and in their first issue represented the then current issue of the L.M.E. drawings. Generally, whenever an L.M.E. drawing is re-issued, the corresponding CE drawing is also re-issued. There are times, however, when the L.M.E. or CE drawing is raised in issue without a change in the other, depending upon the need to incorporate a modification in current production or introduce it into the field, the decision resting with the A.P.O. A specific procedure was established to ensure that local manufacturers were given immediate advice of forthcoming changes so that they could arrange their production accordingly.

The Catalogue is presented on a page per item basis which enables a new page to be issued whenever the design information for a particular item changes. The Catalogue forms part of the contract documentation and equipment is supplied in accordance with the current issue of each page unless permission for a variation is given to the manufacturer by the A.P.O. A sample page is shown in Fig. 4. The item


CROSSBAR INFORMATION SHEET — ITEM NO. 221

ARF — ISSUE NO. 3, DATE 12/63

Title: Rack SLA/B-LRm-8

Serial/Item: 251/198

Description: Complete with 8-SLA switches, 8-SLB switches and BDF details but not including LR/BR relay sets, item 43. Capacity 200 lines.

LME Code: 1/BDD54321

Drawings: CE14297-MOD.1 Iss. 1

Specification:

Marking:

S251/198
CE 14297-MOD.1 Iss. 1
CONTRACT NO. & ITEM NO.
MANUF'RS CODE & YEAR OF MANUF'R

Fig. 4.—Typical A.P.O. Catalogue Information Sheet.

number appearing in the top right hand corner is a basic reference which appears on contracts and delivery schedules, and is used for identifying equipment in correspondence with suppliers, in delivery schedules and in all reviews of State requirements. The Serial and Item Nos. are the primary A.P.O. identification for the purpose of stores holdings, internal accounting and stores issues. All equipment used by the A.P.O. being similarly identified by item numbers within various serials. All items must be clearly marked by the manufacturer as shown on the sample catalogue page. When a page of the Catalogue is reissued it is despatched to A.P.O. Acceptance Testing Officers as well as to manufacturers so that they are kept informed of changes to equipment and see that only correct supplies are accepted into stores. The contract document itself gives no details of technical requirements but simply states the catalogue and serial item numbers, together with a brief item description; hence the need to reissue contracts bcause of technical changes is unnecessary.

In the early stages of the changeover to crossbar equipment, ordering was complicated by the lack of detailed knowledge of the system. For example, it was not known that ROA boards, which are printed circuits mounting electronic components comprising oscillators, amplifiers, etc., would be delivered as separate items. These boards plug in to many relay sets and can in price exceed the value of the relay sets on which they are mounted. Swedish practice is to deliver ROA boards after the relay sets have been installed on the basis that it is a simple matter for the installer to plug in these boards before testing commences. This method is satisfactory where the supplier installs the equipment but for bulk supply contracts and installation by A.P.O. staff it is necessary to minimise the number of items held in Stores and ensure that complete units of equipment are available to installers. This is particularly important where equipment is drawn from capital city stores for use in country centres hundreds of miles distant. It was therefore specified that ROA boards must be delivered with the relay sets to which they belong and be positively associated with them.

Another example is the provision of wire guides for P.B.X. relays on P.B.X. racks. These relays are installed according to the number of P.B.X. lines for each subscriber. They are therefore stocked as a separate item and withdrawn as required. Wire guides through which jumper wires pass are provided according to the number of relays fitted. These guides were provided on initial orders as loose items, separately covered in contracts in quantities estimated as representing likely requirements. Their cost is small and it was considered that it would be more economic to have each rack supplied complete with guides rather than bear the administrative costs of carrying an extra item in stores stock. More important, it would be an advantage to have them readily available to installers when they fitted the relays. Arrangements were therefore made for manufacturers to supply the full quantity of wire guides which could be accommodated on the rack, temporarily fitted to the rack with appropriate screws.

Design Changes

Since design and development of the L.M.E. system to suit A.P.O. requirements was arranged to run concurrently with manufacture in Australia, changes to rack and relay set circuitry and components became inevitable. Such changes have been classified as "Essential" to "Non-Essential", that is those that are necessary to make the system work satisfactorily and those that are desirable. In the essential category, contractors are given the choice of continuing production to completion to the previous design and modifying the equipment before delivery or halting production until details of the change are made known and then continuing to the new design. In either case, it is incumbent on the contractor to secure any necessary components to effect the change.

In some cases it was necessary to release equipment subject to change from the factories to permit urgent cut-over commitments to be met. This meant that modification, sometimes of a temporary nature, had to be made by installers and for this purpose any necessary parts had to be made available quickly. Special orders were placed for modification kits and to simplify the association of these kits with the relevant equipment they are branded with a Kit No. the same as that applying to the Catalogue Item subject to change. These kits are purchased from the contractor offering the quickest possible delivery and in some cases arrangements are made to have them despatched from Sweden by air.

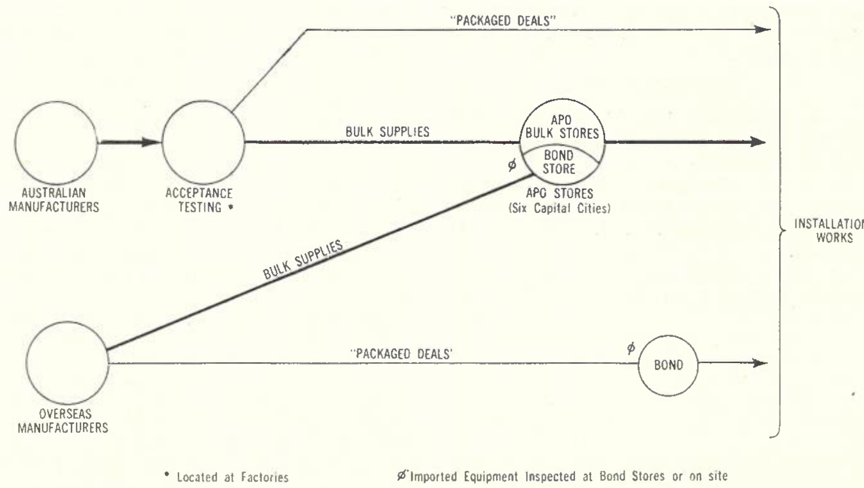


Fig. 5.—Movement of Supplies.

PROGRAMMING AND DELIVERY SCHEDULING

After orders have been placed, the contractors draw up proposed schedules of deliveries, item by item for each State, and submit them to the A.P.O. for approval. The A.P.O. and the contractors co-operate in achieving the most suitable schedule to fit the needs of both parties, that is the A.P.O. must be assured of continuity of supplies and the contractors should be able to proceed with production without the fear of unplanned changes in ordering level. Sometimes, a particular contractor cannot arrange his production to meet all the delivery requirements, perhaps because of difficulty in obtaining subcontracted items, but with three manufacturers in the field and a large installation programme it is generally possible to absorb minor delays by slight adjustments to the programme.

The delivery schedules are circulated to all six States where the Engineering Division examines them in detail against their planned installation programmes. At four-monthly intervals, State Engineers meet with Headquarters to study in detail the progress of the programme and the supply of material and if changes to previous plans indicate likely shortages or difficulties due to late deliveries, interstate transfers of material are arranged from stocks if the need is urgent or the contractors are asked to alter the distribution and priority of supplies to fit the needs. One of the biggest problems in obtaining satisfactory deliveries has been the need for manufacturers to import certain components but the continuing increase in the local manufacture of parts is improving the accuracy of delivery forecasts.

Another factor influencing delivery is the complexity of factory testing of racks and relay sets. The setting up time for testing is long and certain parts of the system must be tested in groups, for example the three parts of the register, REG-L. This means that unless all three parts of the register can be timed to be ready for testing together, holdups occur with resultant delivery delays.

FUTURE TRENDS

The system of bulk ordering adopted by the A.P.O. is not likely to be changed in the near future but methods of improving the system are under constant review. One of the biggest problems with bulk purchasing is the need to hold sufficient stocks of all items in store so that installation work will never be delayed because of short supplies but at the same time keeping stocks within the limits of the Stores Trust Fund. With an ever increasing programme this can only be done by increasing the turnover rate. This, in turn, calls for greater accuracy in ordering and a close control on the delivery times of equipment into store.

Stores stocks could be reduced by having part of each year's bulk supplies delivered direct to exchanges instead of to State stores. (See Fig. 5). This could be arranged for those new exchanges where completion of the exchange building could be forecast with reasonable accuracy. In terms of material value, about 40% of the annual purchase could be organised in this way and "packaged deals" of this type would enable stocks to be reduced by an equivalent amount. Such a scheme might operate on the following basis:—

Forward and short term orders would be placed as at present but contractors would be periodically advised of the items and quantities to be delivered direct to specified buildings by certain dates. Deliveries would be timed to match building completion dates and availability of installation staff.

If the building has not been completed by the date forecast, the equipment would be sent to store but all packages would be branded with the name of the exchange for which it was intended.

The balance of the year's order would be delivered to a central store, probably Sydney and Melbourne, for withdrawal when required by all States.

Now that the local manufacturers of crossbar equipment have an appreciation of the actual costs of production, it is intended to move away from the previous practice of placing orders on the basis of agreed prices and let contracts against quotations from each company for one, or perhaps two, years' supplies. This will entail an entirely new approach to the problems of material ordering involving price comparisons of predetermined blocks of equipment rather than of individual items, and the placing of contracts at ordering levels that will take advantage to the maximum extent of economic production in the factories.

CONCLUSION

The changeover to crossbar equipment was a major undertaking which demanded a new approach by Post Office engineers and technical staff to the problems of planning, programming, purchasing, installation and maintenance. Within five years of making the decision to introduce crossbar equipment as the new standard, 42,000 lines have been installed in 50 exchanges and a further 90,000 lines are at present (May, 1964) in course of installation.

Purchase on a bulk ordering basis proved satisfactory and involved the A.P.O. in detailed examination of the system design from the early stages of manufacture. This resulted in a much quicker and better understanding of the equipment than could have been expected had orders been placed for only fully engineered exchanges.

Although there were some delays in obtaining supplies on time, there were no serious breakdowns in the programme of exchange works. This was achieved not only by the individual and collective efforts of Post Office Staff, but also by the co-operation of the manufacturing companies who appreciated the problems and organised their productive efforts to meet A.P.O. requirements.

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3. E. R. Banks, "Crossbar Switching Equipment for the Australian Telephone Network"; Vol. 13, No. 2, page 85.

4. N. A. S. Wood, "Progress with Australian Manufacture of L M Ericsson Crossbar Equipment", Vol. 13, No. 2, page 113.

5. W. McMurray, "Petersham ARF 102—Crossbar Exchange Installation", Vol. 14, No. 3, page 191.

6. N. A. S. Wood and A. C. Wright, "Programming the Introduction of Crossbar Equipment"; Vol. 14, No. 3, page 174.

FURTHER READING

K. B. Smith, "Telephone Equipment Plant Practices in Australia"; Vol. 14, No. 2, page 122.

D. W. Archer, "Pilot ARF102 Crossbar Exchange — Petersham"; Vol. 14, No. 3, page 201.

N. A. S. Wood, "Introduction of Common Control Switching Equipment in Australia"; Vol. 14, No. 3, page 172.

CHANGE IN SOUTH AUSTRALIAN ENGINEERING DIVISION MANAGEMENT

Mr. V. F. Reeves, B.E.E., A.M.I.E.E., retired from the position of Assistant Director, Engineering Division, South Australia, on 29/6/64. He had a varied career, starting from an apprenticeship with an implement company in Victoria. He studied Electrical Engineering and gained a diploma in mechanical and electrical engineering at the Melbourne Technical College in 1921, followed by the B.E.E. degree at the Melbourne University two years later. Following graduation he spent a period as a lecturer at the Melbourne Technical College.

In 1927 he entered the Department and was appointed as an Engineer in the Transmission Section where he was concerned with transmission measurements in connection with some of the early carrier system installations. He was also involved in the laying of the Victoria-Tasmania submarine cable in 1930. He took his interest in transmission work to Central Office when he was transferred there in 1935. In 1939 he spent some months in South Australia in connection with a number of three channel system installations.

Mr. V. F. Reeves, B.E.E., A.M.I.E.E.,

He was appointed Divisional Engineer in 1942, Sectional Engineer in 1952, and Supervising Engineer in 1954 in the Long Line Equipment Section of Central Office. Then in 1957 he was appointed Assistant Director, Engineering, in South Australia and for the next eight years he steered engineering work in that State through difficult times of rapid growth, limited financial allocations, and major technical changes.

Mr. Reeves was the foundation chairman of the S.A. Division of the Society.

The Board of Editors on behalf of the Society wish to record their appreciation of his contribution to telecommunications in Australia and to wish him a long and happy retirement.

★

Mr. E. J. T. Symonds, B.E. (Mech.) succeeds Mr. Reeves. Mr. Symonds gained his B.E. degree at the Adelaide University in 1926 and joined the Department as an Engineer in the following year. His first three years in the Department were spent in Central Country Division. He was then transferred to Lines Section where he was successively appointed as Divisional Engineer in 1946 and as Supervising Engineer in 1957. During this period he invented the "Earth Saw" for use in installing subscriber cables and gained a major award from the Improvements Board in 1954 as a result. This machine, with further developments, has proved very successful in S.A., and there are now seven in service giving nearly twice the output of more conventional machines of the same size.

Mr. E. J. T. Symonds, B.E. (Mech.)

Mr. Symonds has been prominent in Postal Institute affairs, where he has been made a Life Member and has been an active member of the Professional Officers' Association, where he has also been granted life membership. He was recently appointed chairman of the S.A. Division of the Society. The Board of Editors and the Society have pleasure in congratulating Mr. Symonds on his appointment as Assistant Director and wish him well for the years ahead.

SELF-SUPPORTING AERIAL CABLE

R. A. CLARK, B.E. and P. J. O'NEILL, B.E., Grad.I.E.Aust.***

INTRODUCTION

Self-supporting plastic aerial cables are in small scale use in several overseas countries (1). They are generally special cables with hard drawn copper or cadmium copper conductors and greater than normal insulation thickness. In 1956 trial quantities of cable were purchased with 20 lb. hard drawn copper conductors and 15-20 mils of polythene insulation. The high cost of the special cable and the difficulties in jointing and terminating made the cost of completed installations greater than similar projects using standard cable lashed to a steel bearer wire and no further quantities were purchased.

In 1960 some installations of standard plastic cable as self-supporting aerial cable were made by Engineers in the Geelong Division, Victoria, and at the Training School in Perth. The first portion of this article outlines theoretical studies made to assess the possibility of using plastic cable in this way; the remainder of the article describes an actual installation.

MECHANICAL DATA

Stress-strain diagrams were prepared for "soft" copper cable conductors. These showed:—

Average breaking stress = 32,200 lbs. per sq. in.

Elongation at break = 25%.

Average Youngs Modulus on initial loading to 12,000 lbs. per sq. in. = 7.35 x 10^6 lbs. per sq. in.

Strain at 12,000 lbs. per sq. in. = 0.163%.

Modulus on subsequent loadings = 13.75 x 10^6 lbs. per sq. in.

They also showed that the strain increased by 0.043% after 20 load cycles between zero and 14,500 lbs. per sq. in. Published data for low density polythene was also examined for strains of the order expected in cables. Under normal conditions the strain would not exceed 0.50% and the stress corresponding to that strain would be 70 lbs. per sq. in. at initial loading, reducing to about 40 lbs. per sq. in. after 15 hours. Stresses and strains of this order have negligible effect on polythene. The initial modulus of polythene is about 14 x 10^3 lbs. per sq. in. which is about 0.2% of the modulus of soft copper on initial loading. Thus for equal strains, as in a cable, the stress in the polythene will be only 0.2% of that in the copper.

In a typical 50 pair/6½ lb. conductor (50/6½) cable, with 12 mils insulation on each conductor, the cross-sectional area of polythene is about ten times that of the copper. Thus only about 2% of the tension in a moderately loaded cable would be carried by the polythene so that the plastic can be neglected in designing working sags and tensions.

On substantial overloads, however, the initial modulus of the copper falls significantly while that of polythene remains constant so that at 1% elongation the copper stress would be 18,700 lbs. per sq. in. and the polythene 160 lbs. per sq. in. so that the load ratio, for 50/6½ cable, would be 92% copper to 8% polythene. At 3% elongation the ratio would be 85% to 15% and at 20%, i.e., just before the conductors would break, the ratio is 71% to 29% which means that the short-term breaking load is approximately 40% greater than for the conductors alone. For very slowly applied loads or repeated loadings the increase in strength would not be so great, but would still be significant.

SAG AND TENSION CALCULATIONS

From the above data it was decided that designs based on neglecting the strength of the polythene and on a stress of 17,000 lbs/ per sq. in. in the copper when cables are subjected to wind pressures of 10 lbs. per sq. ft. at temperatures of 40° F. would have an adequate safety factor. The erection sags necessary to achieve this were determined using a Universal Sag Chart. The stress in the copper at erection was also determined. For some heavy cables, viz., 75/10, 75/20 and 50/20, this stress was found to be as high as 14,000 lbs. per sq. in. and, as this was considered excessive, the maximum erection stress for these cables was set at 11,000 lbs. per sq. in.

These sag calculations assume that the modulus of copper remains constant up to 17,000 lbs. per sq. in. and are, therefore, only valid provided cables are prestressed to this figure at erection and then slackened off to their erection sag. The possibility of revising the sag tables to eliminate prestressing was checked, but was discarded, as the erection stress would in all cases approach 17,000 lbs. per sq. in. and the cables would spend their early life at this high stress. Prestressing also tends to ensure that all conductors are stressed equally.

SAG TABLES

Examination of the calculations for twin plastic cables with 12 mils insulation showed that the cables fell naturally into four groups:—

A. Cable sizes up to 15/6½, 10/10 and 5/20—Unsuitable for self-supporting cables.

B. Cables sizes 25/6½, 5/10, 10/20—for sags see Table 1.

C. Cable sizes 50/6½, 75/6½, 25/10, 15/20 —For sags see Table 2.

D. Cable sizes 50/10, 75/10, 25/20, 50/20, 75/20—For sags see Table 3.

OTHER CONSIDERATIONS

Termination

At terminations most of the tension in the conductors must be transferred to some supporting structure so that jointing and allied operations can

TABLE 1: SAGS FOR CABLES IN GROUP B.

Temp.	Span Length in Feet							
	100	132	150	165	180	200	250	300
40°F.	21″	37″	48″	58″	69″	85″	133″	192″
60°F.	22″	38″	50″	60″	71″	88″	138″	198″
80°F.	23″	40″	51″	62″	74″	91″	142″	205″
100°F.	24″	41″	53″	64″	76″	94″	147″	212″
120°F.	24″	42″	55″	66″	78″	97″	152″	218″
Pre-stress	6″	11″	15″	18″	21″	26″	41″	59″

TABLE 2: SAGS FOR CABLES IN GROUP C.

Temp.	Span Length in Feet							
	100	132	150	165	180	200	250	300
40°F.	13″	23″	30″	36″	43″	53″	82″	119″
60°F.	14″	25″	32″	39″	46″	57″	90″	129″
80°F.	15″	26″	34″	41″	49″	60″	94″	136″
100°F.	16″	28″	36″	44″	52″	64″	101″	145″
120°F.	17″	30″	39″	47″	56″	69″	108″	155″
Pre-stress	6″	11″	15″	18″	21″	26″	41″	59″

*Mr. Clark is Engineer Class 3, Lines Section, Headquarters. See page 423.

** Mr. O'Neill is Engineer Class 2, Armidale Division, N.S.W. See Vol. 14, No. 3, page 25.

TABLE 3: SAGS FOR CABLES IN GROUP D.

Temp.	Span Length in Feet							
	100	132	150	165	180	200	250	300
40°F.	9″	15″	19″	23″	27″	34″	53″	76″
60°F.	10″	17″	22″	26″	31″	38″	60″	86″
80°F.	11″	19″	24″	29″	35″	43″	66″	96″
100°F.	12″	21″	26″	32″	38″	47″	73″	106″
120°F.	13″	23″	29″	35″	42″	52″	80″	116″
Pre-stress	6″	11″	15″	18″	21″	26″	41″	59″

be performed. As the conductors cannot be connected directly to the supporting structure this tension transfer must take place through the conductor insulation and the sheath.

A suitable termination would be one where the cable is coiled around a drum. Then at any point if the radius of the bend in a conductor is R inches and the tension is T lbs. the reaction between the conductor and the insulant is T/R lbs. per inch of conductor. If the conductor diameter is D inches and we assume uniform pressure between the conductor and the insulant the pressure is T/RD lbs. per sq. in.

For polythene insulation the pressure should not exceed about 200 lbs. per sq. in.

For $6\frac{1}{2}$ lb. conductors, $T_{max} = 6$ lbs. approx.

and $D = 0.020''$

$\therefore R_{min} = 1.5$ ins.

And for 20 lb. conductor, $T_{max} = 18$ lbs. approx.

and $D = 0.035''$

$\therefore R_{min} = 3.2$ ins.

The actual pressure is not uniform, particularly with twin cable, so that drums of radii 5 ins. to 9 ins. are probably essential. An interesting observation on these results is that the performance of cables with small soft copper conductors is likely to be better than that of cables with large and high strength conductors.

Checking the pressure between the cable sheath and the drum shows that the pressure per unit length is again T/R where T is now the total tension in the cable. For a pressure not exceeding 200 lbs. per sq. in. the resultant flat contact between a flat drum and the deformed cable sheath would be about 0.2 in. wide for a $15/6\frac{1}{2}$ and 0.4 in. for a $75/6\frac{1}{2}$ cable. These deformations should be tolerable but, of course, grooved drums are to be preferred.

The number of loops required around the drum can be assessed by the "belt-on-pulley" formula $T_1/T_2 = e^{kw}$ where

T_1 is the inspan tension.

T_2 is the residual tension.

k is the co-efficient of friction between the sheath and the drum.

w is the angle through which the cable is wrapped, around the drum, in radians.

e is 2.718.

Thus T_2 will never be zero but, for $k = 0.4$, $1\frac{1}{2}$ loops around the drum will reduce T_2 to about 1/40th of T_1 which should be satisfactory.

Alternatively terminations could be made using the principles of the patented "Preformed Guy Grips". With these there is no doubt that sufficient bond will be achieved between the grip and the sheath but unless the grip is longer and tighter than normal there may be insufficient friction between the cable core and the sheath.

Support at Intermediate Poles

At intermediate poles the vertical reaction equals the weight of the cable plus an allowance for vertical and/or horizontal angles in the route. The pressures developed will not be excessive provided the loading can be distributed over about two to four inches for angles up to 20°. Over this angle it is desirable for the cable to be terminated.

Changes in Sag in Service

Even after pre-stressing there will be a gradual increase in the sag under no wind ambient temperature conditions because the modulus of the copper wire is slightly lower for increasing stresses than for decreasing stresses. Thus a typical cable at 80°F. and no wind in a 165-foot span might have a sag of 44 ins. If the cable is subject to a 10 lbs. per sq. ft. wind at 40°F. and then returned to 80°F. and no wind, the sag will increase to 44.6 ins., i.e., about 1% increase. Subsequent loadings would not increase the sag as much. The smaller stress changes due to temperature variation and light winds would have very little effect individually, but may have a noticeable effect over a long period.

However, cables could be re-sagged to their original condition many times without detrimental effect.

Effect on Cable Characteristics

Placing the conductors of twin or quad cable under tension will reduce the average conductor spacing inside the cable core thus slightly increasing the mutual capacity. It is unlikely that the increase would take the cable outside its specification limits. The slight elongation of the conductors will have negligible effect on conductor resistance.

APPLICATION TO QUAD PLASTIC CABLE

In 1963 quad plastic cables with reduced insulation and sheath thickness in most sizes were adopted as standard. The sag and tension calculations were repeated for the new cable and it was found that tolerable sags could be achieved at lower stresses thus leading to an improved safety factor and reduced stresses at supports. The design basis for these cables was:—

Maximum stress under high winds and low temperatures—14,000 lbs. per sq. in.
Maximum stress at erection—900 lbs. per sq. in.

The cables were again grouped into the four erection sag categories used previously, viz.

Group A—Up to 30/4; up to $20/6\frac{1}{2}$; 10/10.

Group B—50/4; 70/4; $30/6\frac{1}{2}$; 20/10; 30/10; 10/20.

Group C—100/4; $50/6\frac{1}{2}$; $70/6\frac{1}{2}$; 50/10; 20/20.

Group D—70/10; 100/10; 30/20; 50/20; 70/20; 100/20.

FIELD INSTALLATION

Trial installations have been made in several States and the results to date indicate that self-suporting cables are technically feasible and economically attractive in situations where frequent access to pairs for distribution purposes is not required. The only reported troubles have been on one installation where two conductors failed at repair joints inserted during manufacture. The rate of increase of sag has in all cases been very slow.

Self-supporting cables are particularly attractive for non-permanent installations. The remainder of this article describes one such case. It was the provision of extra junction circuits between Inverell and Elsmore, N.S.W., to meet Extended Local Service Area (E.L.S.A.) needs. The logical method of providing the additional circuits was by erecting physical open wire lines on the existing aerial trunk route between Inverell and Glen Innes and providing extensions on the spur routes where necessary. The provision of all the circuits by open wire would have meant that less than standard clearances would apply over road crossings in the Inverell town area. This problem will eventually be solved by upgrading the route. In the meantime, it was decided to use aerial cable, 15 pair 20 lb. conductor plastic cable being chosen. The length of cable to be provided (some 11.3 miles) meant that loading would be necessary, 5,000 feet intervals between loading points being used instead of the more usual 6,000 feet intervals to allow for the different transmission characteristics of the plastic cable as opposed to paper insulated lead covered cable.

Installation Methods

Renewal of Poles: The route chosen was one which was in the process of being respaced progressively in conjunction with pole renewals. All "key"

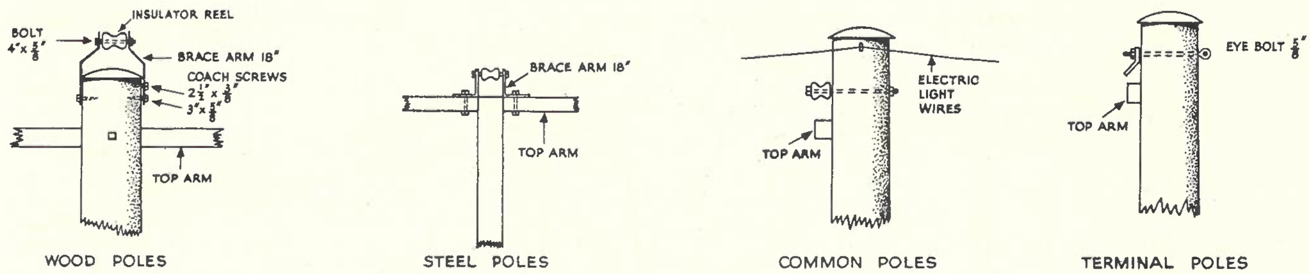


Fig. 1.—Methods of Attaching Self Supporting Cable to Poles.

poles with an expectant life of less than five (5) years were replaced on their correct spots so that pole renewals would be simplified during the expected life of the cable. "Key" poles in this case were poles on which joints were to be made and particularly those in the vicinity of which loading coils were to be installed.

Supports: Owing to clearance problems, it was decided to suspend the cable from or near to the tops of all poles along the route. On wooden poles the support was fashioned from a reel insulator and an 18-inch arm brace attached to either side of the head of the pole with 3 in. x $\frac{5}{8}$ in. coach screws. A further $2\frac{1}{2}$ in. x $\frac{3}{8}$ in. coach screw was fastened through one brace to the pole to position the support. On steel poles, the braces were simply bent at right angles and attached to the top cross-arm. On common poles, a $\frac{5}{8}$ in. bolt and a reel insulator were used. Fig. 1 shows the different methods.

Terminations: Guy grips were attached to poles and wound round the cable to hold it at either side of all joints, angle poles and road crossings. In addition, a bearer wire was erected at all road crossings and the cable attached to it by means of a cable spinning machine. This was done as a safety precaution and also to get the necessary clearance at some crossings.

The grips used were preformed terminations consisting of five strand twisted galvanised iron wire with a resin coating on the inside. The grips were found to be very stiff to apply, so two of the strands were unwound and removed. The resulting three stranded grip was then applied fairly easily except for the last turn or two. These turns were left unwound in the finish as the grip was already secure enough. Fig. 2 shows the grips at a jointing pole. The grips were attached to the pole by passing them through a $\frac{5}{8}$ in. eyebolt and lug. Some difficulty was experienced in passing the grip through the lug and it was necessary to first remove the thimble fitting.

Erecting Cable: The cable was laid out prior to erection and a method was devised to position the cable from the ground. This was done in the following steps which are illustrated in Fig. 3.

Stage 1—One end of the cable was tied in using a preformed termination. One man then pulled a loop of slack cable into the centre of the line, using a forked stick with a hook on the side at first, while the second man assisted the cable to slide over the live wires.

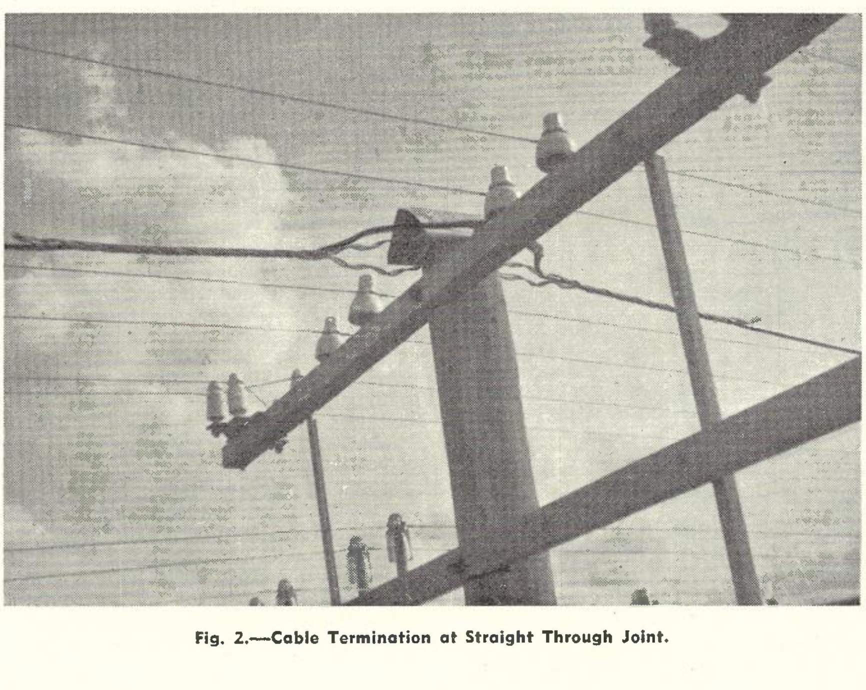


Fig. 2.—Cable Termination at Straight Through Joint.

Stage 2—Both men walked along the span, one in the centre of the wires to keep the running loop in the cable, and the other at the side to assist in sliding it over the wires.

Stage 3—At the next arm, the leading man flicked the cable over the spindles and insulators into the centre.

Stage 4—The man in the centre then let go the slack and used the fork on the stick to lift the cable onto the reel insulator. He then pulled the slack into the next span and so back to Stage 1.

This method used a small number of men, reduced climbing of poles to a minimum and did not cause any interference to the working open wire lines.

Tensioning: The cable was tensioned in accordance with the values of sag given in Table 2—pre-stressing to a tension equal to that likely to occur under design maximum load conditions was carried out to minimise the gradual increase in sag expected during the early years after installation. One of the preformed terminations was used as a tensioning grip and the cable was pulled up with a truck. Two men were required up suitable poles with sighting sticks fixed at the required pre-stress and final stress distances as stipulated in the sag tables for the prevailing temperature. A truck driver and a man in charge were also necessary.

An attempt was made, using a dynamometer in the tensioning line, to convert the sags to tensions and so reduce the labour involved. However, the tension readings taken for the same sags at the same temperature varied by as much as 24% and this method was abandoned. It is probable that the variation in tensions was due to the varying number of spans in a length to be tensioned, thus varying the total frictional resistance of the supporting reels. Another factor may have been the unevenness of the ground.

Tying In: The cable was tied in to the reel insulators at every pole except those at which terminations were provided. A length of plastic pipe with a helical slit was wrapped around the cable to give added protection against rubbing and 60 lb./mile galvanised iron binding wire was used to do the actual tying in.

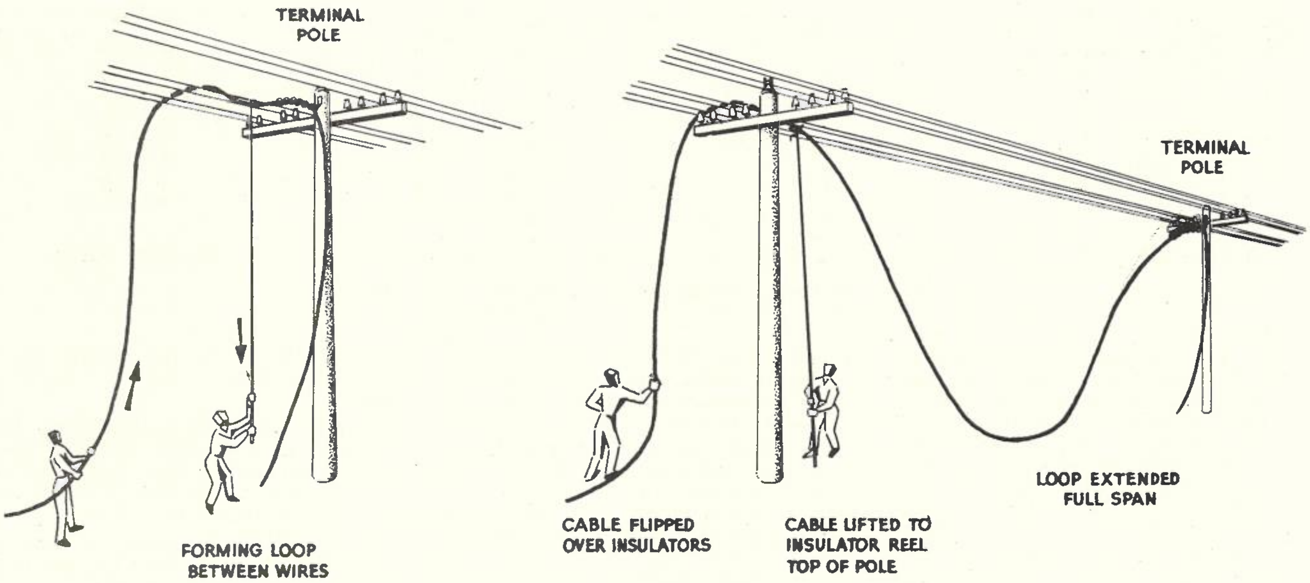


Fig. 3.—Erection of Self Supporting Aerial Cable.

Jointing: All the straight through joints were made up the pole. Hot twist conductor joints were used. To protect the jointer and his torch from the wind a jointer's tent was modified to allow it to be installed up the pole. A special jig to hold the cable was also developed. Fig. 4 shows the equipment in use.

Loading: The loading coils were small enough to be installed in a standard 36 in. x 18 in. x 18 in. asbestos jointing pit. The loading coil tails were jointed to two lengths of steel tape armoured cable which were taken up the pole and jointed to the aerial cable using an aluminium sleeve and expanding rubber plug with holes of suitable size. As it is reasonably simple to gain access to the joints in the aluminium sleeves, only the working pairs in the aerial cable were jointed to the lead cable leading to the loading coils. This was done to protect the spare coils in the loading pots from lightning damage.

Suggested Improvements

If this method of providing circuits becomes widespread, a number of improvements could be implemented. Selected lengths of cable could become an economical proposition for long extensions. With 20,000 yards (i.e., 40 x 500 drums) of cable used on this job, an average waste of a half a span ($22\frac{1}{2}$ yards) was left over per drum. This resulted in 900 yards of short lengths being left over.

The manufacture of supports from other standard items of equipment cannot be economical, and their standardisation and special manufacture, together with the attendant benefits of collective schedule purchases, would be desirable. This would also apply to the manufacture of standard clips for holding the cables at loading points to the poles; in the Inverell-Elsmore case these were also specially manufactured. Four way combiners were attached to the pole at the top of the cable run to prevent a ladder against the pole from crushing the cables and these could probably be replaced with a cheaper new item.

The discarding of the two strands from the grip and the thimble from the terminating lug is wasteful. A grip, using, say five (5) strands of a lighter and more flexible wire with a heavier coating of resin is desirable.

Fault History

At the date of writing this article, the cable had been in service for just on two years and its performance had been quite satisfactory. Transmission measurements made initially indicated that the cable has characteristics equal to that of underground paper insulated cable of the same conductor weight and no deterioration in these characteristics has become evident.

Special arrangements were made to ensure that lightning strikes would not penetrate from the aerial cable to the underground cable at the Inverell end. Arrestors to earth from each leg of each pair of the aerial cable were provided by jointing the aerial cable to the tail of a protected terminal box. This box was tied to a second box with bridle wire and its tail jointed to the underground cable.

Some of the grips failed to hold and the slack in the cable at angle poles was taken up. Whilst this did not cause any faults, it was undesirable. The slipping was considered to be due to the grips having been taken off and put on a few times during installation, resulting in much of the resin being rubbed off.

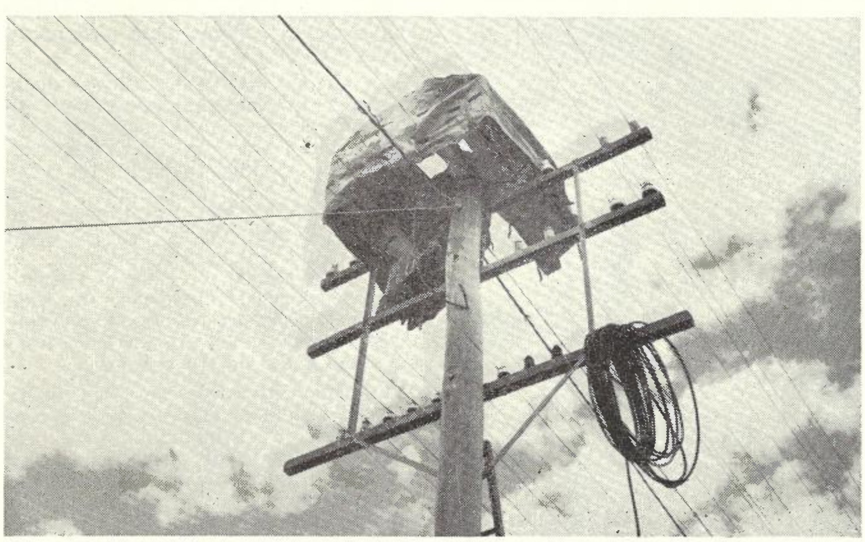


Fig. 4.—Jointers Tent Installed up a Pole.

Replacement of faulty grips has been effective in stopping a recurrence of this trouble and better designed grips should probably eliminate it. No significant sag changes have been observed.

A fault caused by a bullet piercing the sheath and severing some of the wires has been recorded. A short-circuit was in evidence and the approximate location was obtained by standard methods. Accurate location was then made by visual inspection of the cable in the vicinity of the fault using field glasses from the ground. The repairs were made by erecting a bearer wire in the span affected and spinning the cable onto it. This may be an appropriate method of remedying all faults in span.

The only other faults recorded were two open circuits and these were both located with considerable accuracy using a Line Fault Test Set. In each case the fault was the result of a manufacturing joint in a wire breaking under strain at the point where it had been welded. The answer to this may be an approach to the manufacturer to improve his technique in this regard.

CONCLUSION

Although some difficulties were encountered in an initial field installation, particularly with the design of the terminating grips, it is suggested that the use of self-supporting aerial cable may prove more economical that spinner-erected cables and possibly even more economical than integral bearer cables.

REFERENCE

1. J. Bluring and H. F. Snow, "Experiment in Aerial Cable Construction"; Post Office Electrical Engineers' Journal, Vol. 52, Part I, page 47.

Mr. W. H. WALKER, B.E., A.M.I.E.Aust.

Mr. W. H. Walker retired from the position of Assistant Director-General, Lines, Headquarters, on 7th August, 1964, after an outstanding career which began in Queensland in 1929.

Mr. Walker's initial service as Engineer in the Department was in the Queensland Metropolitan Lines, Transmission and Country District Works Divisions. After 10½ years' field experience, he transferred to Headquarters in 1940, where he became an expert on transposition and trunk line design. During World War 2 he prepared many designs for new trunk lines and carrier bearers to provide urgently required defence circuits in the northern part of Australia.

In 1951 Mr. Walker transferred to the Victorian Administration as Divisional Engineer, Trunk Planning, and in 1953 was promoted back to Headquarters Lines Section as Sectional Engineer, Service. In this capacity, he was largely responsible for the creation of the Joint Power Co-ordination Committees and the preparation of Codes of Practice to meet power co-ordination problems arising from the post-war expansion of rural power line construction.

In 1959 Mr. Walker was appointed Supervising Engineer, Lines, where his first major task was the co-ordination of all external plant aspects of the Sydney-Melbourne Coaxial Cable Project. Under his wise leadership the Headquarters Lines Section has successfully met many problems and pressures arising from the application of new materials and techniques. Mr. Walker was particularly active in ensuring that the Headquarters Lines Section continued to provide a high calibre of support and assistance to the various States in their endeavours to meet continually increasing demands for service on limited budgets.

Mr. Walker displayed great qualities of leadership as well as high technical ability. His quietly spoken manner, mature judgment, and warm personal charm endeared him to hundreds who were fortunate to be associated with him. An outstanding attribute was his capacity to imbue team spirit into all levels of his staff; he had a knack of making even the junior officer feel important and was always ready to see problems from the other person's viewpoint.

Mr. Walker took a keen interest in the Telecommunication Society of Australia and actively supported the Journal. He was the author of several excellent articles and encouraged the writing of many more. He was Honorary Secretary of the Postal Electrical Society of Victoria from 1942 to 1951 and on his resignation was elected Life Member of the Society.

The Board of Editors on behalf of the Society take this opportunity of acknowledging Mr. Walker's fine service to the Department and the Society and trust that he will enjoy a long and happy retirement.

NEGATIVE IMPEDANCE REPEATERS—PART I.

*M. O'CONNOR, B.E.E.**

INTRODUCTION

The Australian telephone network has a requirement for two types of trunk lines:—

(i) Those where the transmission loss from end to end can be adjusted to a nominal value of zero (called "zero equivalent circuits").

(ii) Those where the transmission loss from end to end is restricted to a maximum of 6 db (called "6 db equivalent circuits").

These trunks are constructed into a transmission network in which no more than two 6 db equivalent circuits can be in any one connection.

In big cities, the network consists of either relatively short circuits each with a loss of about 4 db., a typical connection consisting of three such circuits in tandem, or direct circuits, with a loss of approximately 10 db., which connect exchanges without intermediate switching. The latter type is becoming common with the introduction of crossbar switching. Such circuits will be referred to as "city junctions".

Up until recently the 6 db. equivalent circuits and the city junctions were exclusively passive, a heavier gauge conductor being used to keep the loss within the limit as the length became longer. However, the cost of these passive circuits is very high, and in recent years the practice of amplifying lighter gauge conductors has been introduced.

PERFORMANCE OF V.F. AMPLIFIED CIRCUITS

Three types of amplified circuits available are:—

(i) 4-wire.

(ii) 2-wire with hybrid coil amplifiers or repeaters.

(iii) 2-wire with negative impedance repeaters.

Types (i) and (ii) have been used in the trunk network for many years. 2-wire amplified circuits have never been highly regarded due to various factors. The use of 2-wire repeaters in the early days, in open wire lines on which varying climatic conditions have an adverse effect on the constancy of line-up levels, is one example of this; another is their use over links which originally may have been allowed some loss, but which in the evolution of the trunk network became zero equivalent links. Although little can be done to remove the limitations of 2-wire amplified circuits, they can nevertheless provide a satisfactory circuit if allowed to operate on suitable lines and at some loss as in the case of 6 db equivalent circuits and city junctions.

Four-Wire Circuits

A typical four-wire circuit is shown in Fig. 1. It is readily observed that a signal originating at, say, hybrid-line at station A will reappear at its starting point changed in level by the loop gain which equals:—

$$2G - 2L - R(Z_y/Z_c) - R(Z_x/Z_c)$$

where: G db is the total gain of the amplifiers in each direction; L db is the in each direction; $R(Z_y/Z_c)$ db is the drop in level experienced by the signal when it is partially reflected at hybrid-line at station C (this is equal to the return loss between the terminating impedance Z_y and the hybrid network "compromise" impedance Z_c); and $R(Z_x/Z_c)$ db is the corresponding drop in level at Station A. If simultaneously at any frequency the loop gain becomes equal to or greater than zero db and the corresponding loop phase change is some whole number multiple of 360 degrees, then the system will oscillate at that frequency.

When the circuit is lined-up at some nominal frequency to a zero equivalent from hybrid-line at one end to hybrid-line at the other end, i.e. $G = L$, the loop gain will equal:—

$$-R(Z_y/Z_c) - R(Z_x/Z_c),$$

and under these conditions the system is liable to be unstable when the return losses are zero or worse.

It is worth noting that since the amplifiers are one way devices only, any reflected currents set up in the 4-wire path due to mismatches in the line (irregular loading sections, changes of gauge in the conductor, etc.) or a mismatch between hybrids, lines and amplifiers, would only be of a secondary order of magnitude when contributing to instability. (These same defects may also cause irregularities in the insertion loss/frequency response of the line, thus making the loop gain at some frequency higher than at the line-up frequency. Instability due to this aspect is rarely a problem.)

It may be concluded then that the only important contributors to instability in a zero equivalent 4-wire amplified circuit terminated with finite impedances are:—

(i) reflections at the terminations.

(ii) irregularities of the amplifier gain or line loss over the pass band which cause the loop gain at a particular frequency to be greater than that at the line-up frequency.

With proper engineering control these two items can be reduced to almost negligible proportions, thus making 4-wire circuits suitable for use as zero equivalent circuits.

Two-Wire Hybrid Repeaters

A typical 2-wire hybrid type amplified circuit is shown in Fig. 2. It will be observed that the hybrid coils may have two different types of balance networks—one Z_c, the same as in the 4-wire case (the compromise network) and another Z_p, called the precision network, which is designed to represent as closely as possible the sending end impedance of the line on the other side of the hybrid. The expression for the loop gain of 2-wire amplified circuits such as the one shown in Fig. 2 will contain the factors derived above together with:—

(i) terms resulting from return losses between Z_p and the line impedance, Z_1, at each point where a mismatch occurs between these impedances. These will be called the "precision return loss factors".

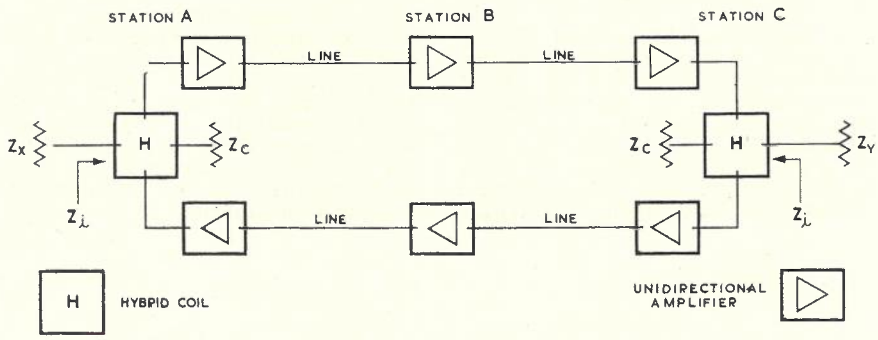


Fig. 1.—Typical 4-Wire Circuit.

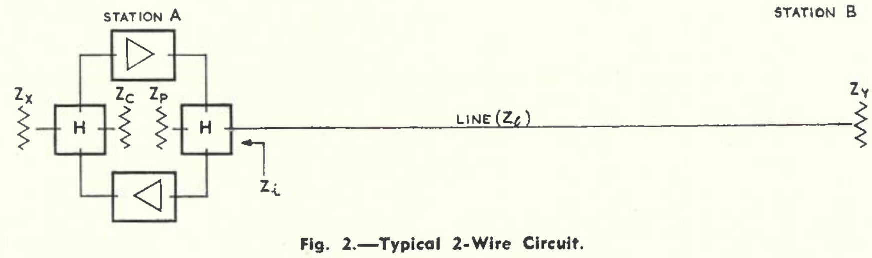


Fig. 2.—Typical 2-Wire Circuit.

*Mr. O'Connor is Senior Engineer, Overseas Telecommunications Commission. See page 422.

(ii) terms resulting from reflections within the line itself due to bad loading, etc., which will be called the "structural return loss factors".

(iii) terms resulting from return losses between Z_1 and Z_i, which will be called the "image return loss factors". (Z_i, the image impedance of the repeater, is mainly a function of the parallel combination of the input impedance of the transmitting amplifier and the output impedance of the receiving amplifier.) Normally, when the line is equipped with only one repeater, this factor will not be very important but with more than one repeater in the line it has a large effect since the reflected signal is amplified.

Since the hybrid repeaters amplify in both directions, these three items contribute towards instability to such a degree, that this type of circuit cannot be successfully operated at a zero equivalent.

Two-Wire Negative Impedance Repeaters

If some negative resistance (—R) is inserted into a line such that it carries a current I, then the power absorbed by the negative resistance is $—I^2R$, i.e., power equal to I^2R is supplied to the line in the form of an amplification of the signal. Use can be made of this for producing an amplifier for a transmission line. Such an amplified line will also have stability problems, but these will not be discussed until negative impedance repeaters have been investigated in the following sections.

It may be stated, however, that there are generally more stability problems encountered with negative impedance repeaters than with 2-wire hybrid repeaters.

NEGATIVE IMPEDANCE REPEATERS

Concept of Negative Impedance

In Fig. 3 the impedance-frequency loci of several commonly known passive networks have been drawn on the usual impedance axes using frequency as a "running parameter".

f_0 denotes 0 cps.

f_∞ denotes high frequency.

f_m denotes some mid-band frequency.

It is not surprising to note that no parts of the loci appear on the left-hand side of the vertical axis since this would be the domain of negative resistance which cannot be obtained in a passive network. However, if the possibility of active elements can be admitted then it should be possible for a locus similar to, say, Fig. 3 (c) to be drawn on the left-hand side of the axis as shown in Fig. 4 (a); i.e., the locus of a generalised negative impedance.

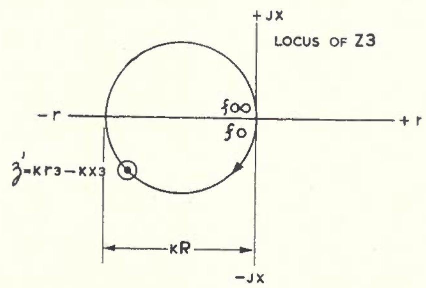
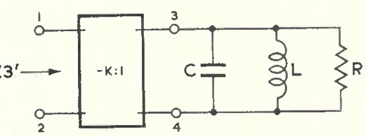


Fig. 4.—(a) Locus of a Negative Impedance.



(b) Negative Impedance Conversion.

In synthesising apparatus to provide this locus, a 4-terminal device 1234, as shown in Fig. 4 (b), would be needed, where k is some proportionality factor (assumed for the moment to be a real number and independent of frequency).

Negative Impedance Converters

There are various circuits which are capable of transforming a positive resistance to a negative quantity but all suffer the following disadvantages:—

(i) the transformation ratio k is not constant over the frequency band.

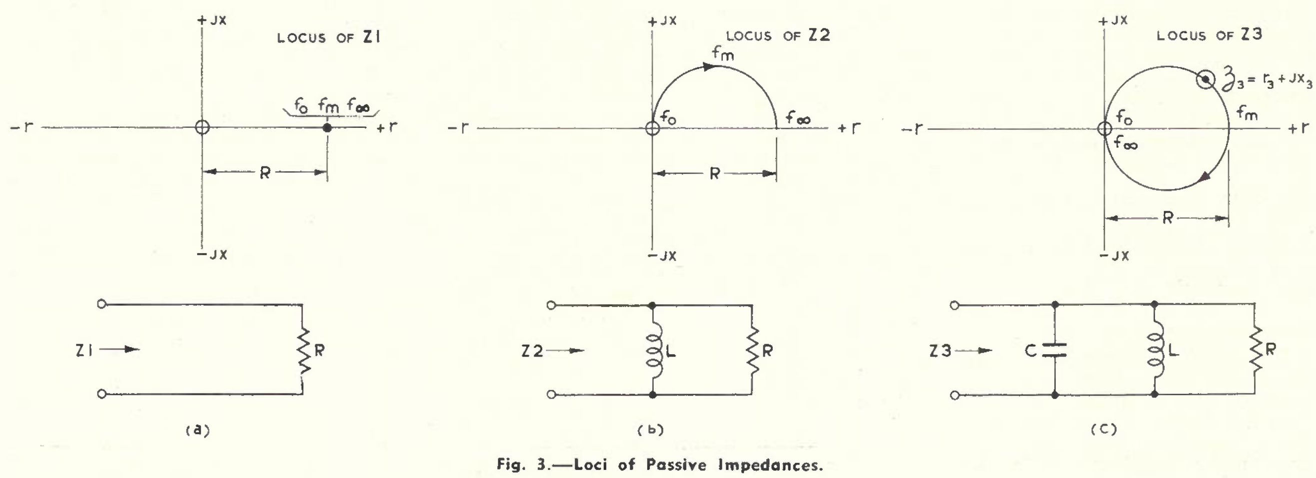
(ii) k approximates to a real number at mid-band only and takes on complex values at low and high frequencies. This is due, as can be expected, to the presence of unwanted parasitic reactances present in all valve and transistor circuits, i.e. series inductance and shunt capacitance at high frequencies, and series capacitance and shunt inductance at low frequencies.

(iii) the inevitable amount of parasitic impedance associated with the circuits will have the effect of converting an impedance Z_n, not into $—kZ_n$, but into $(Z_u —kZ_n)$. Z_u, the unwanted component, can be reduced to a small order by good design.

The circuitry used in these converters is not new (Bartlett considered them in 1927) and devices to obtain negative resistance were used in early radio receivers. It has only been recently, however, that suitable lines, and modern components have made the device suitable for use as telephone line amplifiers.

Classical feedback techniques are used in the design of the converters since they always consist of some form of regenerative circuit. (References 2, 3, 4, 6, 7, 8.) Fig. 5 which illustrates a complete "series-shunt" negative impedance repeater contains two modern transistorized converters.

Series and Shunt Converters: In Appendix A some basic feedback considerations are discussed to illustrate that negative impedance converters fall into two groups—those which remain stable (i.e., will not produce self-sustained oscillations) when their input terminals are open circuited, but are unstable when they are short circuited, and those which remain stable when their input terminals are short circuited but are unstable when they are open circuited. The former type of converter is obtained from an amplifier by feeding back a reversed voltage in series



(a) (b) (c)

Fig. 3.—Loci of Passive Impedances.

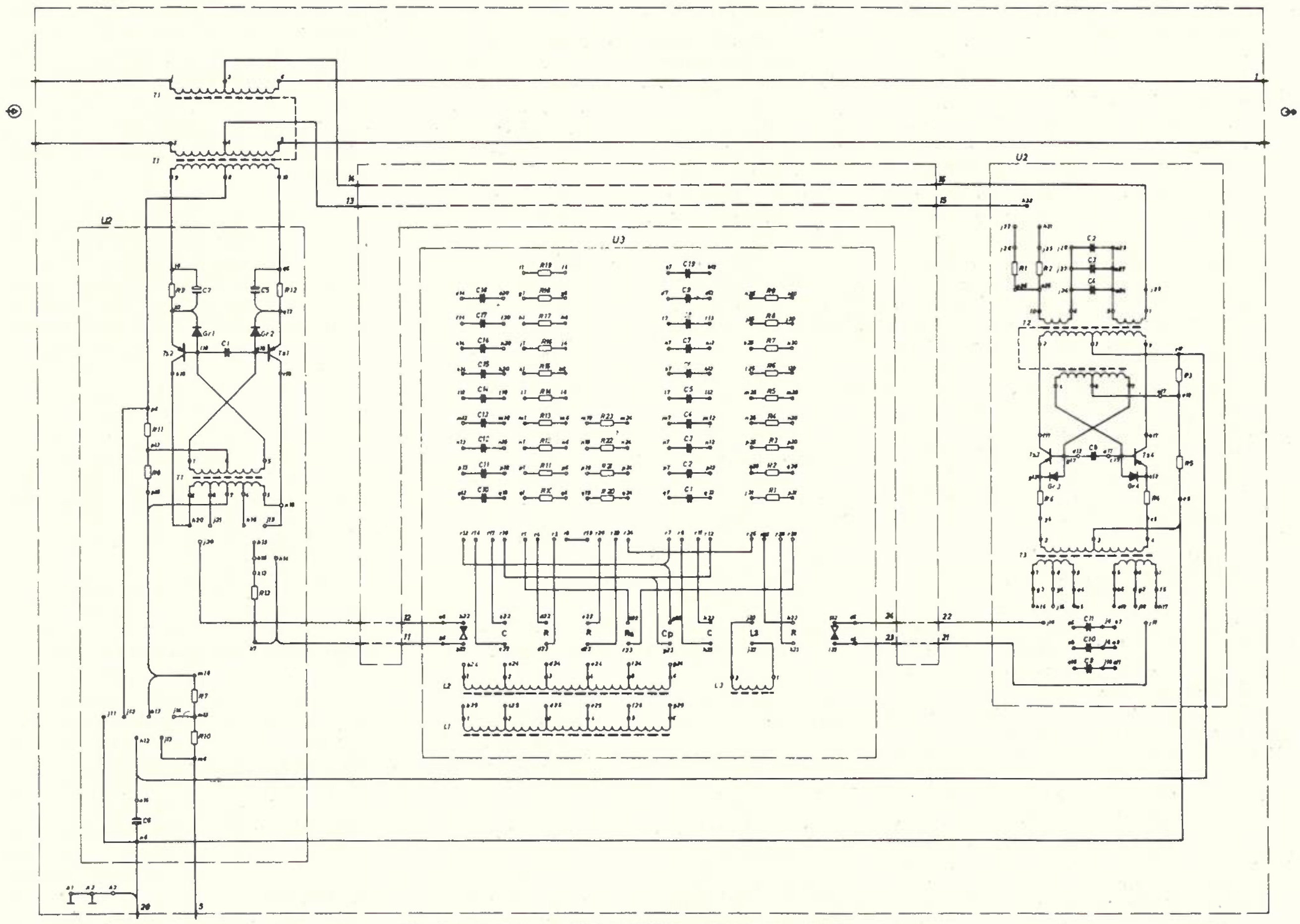


Fig. 5.—Circuit Details of Philips Negistor, Type 8TR 137.

with the input signal (positive series feedback) and consequently this unit is called a series converter. The latter type is obtained from an amplifier by feeding back a reversed current in parallel with the input signal (positive shunt feedback), and consequently this unit is called a shunt converter.

Appendix A also shows that the four terminal network 1234 of Fig. 4 (b) provides a series type converter when the positive impedance is connected to terminals 3 and 4, while a shunt type converter is provided when the positive impedance is connected to terminals 1 and 2, provided $0<k<2$. This suggests that, as far as the electrical repercussions are concerned, multiplying by —1 is different from dividing by —1. Recalling that the series converter is provided by reversed voltage type feedback, (i.e. $-Z = \frac{-V}{I}$), and that the shunt converter is provided by reversed current feedback, (i.e. $-Z = \frac{V}{-I}$), this statement is not so surprising.

The peculiar properties of series and shunt converters demand that they be inserted into a circuit in a particular manner. In Fig. 6 converters are shown being interposed between a source of e.m.f. and a matched load in two ways.

Two points should be observed:—

(i) Without making the distinction between series and shunt converters, the above two circuits will be unstable when $k = 2$ since in this instance the source of e.m.f is required to supply a current to a circuit with a zero impedance. Therefore, when using negative impedance converters there is a value of k to be avoided. Now in Fig. 6 (a) when k is much less than 2 the negative impedance will not have much effect; when k is increased just beyond the critical value of 2 the current should be very high (as when k is just less than 2), but will be reversed in direction. As k is increased still further, the reversed current should diminish in value. The opposite effect occurs in Fig. 6 (b).

(ii) It is shown in Appendix A that one of the various differences between series and shunt converters, is that the series converter will be unstable when the total impedance in the circuit is negative (corresponding to $k > 2$), while the shunt converter will be unstable when the total impedance is positive (corresponding also to $k > 2$). Therefore, it would be misleading to analyse such circuits as Fig. 6 without distinguishing between the properties of series and shunt converters in this respect.

Pursuing this difference in the behaviour of series and shunt converters, it is easy to establish the following rules.

If $0 < k < 2$, then the converter in Fig. 6 (a) will need to be a series converter to keep the total impedance positive. The converter in Fig. 6 (b) will

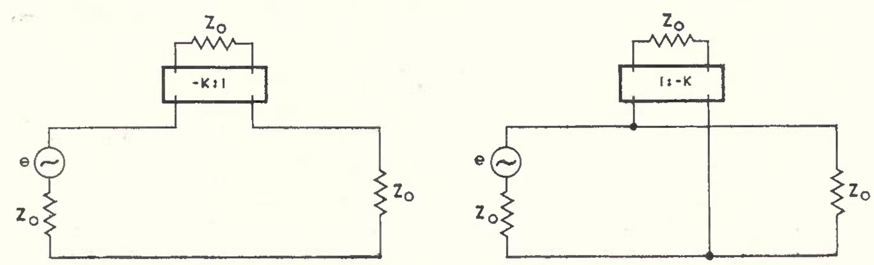


Fig. 6.—(a) Series Negative Impedance. (b) Shunt Negative Impedance.

need to be a shunt converter to keep the total impedance negative.

Conversely, if $2 < k < \infty$, then the converter in Fig. 6 (a) will need to be a shunt type while the converter in Fig. 6 (b) will need to be a series type.

Therefore, series converters are not necessarily inserted in series with a line or shunt converters are not necessarily inserted in parallel with a line. It is normal, however, for $0 < k < 2$ so that the series converter is usually inserted in series and the shunt converter, usually in shunt.

Table 1 summarises the properties of series and shunt converters.

Shunt Element

$$\text{Return loss} \quad 20 \log (2l - 1) \text{ db} \quad \ldots (4)$$

It should be observed that when $-l$ is made equal to $\frac{1}{-k}$ then equations (3) and (4) become identical to equations (1) and (2) respectively.

In Fig. 8 a graph is drawn plotting equations (1) and (2) with k as the abscissa.

The limitations of simple negative impedances as repeating elements should be apparent from these curves. When the gain exceeds 6 db ($k = 1$), the return loss changes sign and becomes negative, i.e., it becomes a return gain. Thus the converter at this stage not only amplifies the forward signal but also the reflected signal.

Under these conditions a severe limitation would be placed on the structural return loss so that the effect of the negative value of the image return loss may be reduced.

Fig. 8 also demonstrates why it is usual to use series converters in series and shunt converters in parallel, because in this event the converters need to be operated in the $0<k<2$ region which offers superior return loss characteristics to the $2<k<\infty$ region. Furthermore, if a series converter in series or a shunt converter in parallel is worked in the $2<k<\infty$ region, they will be unstable as a consequence of the third property of converters listed in Table 1.

TABLE 1: PROPERTIES OF SERIES AND SHUNT CONVERTERS

Property	Series Converter	Shunt Converter
1. Stable condition.	Open circuit input	Short circuit input
2. Unstable condition.	Short circuit input	Open circuit input
3. (External impedance ÷ Negative impedance) must be	> 1	< 1
4. When terminating impedance and source impedance equal Z_0, connections to the line should be made—		
(i) if $0 < k < 2$	—k : 1 in series	1 : —k in parallel
(ii) if $2 < k < \infty$	1 : —k in parallel	—k : 1 in series
5. Feedback	Positive series	Positive shunt
6. Impedance formula	$\frac{-V}{I}$	$\frac{V}{-I}$

Negative Impedance in a Circuit

Fig. 7 shows (a) a negative impedance ($-kZ_0$) inserted in series between a generator and load both of impedance Z_0, and (b) a negative impedance ($-lZ_0$) inserted in shunt between the same generator and load.

The insertion gain and the return loss at the repeater terminals can be shown to be:—

Series Element

$$\text{Insertion gain} \quad 20 \log \frac{2}{2-k} \text{ db} \quad \ldots (1)$$

Shunt Element

$$\text{Insertion gain} \quad 20 \log \frac{2l}{2l-1} \text{ db} \quad \ldots (2)$$

Series Element

$$\text{Return loss} \quad 20 \log \frac{2-k}{k} \text{ db} \quad \ldots (3)$$

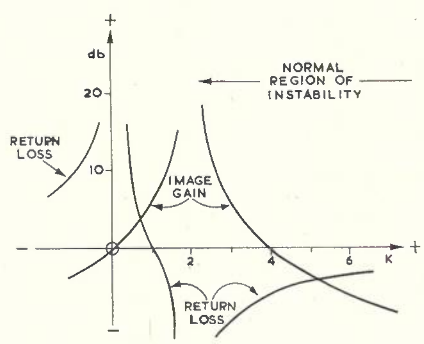


Fig. 8.—Image Gain and Return Loss Versus K Characteristics for Series or Shunt Negative Impedance.

Series—Shunt Negative Impedance

It is apparent from the foregoing paragraphs that when amplification of a practical transmission line is required, a simple shunt or series negative impedance can only be used satisfactorily to achieve fairly small gains, while still providing good return losses at the ends of the line. However, it is possible to combine the series and shunt negative impedance into a unit where there is no theoretical limit on the gain due to return loss deterioration, and in fact the unit can be made to have an image impedance independent of the gain. This combination of series and shunt converters can be a T, Pi, lattice or bridged T construction. For the bridged T configuration, the bridged elements can be either impedances equal to the characteristic impedance of the line, or as shown in Fig. 9, a centre tapped coil can be used. (This latter arrangement has the advantage that DC or low frequency signals can be transmitted through the device unimpaired.)

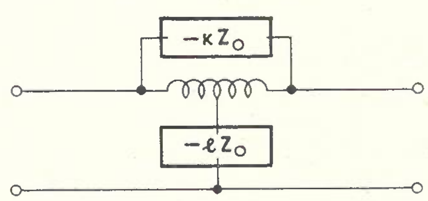


Fig. 9.—Series Shunt Negative Impedance.

It is shown in Appendix B that if the inductance of the coil in Fig. 9 is high, the image impedance of the bridged T circuit is given by:—

$$Z_I = \sqrt{Z\text{ series } Z\text{ shunt}} \quad \ldots\ldots\ldots\ldots (5)$$
$$= Z_0\sqrt{(-k)(-l)}$$

and the attenuation is given by—

$$A = 20 \log \frac{1+\frac{1}{2}\sqrt{\frac{Z\text{ series}}{Z\text{ shunt}}}}{1-\frac{1}{2}\sqrt{\frac{Z\text{ series}}{Z\text{ shunt}}}} \text{db} \quad \ldots\ldots\ldots (6)$$

$$= 20 \log \frac{1+\frac{1}{2}\sqrt{\frac{-k}{-l}}}{1-\frac{1}{2}\sqrt{\frac{-k}{-l}}} \text{db}$$

Now, if $-l$ is maintained equal to $\frac{1}{-k}$, the image impedance becomes

$$Z_I = Z_0 \quad \ldots\ldots\ldots\ldots (7)$$

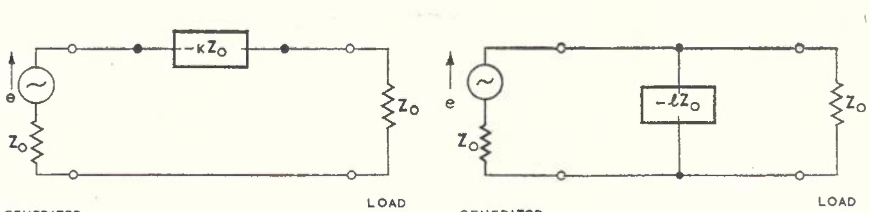


Fig. 7.—(a) Series Negative Impedance in a Circuit. (b) Shunt Negative Impedance in a Circuit.

where Z_0 could easily be made equal to the characteristic impedance of a transmission line, thus obtaining perfect matching for the device used as a line repeater. Furthermore, the attenuation will become negative, thus giving the device a gain of

$$\text{gain} = 20 \log\left(\frac{2+k}{2-k}\right)\text{db} \quad \ldots.(8)$$

It should be observed that a change in k still changes the gain (c.f. equation (i)) and that the image impedance is independent of k.

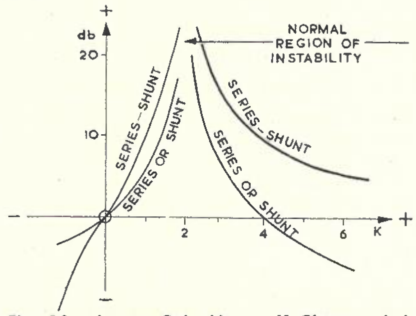


Fig. 10.—Image Gain Versus K Characteristic for Series-Shunt and Series or Shunt Negative Impedance.

These expressions for image impedance and image gain overcome the limitations of series or shunt negative impedance used alone.

By considering Fig. 9 as a balanced bridge when inserted into a line of impedance Z_0, it is easily seen that the impedance across the input of the $-kZ_0$ converter is $2Z_0$ while the impedance across the input of the $-lZ_0$ converter is $\frac{1}{2}Z_0$. Therefore if $0<k<2$ then the $-kZ_0$ converter must be a series type and the $-lZ_0$ converter must be a shunt type. If k is greater than 2, these types must be interchanged.

In Fig. 10 the gain of the series-shunt negative impedance converter is plotted as a function of k and compared with Fig. 8.

It can be shown (4) that if a series or shunt or series-shunt repeater is inserted into an ideal line, and k is adjusted to give just stable conditions, then k will be identical in each case. Consequently the difference between the two curves in Fig. 10 represents the gain advantage of series-shunt repeaters over the series or shunt type. Under actual line conditions, the series-shunt repeater is not favoured so much. A further observation can be made from Fig. 10. Should either the series or shunt section of a series shunt repeater fail, and the circuit still remains stable, then the repeater gain will be reduced by about one third.

Negative Impedances in a Transmission Line

Since the main application of negative impedance repeaters will be on inductively loaded cable pairs, the considerations of this section will be confined to this type of line. It will be found that the behaviour of a negative impedance repeater is closely related to the behaviour of the line in which it operates. Fig. 11 is intended to acquaint the reader with some of the characteristics of VF loaded lines.

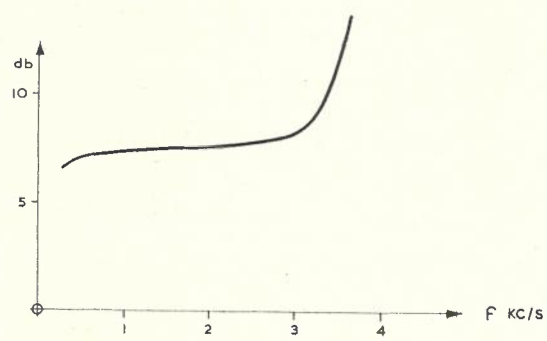
The loading used on the lines represented in Fig. 11 consists of series inductance of 88 millihenry each 6,000 feet with the end sections each 3,000 feet. If for practical reasons these distances cannot be accommodated, deficiencies are made up by the insertion of shunt capacitance and perhaps series resistance. Figs 11 (a) and 11 (b) represent the attenuation and characteristic impedance of 10 lb. cable when image terminations are used. Under working conditions, however, the important quantities are insertion loss and sending end impedance for some specified termination, and Figs. 11 (c) and 11 (d) show typical curves for 10 miles of 10 lb. cable. The ripples are caused by various structural irregularities and the departure of the terminations from image conditions.

Series-Shunt Negative Impedance Elements: When designing suitable values of negative impedance to insert into the transmission line, (which for the sake of this discussion will be assumed to consist of 10 miles of 10 lb. loaded cable), there are two things to be decided:—

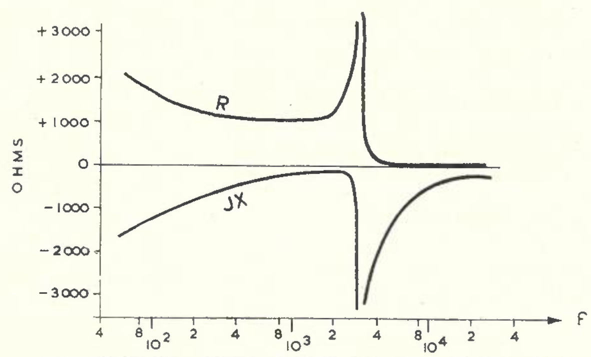
(i) the required gain (i.e. what value of k).

(ii) the required image impedance.

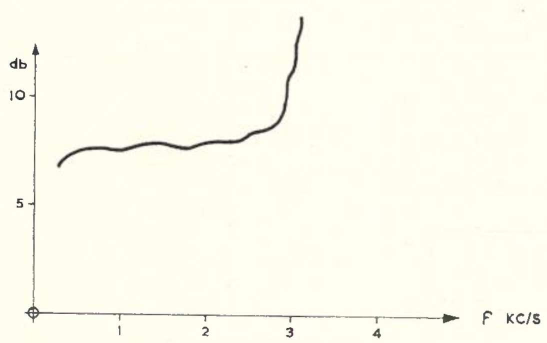
The required gain is easily obtained from the requirements of the circuit which will be assumed to be a metropolitan junction requiring a maximum loss between 1,200 ohm terminations of 4 db at 1.6 Kc/s. The required gain is calculated as $(10 \times 0.76) - 4.0 = 3.6$ db. By substitution of this gain value in equation (8) k is obtained.



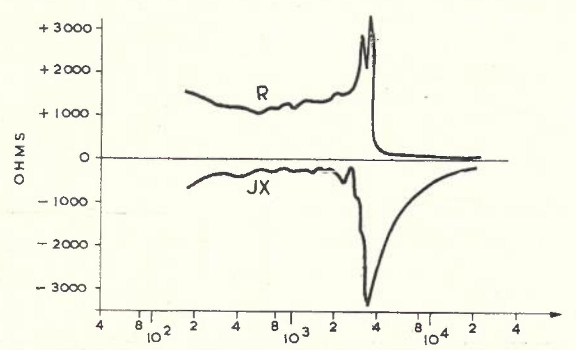
(a) CALCULATED ATTENUATION OF 10 MILES OF 10 LB CABLE



(b) CALCULATED CHARACTERISTIC IMPEDANCE OF 10 LB CABLE.



(c) TYPICAL MEASURED INSERTION LOSS (1200 OHM) OF 10 MILES OF 10 LB CABLE.



(d) TYPICAL MEASURED SENDING END IMPEDANCE (1200 OHM TERMINATION) OF 10 MILES OF 10 LB CABLE.

Fig. 11.—Frequency Characteristics of V.F. Loaded Cable.

Now of course, Z_i should be made equal to the line impedance Z_0, and thus kZ_0 and $\frac{Z_0}{k}$, the required values of series and shunt negative impedance, can be determined from equation (5). The converters and terminating networks can then be designed in the most convenient form. However, in order to match an impedance such as that shown in Fig. 11 (d), the value of Z_i should vary with frequency in a similar manner.

Actually, if the repeater is to be placed at the end of a circuit, the impedance on the office side would be the rather indefinite office impedance while if the repeater is to be placed at the centre of the circuit, the impedances to either side would be slightly different to Fig. 11 (d) due to the shortening of the line from 10 miles to 5 miles. (In voice frequency transmission considerations, this kind of impedance variation is always difficult to handle. The same problem seldom arises in the carrier or radio frequency range where, because of the higher frequencies, the lines are almost always electrically long enough to exhibit their characteristic impedance which itself is substantially independent of frequency; e.g., the impedance of 3 miles or more of 40 lb. unloaded cable is approximately (140 + j 0) ohms for all frequencies above 100 Kc/s.) Thus, it is obvious that the impedance requirement of every case cannot be met, so a compromise value for the required image impedance is selected, and the frequency response of the converters and/or the terminating networks is carefully controlled so that departures from the selected compromise in the actual line impedances over the frequency range are accommodated. It is important to repeat that only one value of Z_i can be accommodated at any one frequency, so that when a repeater has differing impedances on either side of it, the compromise uses up some of the available stability margin. This will be discussed later.

Series or Shunt Negative Impedance Elements: Despite the limitations of this type of repeater many thousands have been used by overseas administrations for amplifying junction lines. The series type of negative impedance appears to have been exclusively used for this purpose. This is probably because the high low frequency line impedance (Fig. 11 (d)) and the need for a DC blocking condenser made low frequency stability difficult to achieve in the shunt repeaters.

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APPENDIX A

How Negative Impedance is Obtained from an Amplifier

To show that:—

(i) Negative impedance can be obtained from an amplifier using positive feedback.

(ii) Two types of negative impedance converting devices are obtainable—one that is open circuit stable and another that is short circuit stable.

(iii) One type is converted into the other by interchanging input and load.

Consider an amplifier, voltage gain μ, with high input impedance and with output impedance Z arranged with positive feedback as in Fig. 12.

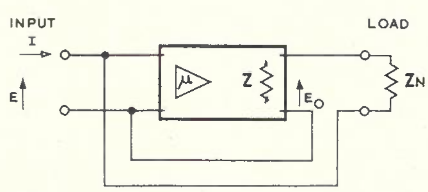

Fig. 12.—Amplifier with Positive Shunt Feedback.

The current I flows in a loop impeded by Z_n and Z, and is generated by the difference between E, an imposed voltage, and E_0 the output voltage of the amplifier:—

$$\text{i.e.} \quad I = \frac{E-E_0}{Z+Z_n} \quad \ldots\ldots\ldots(10)$$

$$\text{But } E_0 = \mu E$$

$$\therefore \frac{E}{I} = \frac{Z+Z_n}{(1-\mu)}$$

i.e. The input impedance

$$= Z_{in} = \frac{E}{I} = \frac{Z+Z_n}{-(\mu-1)}$$

Now Z_n can be arranged to be high compared with Z, and the gain of the amplifier will be greater than 1. Putting $(\mu-1)$ equal to k (a positive number)

$$Z_{in} = \frac{Z_n}{-k} \quad \ldots\ldots\ldots(11)$$

It should be noticed that in short circuiting the input terminals, no signal can be impressed upon the amplifier and, therefore, the current falls to zero, i.e., the system is short circuit stable. Moreover, if the input terminals are open circuited then (since the amplifier input impedance $>>$ Z or Z_n) any amplifier input signal would be returned to the amplifier input by the feedback loop, multiplied by μ, (>1), i.e., self sustained oscillations would build up and, therefore, the system is open circuit unstable.

It is also important to observe that if the input is loaded with any impedance equal to or more than the negative impedance produced by the converter (i.e., $Z_n/(\mu - 1)$) then the system will oscillate, since for this critical impedance the forward gain is μ, the feedback factor is $\frac{1}{\mu}$ thus making the overall loop gain from input to input equal to 1.

Another set of relationships can be obtained when Z_n in Fig. 12 is connected to the input terminals and a voltage E is impressed upon the other terminals as in Fig. 13.

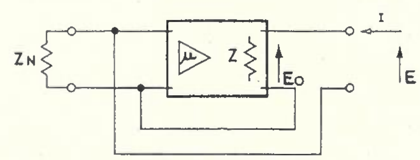

Fig. 13.—Amplifier with Positive Series Feedback.

Once more, the current flows in a loop impeded by Z_n and Z is generated by the difference between E and E_0, but this time the input voltage to the amplifier is $-IZ_n$ which makes the output voltage:—

$$E_0 = -\mu I Z_n$$

Substituting this in (10):—

$$I = \frac{E+\mu I Z_n}{Z+Z_n}$$

$$\text{i.e. } \frac{E}{I} = Z-(\mu-1)Z_n$$

which, applying the same conditions as previously, reduces to:—

$$Z_{in} = -k\, Z_n \quad \ldots\ldots\ldots(12)$$

This time, it should be noticed that an open circuit at the input will cause the current to fall to zero, i.e., the system is open circuit stable. Moreover, if the input terminals are short circuited then any amplifier input signal would be returned to the amplifier input multiplied by μ (>1), i.e., the system is short circuit unstable.

By similar reasoning it is seen that the system will oscillate if the input is loaded with any impedance equal to or less than the negative impedance produced by the converter.

APPENDIX B

Derivation of Formulae for Gain and Impedance of the Series-Shunt Repeater

To determine the propagation constant and image impedance of the network shown in Fig. 14.

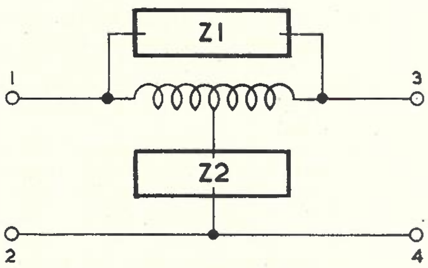

Fig. 14.—A Bridged T Network.

The coil in Fig. 14 has been redrawn in Fig. 15 (a). Let its inductance be L′ and assume that it is exactly centre tapped into halves each L. Then if the mutual inductance from one half to the other is M,

$$L' = 2L + 2M.$$

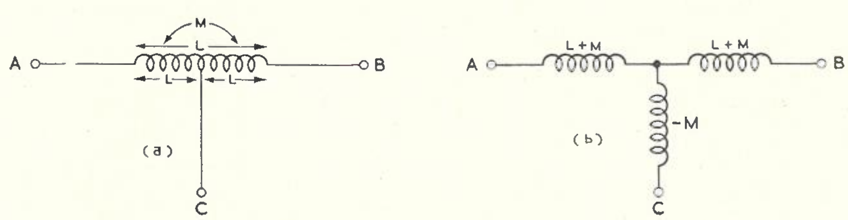

Fig. 15.—Alternative Representations of a Centre Tapped Coil.

To enable Bartlett's Bisection Theorem to be employed without the complication of mutual inductance, Fig. 15(*b*) shows a 3-terminal network exactly equivalent to Fig. 15 (*a*) and which uses only self inductances. This is easily proved as follows:—

In Fig. 15(*a*)

$L_{AC} = L_{CB} = L$

$L_{AB} = L' = 2L + 2M$

In Fig. 15(*b*)

$L_{AC} = L_{CB} = L + M - M = L$

$L_{AB} = 2L + 2M = L'$.

To further simplify the proof, assume tight coupling:—

i.e. $M = \sqrt{L \times L} = L$

Then, bisecting the network shown in Fig. 14, that of Fig. 16 is obtained.

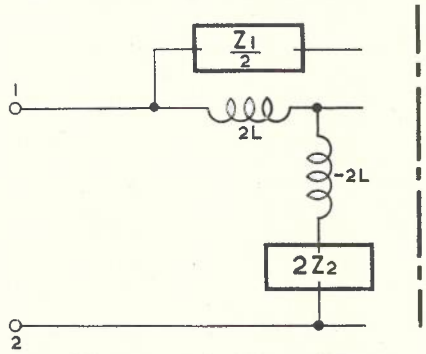

Fig. 16.—Bisected Equivalent of Fig. 14.

The open circuit impedance of the bisected network is:—

$$Z_{oc} = 2Z_2$$

and the short circuit impedance is

$$Z_{sc} = \frac{Z_1}{2} \text{ in parallel with } 2L$$

$$= \frac{Z_1}{2} \text{ if L is large enough.}$$

The image impedance (Z_I) of the full network (Fig. 14) is given by:—

$$Z_I = \sqrt{Z_{sc}\, Z_{oc}}$$

$$= \sqrt{Z_1\, Z_2}$$

$$= \sqrt{Z_{series}\, Z_{shunt}} \qquad \ldots(13)$$

and the propagation constant (P) is given by:—

$$\tanh\frac{P}{2} = \sqrt{\frac{Z_{sc}}{Z_{oc}}}$$

$$= \sqrt{\frac{Z_1}{4Z_2}}$$

(Note that $P = \alpha + j\beta$ where α is the attenuation in nepers and β is the phase constant.)

Rearranging this equation:—

$$\sqrt{\frac{Z_1}{4Z_2}} = \frac{e^{P/2} - e^{-P/2}}{e^{P/2} + e^{-P/2}}$$

$$= \frac{e^P - 1}{e^P + 1}$$

$$\therefore e^P = \frac{1 + \sqrt{\frac{Z_1}{4Z_2}}}{1 - \sqrt{\frac{Z_1}{4Z_2}}}$$

$$\text{i.e. } e^{\alpha + j\beta} = \frac{1 + \sqrt{\frac{Z_1}{4Z_2}}}{1 - \sqrt{\frac{Z_1}{4Z_2}}}$$

$$\text{i.e. } e^{\alpha} = \text{real part of } \frac{1 + \sqrt{\frac{Z_1}{4Z_2}}}{1 - \sqrt{\frac{Z_1}{4Z_2}}}$$

$= 10^{\frac{A}{20}}$ where A is the attenuation in decibels

$$\left(\text{since } \frac{\text{power}}{\text{reference power}} = e^{2\alpha} = 10^{\frac{A}{10}}\right)$$

$$\therefore A = 20 \log \left[\text{real part of } \frac{1 + \frac{1}{2}\sqrt{\frac{Z \text{ series}}{Z \text{ shunt}}}}{1 - \frac{1}{2}\sqrt{\frac{Z \text{ series}}{Z \text{ shunt}}}}\right] \text{db} \qquad \ldots\ldots\ldots\ldots(14)$$

Now in the series-shunt negative impedance repeater, Z_1 equals $-k\, Z_o$ and $Z_2 = \frac{Z_o}{-k}$; substituting these values in (13) and (14)

$Z_I = Z_o$, where Z_o is the impedance of the lines connected to the repeater.

$$A = -20 \log\left[\text{real part of } \frac{2+k}{2-k}\right] \ldots(15)$$

$$\text{i.e. gain} = 20 \log\left[\text{real part of } \frac{2+k}{2-k}\right] \ldots(16)$$

OPERATING AND SERVICING OF THE MELBOURNE TELEPHONE NETWORK

*E. J. BULTE, B.Sc.**

INTRODUCTION

General

The aim of this article is to give a resume of the methods and practices involved in operating and servicing the Melbourne telephone network, including an indication of improvements introduced in recent years directed towards improving service rendered to the public, at the same time achieving a greater overall productivity in providing service. It is proposed to discuss the various indicators by which results are measured, and to give details of probable future trends.

Composition of the Network

The Melbourne telephone zone is defined as the area included in a circle of 15 miles radius from the G.P.O. and within this area are located a total of 102 automatic exchanges. The majority of these exchanges have all step-by-step equipment including pre-2000, 2000 and SE.50 types. Included in the total are one Siemens No. 17 type motor uniselector exchange, one Siemens & Halske E.M.D. type motor uniselector exchange, one Pentaconta crossbar exchange manufactured by Compagnie Generale de Constructions Telephoniques and installed by Standard Telephones & Cables Pty. Ltd., Australia, and 15 exchanges either fully L M Ericsson type crossbar or part crossbar and step-by-step equipment. The subscribers have dialling access with each other on a unit fee basis for untimed calls. The number of services involved total approximately 390,000, to which approximately 530,000 telephones have access (see Fig. 1). These services may dial on a unit fee basis into the six adjacent telephone zones contained in the area of

*Mr. Bulte is Engineer Class 4, Metropolitan Service, Victoria. See Vol. 13, No. 1, page 80.

Fig. 1.—The Melbourne Telephone Zone.

the annulus between the 15 and 25 mile circles from the G.P.O. These are the Werribee, Sunbury, Kalkallo, Whittlesea, Croydon and Dandenong zones respectively and the total number of exchanges contained in these zones is 50 involving about 30,000 services. Although the plant within these outer zones is maintained by the Country Branch, whereas that within the Melbourne zone is controlled by the Metropolitan Branch of the Engineering Division, the service performances of the two areas are obviously fairly closely inter-related, and in this regard the service observations taken to assess the performance of the exchanges within the Melbourne telephone zone do not differentiate in the overall results between calls which terminate in the Melbourne telephone zone and those directed into the six adjacent telephone zones mentioned. This article however will deal primarily with the conditions within the Melbourne zone, and in particular with internal plant problems, although some mention will be made of the external plant involved, in so far as the service to subscribers is involved, and also to the extent that exchange staffs are involved in testing and restoration work for external plant faults.

Work Force and Its Deployment

The total number of technical staff involved in operating and servicing the switching system, clearing faults from exchange, private automatic branch exchange (P.A.B.X.) and other subscribers' equipment is approximately 1,150. The staff involved in the several maintenance activities are exchange plant—870, P.A.B.X.'s—80, other subscribers' equipment including telephones and private branch exchanges (P.B.X.'s) —200.

The exchange plant staff are based on the 80 largest exchanges, the smallest 22 exchanges being attended only on an "as required" basis. Some 16 of the largest exchanges are continuously staffed, the hours of staffing of the remainder being on a sliding scale depending on the size, the type of plant involved and the general spread of the traffic load. The continuously staffed exchanges serve as control and testing centres to attend to urgent faults in the smaller exchanges when the staffs of the latter are off duty. Urgent or "no-service" subscribers' equipment faults are also attended from these centres during week-day "after hours" times.

Subscribers' equipment including P.A.B.X.'s are in general maintained by staff based on the associated exchange, although in certain large P.A.B.X.'s the technical staff is located at the P.A.B.X. In the city area proper too, the subscribers' equipment staff tend to operate from a base located within the sub-area where their main activities lie.

For weekends and public holidays the clearing of faults on subscribers' equipment (and also external plant) is taken over by three centralised fault control centres, located at Collingwood, Malvern and South Yarra respectively. All instructions regarding despatch to faults are given from these centres. The fault staff normally controlled total 16 for subscribers' equipment and 12 for aerial plant faults.

EXCHANGE EQUIPMENT MAINTENANCE

General

Qualitative Maintenance (Q.M.) is the term applied to the method of servicing the exchange equipment. The aim of this method is to maintain the plant in such a way that the service provided to the subscriber is at a satisfactory level, but that excessive time is not spent on readjustment of plant which is giving a satisfactory performance. Previously with the preventive maintenance scheme, regular checking and readjustments of plant were carried out mainly on a time table basis, irrespective of the consideration as to whether the readjustments were necessary to keep the service given by the plant at a satisfactory level. With Q.M. it is still necessary to perform regularly certain preventive routines, such as oiling and cleaning switches, adjusting wipers and cleaning banks. In general, however, a low priority is given to intermittent faults which are not affecting many calls. In order that the service given to the subscriber may be maintained at a satisfactory level it is most important that service affecting faults be quickly detected and cleared as soon as possible. The following paragraphs give details of the main features of Q.M. as practised in the Melbourne network, including new practices introduced recently.

Subscribers' Trouble Reports (Complaints)

What the subscribers tell us about the troubles they have in obtaining service, merits the utmost consideration. The number of trouble reports received is in itself a measure of the quality of service rendered, and is used in gauging the overall satisfaction we are giving from the services involved. We use this information also to assist in pinpointing faults both in the plant within the exchange as well as that located outside such as line plant and telephones.

In view of the importance of this matter the facilities for subscribers to make trouble reports and the data received to be expeditiously dealt with have recently been given extensive consideration and as a result a large scale reorganisation carried out, including the installation of completely new answering suites, equipped with many valuable facilities (see Fig. 2).

Previously subscribers in the Melbourne telephone zone were required to report service difficulties to one of 13 locations, each with a different call number, the number to be used depending on the location of the service from which trouble was being experienced. With the new equipment a common calling number "1100" has been introduced and the incoming complaints are automatically switched into the appropriate one of the three complaints suites which have been located near the Russell, Windsor and Hawthorn exchanges respectively. In addition to the usual facilities for answering calls and connecting the callers when necessary to numbers they are unable to obtain themselves, each operator has test distributor access to all subscribers in the network, so that queries as to whether services are "busy out of order" or "busy speaking" may be dealt with without the necessity of calling the technical staff. At the same time a "go-no-go" test for determining whether a bell and condenser are connected to a

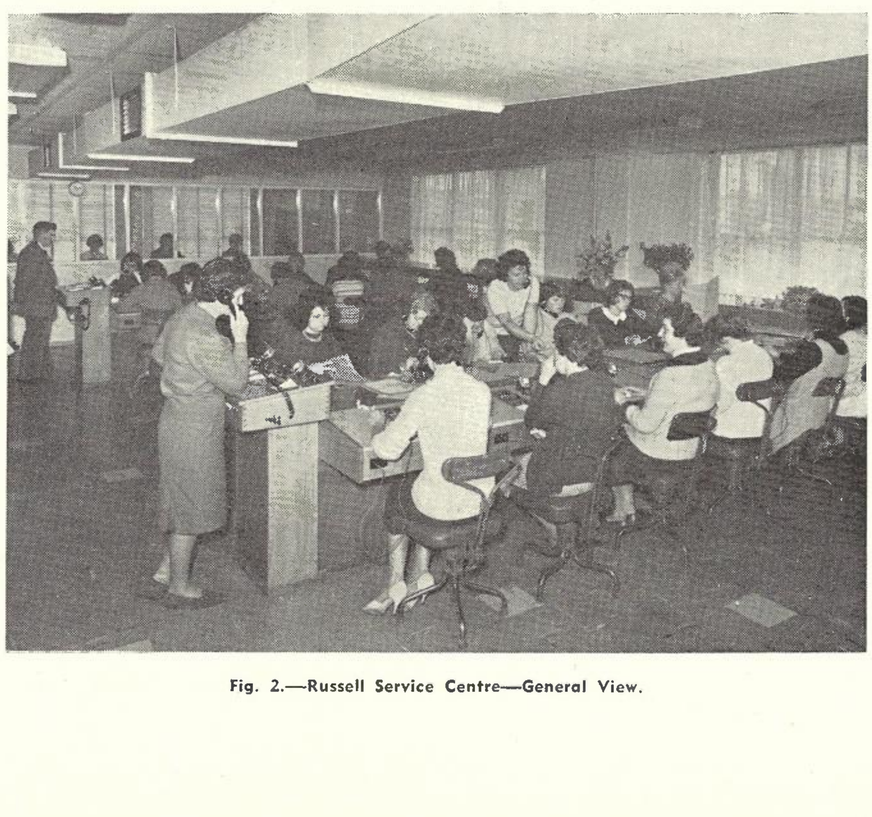

Fig. 2.—Russell Service Centre—General View.

Fig. 3.—The Melbourne C.A.R.G.O. Room.

subscriber's line reported by a subscriber as not answering is available. Another useful facility is the ability of the operators to hold calls which persistently fail to mature, apply "fault trace" tone and hand over to the technical staff for attention.

At each of the three centres, teleprinters are provided which have access by means of an automatic network to every staffed exchange in the network and also to the Complaints Analysis and Graphing Organisation (C.A.R.G.O.) centre. The teleprinters are used for printing fault dockets giving details required by the technical staff to locate and clear faulty equipment, whether it be in or out of the exchange buildings.

C.A.R.G.O. Operations

Omond (1) has described the methods used in the Adelaide network for analysing subscribers' complaints to find faulty switching equipment. In general, similar methods are used in the Melbourne C.A.R.G.O. which is located in the Batman exchange building. Since its inception in January, 1962, this technique has proved to be a powerful tool for achieving network improvement and providing better customer service (see Fig. 3) and has greatly strengthened co-operation between the various Sections, Branches and Divisions which are concerned in its operation. The performance of the network has improved as is clearly shown by the Service Observation results and it is considered that the importance of this organisation will continue to increase as the scope and size of the network expand. C.A.R.G.O. has been appreciated by the exchange staffs because it assists them in quickly locating faults which are not shown up by the fault finding methods available in the exchanges. In stating these facts however, it should be made clear that our aim is to operate the network as far as possible on a reducing number of complaints; that is most faults should be found and removed *before subscribers are inconvenienced by them.*

Fault Records

Records of faults found in different parts of the exchange plant are a valuable aid to pin-pointing equipment limitations in design or performance, and also in deciding what variations in maintenance procedures are necessary. For example, the fault rate per switch of uniselectors is clearly seen from fault graphs to be much smaller than for final selectors, indicating the need for more technical attention to servicing the latter. Efforts to introduce fast functional testers, and circuit improvements are thus also called for in the more fault-prone equipment.

One example of equipment causing excessive trouble which has been shown up by a study of the number of faults is the M.D.F. equipment. It has been noted that a great number of faults have occurred on heat coils, due primarily to weaknesses in their design. This has resulted in a close study being made of the protection value of heat coils and it has been demonstrated that they may be eliminated in many cases without increasing the protection risks. It is of interest that a survey disclosed that about 7,000 heat coils operated per annum but only 140 power line crosses occurred in the same period, and only in two of the latter cases did the heat coils operate. The overall result of reducing the number of heat coils in service has been a reduction in service affecting faults, improved service and a reduction in equipment capital costs.

Another aspect of fault statistics is to use a graph in each exchange to show by what means faults are located such as by alarms, traffic route tester (TRT), C.A.R.G.O., spark test (a simple functional test of selectors), etc. By this means each exchange can be helped to determine the most economical way of finding and clearing faults in their particular exchange.

In some cases, the fault rates in different exchanges can be used to confirm the relative reliability of those exchanges. For example, there are many fewer faults per erlang of traffic carried occurring in crossbar and motor

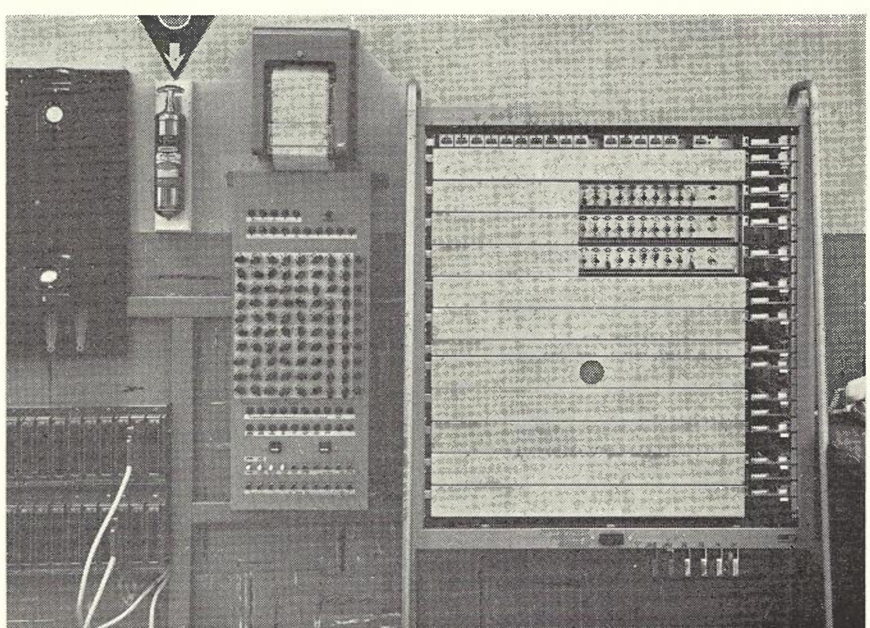

Fig. 4.—East Doncaster—T.R.T. and Centralograph.

uniselector exchanges than in the step-by-step exchanges. For example, whilst the Kew exchange was composed of step equipment, the fault rate for the eight months prior to its cutover to crossbar was 37 faults per month. A recent check showed that there is an average of 9 faults per month occurring in the equipment, even though more switching facilities are carried out within the Pentaconta crossbar equipment which now carries the traffic. It is necessary, however, to exercise care in attempting to judge the performance of various exchanges entirely by the number of faults found. For one thing, some faults which affect service severely such as those in first choice switches, can cause more degradation in service than others which are for example in late choice switches. Secondly, the length of time that faulty plant remains unrepaired has a bearing on the grade of service provided, and this aspect is not recorded in fault statistics.

Use of Artificial Traffic Equipment or Traffic Route Testers

The T.R.T. has had a profound effect on exchange equipment maintenance and action has been taken to equip every staffed exchange with one. Also a portable unit has been developed; this can be used as required in the unattended exchanges and P.A.B.X.'s. They may be used on either a "fault trace" or "observe service" basis, and recognition (answering) bases are installed at all exchanges, so that complete coverage of the network may be obtained, as required. They are valuable in cases where C.A.R.G.O. indications are that trouble exists on a particular route, particularly when other fault finding methods do not result in faulty plant being found.

In a crossbar exchange, they are a most vital part of the maintenance equipment, as they provide a most economical means of checking that all the traffic paths through the exchange are functioning correctly (see Fig. 4). In a step-by-step exchange they perform a similar function, and are also most valuable as a fault finder.

Functional Testing

The T.R.T. is essentially a functional tester which checks the end to end working of equipment throughout typical complete trains of digits. Automatic routiners, switch or relay set functional testers, on the other hand, check the working of individual switches, or small combinations of switches and relay sets, e.g., the repeater routiner checks the repeater relay set and the associated junction and incoming selector (see Fig. 5). Another recently introduced example is the automatic functional tester which checks on a daily basis the overall transmission and signalling functions of carrier junctions and associated switches and relay sets between City West and the exchanges in the six telephone zones adjacent to the Melbourne zone. Most of the traffic to and from these outer zones is distributed to the various exchanges in the Melbourne zone via the City West exchange.

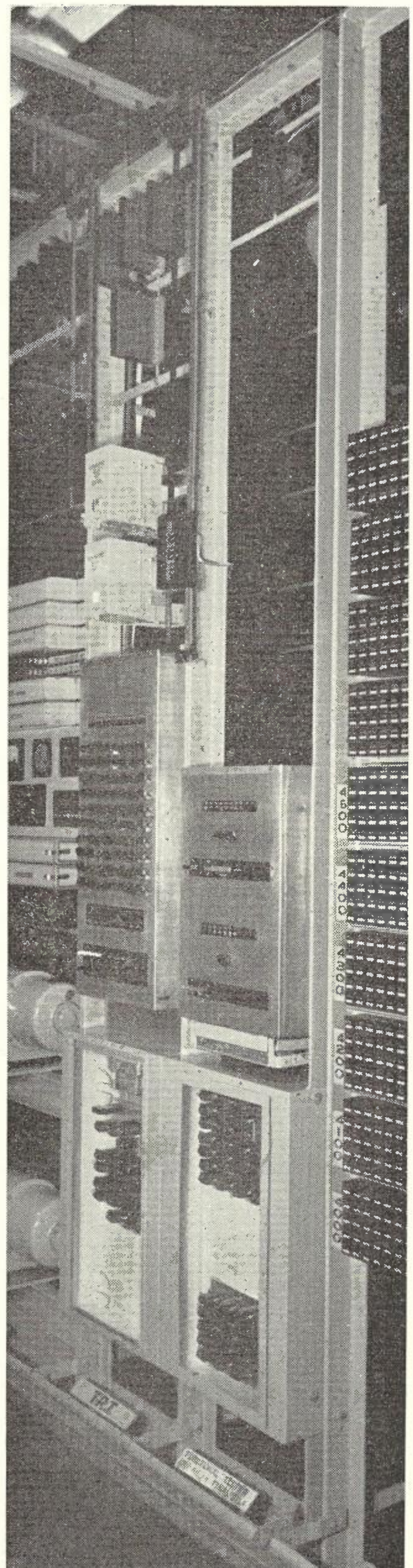

Fig. 5.—Civic T.R.T., Group Selector and Final Selector Functional Testers.

It has been found that frequent use of functional testing, preferably using automatic testers, plays an important part in finding and clearing faults in the exchange equipment. The use of the testers is determined in the particular case, by their effectiveness in finding faults, in relation to other maintenance aids in the exchange. For example, in some exchanges the use of the quick "spark" or "snake" test on bimotional switches, usually on a daily basis in the early pre-traffic period, has been found to be an effective means of detecting and clearing faults from the exchange equipment. Recent studies have indicated the desirability of incorporating in all types of functional testers the facility to use input impulses which are distorted at least to the degree of those which are likely to arrive from other parts of the network to the switches being tested.

"Dead" Level Traffic Observation

The interception of traffic arriving at unallotted swiching levels in the network on an "as required" basis has been introduced as an aid to finding out various faults in the network. This observation is often carried out on the Test Desk, as a matter of convenience. As might be expected, quite a few calls arriving at dead level are due to subscribers' errors, however, to quote the statement of one Supervising Technician when he first started this practice in his exchange, "the results were astounding". This was because he found out from the results that the service was being degraded in several cases by faults in his exchange which he had not picked up by other fault finding methods, but which nevertheless were in many instances quite serious faults.

Dust Elimination from the Equipment

It has been proved that exchange equipment works more reliably for longer periods if kept in a dust free condition. Jolley (2) has given details of trials made at the Civic exchange in dust proofing group selector racks. In view of the favorable results achieved, arrangements have been made to gradually extend the practice of enclosing bimotional switches in dust proof covers. Periodic blowing out of racks of equipment with air compressors, working under carefully controlled conditions, is practised in efforts to improve the performance of the equipment. Specially treated lint-free coats are worn by the technical staff who are required to enter the equipment room, and building plans are arranged as far as practicable so that staff not concerned with equipment attention need not enter the equipment rooms. Specially treated sweeping cloths impregnated with an oil and water emulsion to which dust adheres readily are used to keep floors, walls and outer equipment surfaces clean so as to minimise the amount of dust which could settle on the equipment working parts, including contacts. Special regularly cleaned mats are located near the entrance doors to equipment rooms to reduce the amount of dust brought into these rooms on the shoes of the staff.

It is hoped that these measures will reduce faults from this source and further improve the service given by the equipment; there is general evidence that these aims are being met. Dust count measurements are made as required in equipment rooms to check the effectiveness of dust control methods.

Reduction of Congestion

When traffic routes are at or near the congestion mark the service is degraded in two ways. Firstly, the calling subscriber who encounters "busy during dialling" conditions must dial again to get his number. Secondly, during congestion, particularly if it is of a severe nature, there is an increased risk of triple connections, and no progress on calls made, one of the causes being cut in on the unguarded period of releasing switches or relay sets.

Arrangements have been made therefore to install overflow meters on a wide scale, so that exchange staffs will have a ready means of knowing that congestion exists on certain routes, with a view to action being taken to install additional plant on the route involved. Allied to this is the need to have direct reading erlang meters at all exchanges, so that again the necessary detailed traffic readings may be made quickly when it is realised that congestion exists, so that the provision of additional plant may be expedited (see Fig. 6).

Automatic Checking of "Off Normals" and "Permanents"

Glick (3) has described a method of automatically "howling down" P.G.'s as they occur and counting the residual lines which remain, thus obtaining a reliable and quick cable fault alarm. This method has been installed on a trial basis at Burwood exchange, and the results have been so good that action is now proceeding to extend this on a wide basis throughout the network. The double benefit of obviating manual checking for "permanents" and getting a reliable cable fault alarm represents both a time saver and an improvement to service. It is of interest to record that in one period of 12 days, meter readings showed that during this time with the meters connected only between 8 a.m. and 5 p.m. on each day, 654 P.G.'s were automatically howled and 86.6% were cleared by the replacement of receivers.

More or less allied to this is a recent trial at the Camberwell and Burwood exchanges of automatic throw-out of called subscriber held final selectors. This trial has also been most successful, in that the time consuming checking for off normals is practically eliminated, also disruption to held subscribers is eliminated. It is intended to extend this scheme on a wide scale to the step-by-step exchanges in the network.

External Plant Fault Testing

A considerable amount of time is spent by exchange staffs in testing and clerical work associated with faults on external plant connected to the exchange. Any reduction in the number of faults in this field is valuable, both from the point of improving overall service to the subscribers and in allowing the available exchange technical staff to concentrate on exchange equipment aspects. The progressive and now almost complete application of gas pressurising to junction cables in the network has resulted in the reduction of junction cable faults to negligible proportions. Progressive gassing of subscribers' cable plant, together with improved plastic cables and associated jointing techniques offer prospect of reducing faults in this section of the plant. Faults on subscribers' cables have tended to increase in recent years but the results for 1963/64 have shown a welcome downward trend (see Fig. 7).

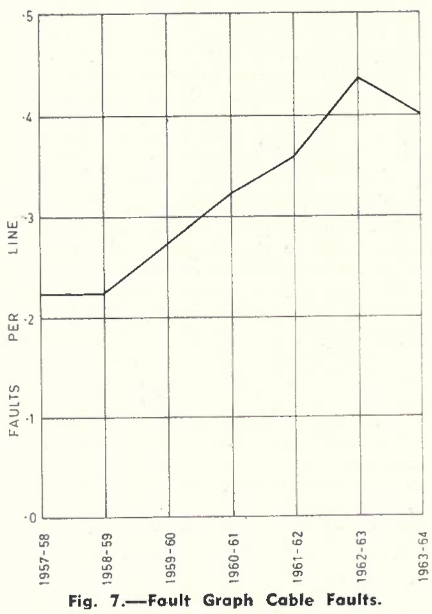

Fig. 7.—Fault Graph Cable Faults.

In regard to faults on aerial distribution on subscribers' lines, it is evident that these are decreasing, as may be seen from Fig. 8.

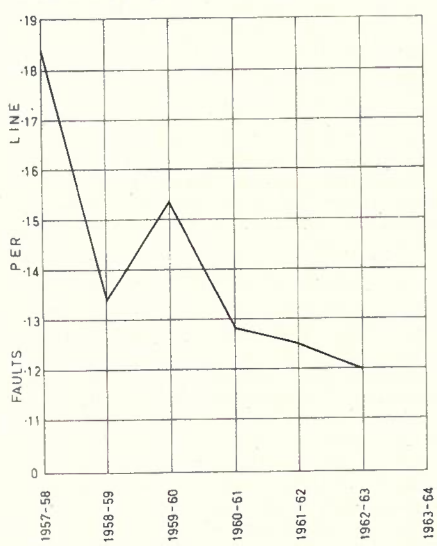

Fig. 8.—Fault Graph Aerial Faults.

Drayson (4) has given details of the operation and use of the automatic line insulation routiners which cover the Melbourne network. These are regarded as an important aid to improving the overall service rendered to subscribers, and in general they tend to improve the overall line testing efficiency and economy, by reducing the amount of slower manual testing which would otherwise be necessary.

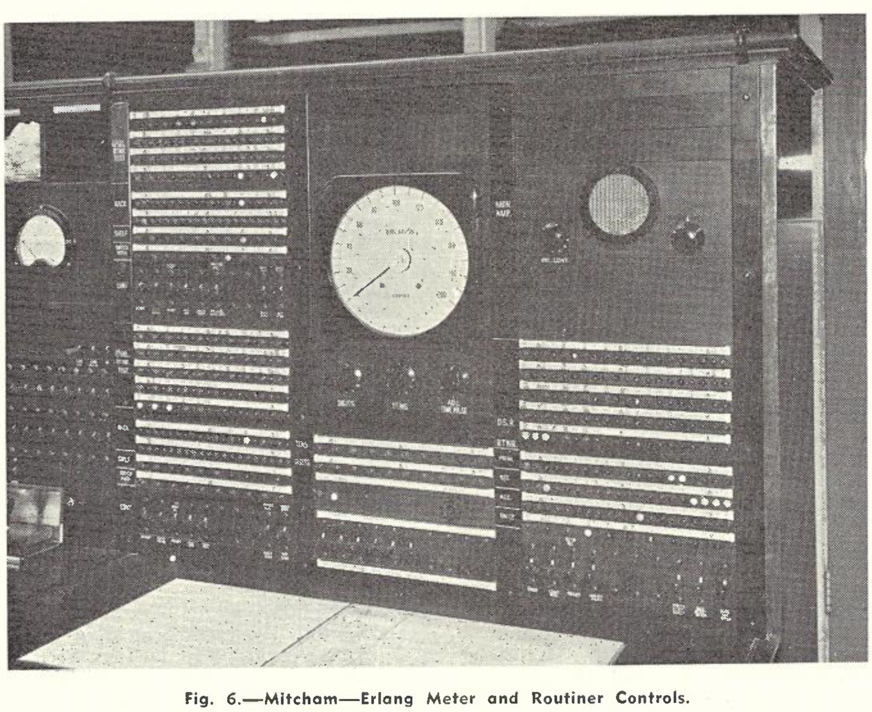

Fig. 6.—Mitcham—Erlang Meter and Routiner Controls.

Automatic Back-Busy of Junctions

The fact that the junctions between exchanges do not have a "back-busying" feature as do the links between switching stages within an exchange, undoubtedly leads to many misdirected and lost calls in the network. Many of these troubles are detected by C.A.R.G.O., including the troubles caused when staff fail to manually busy at the outgoing end junctions which are being worked upon at the incoming end. Maintenance attention to the switches is also slowed down because of this feature, because it is necessary to contact staff at the exchange from whence the junction comes to busy and unbusy the junction whilst repairs are being made to the incoming switch.

Concentrated attention has been given to this problem in recent years, circuits tried out and perfected and trial installations made. All of the routes to and from exchanges in the "2" group have now been completely back-busied, and this has resulted in improved service in this group, together with a saving in maintenance time. The complete treatment of all routes in the network has accordingly been decided upon and it is expected this will be completed within two years. It is certain this will further improve the service and reduce maintenance costs. In this regard recent tests carried out by the staff of the Metropolitan Service Laboratory on the length of release "blinks" on repeaters showed that in many cases they overlapped the releasing times of HA relays in selectors. From this it is clear that lost calls would result where certain switches and repeaters are associated in switching operations. With back-busy conditions applying, the relative importance of the rather finicky and time consuming "blink" adjustments is very greatly reduced. Another important advantage of back-busying conditions is that in the case of junction cable faults, the junctions are automatically taken out of service and a lamp indication provided at the outgoing end of the junction.

The Impact of Crossbar Equipment

Although the amount of crossbar equipment in the network is still relatively small, it is evident that it is reducing the equipment maintenance manhour requirements and improving the service. This is because less time is necessary on preventive maintenance due to the greater reliability of the components, from both an electrical and mechanical point of view, and the extensive provision of automatic fault indication equipment such as service and fault alarms, lamp sets, TRT, route alarms, etc. The trunking arrangements, including the automatic alteration of routes through the equipment on successive calls, as against the graded access used on step equipment prevents repeated lost calls on faulty first choice routes thus improving service and reducing trouble reports from subscribers. The more extensive use of direct routes between exchanges, involving fewer repetitions through equipment in intermediate exchanges, also increases the reliability of the network.

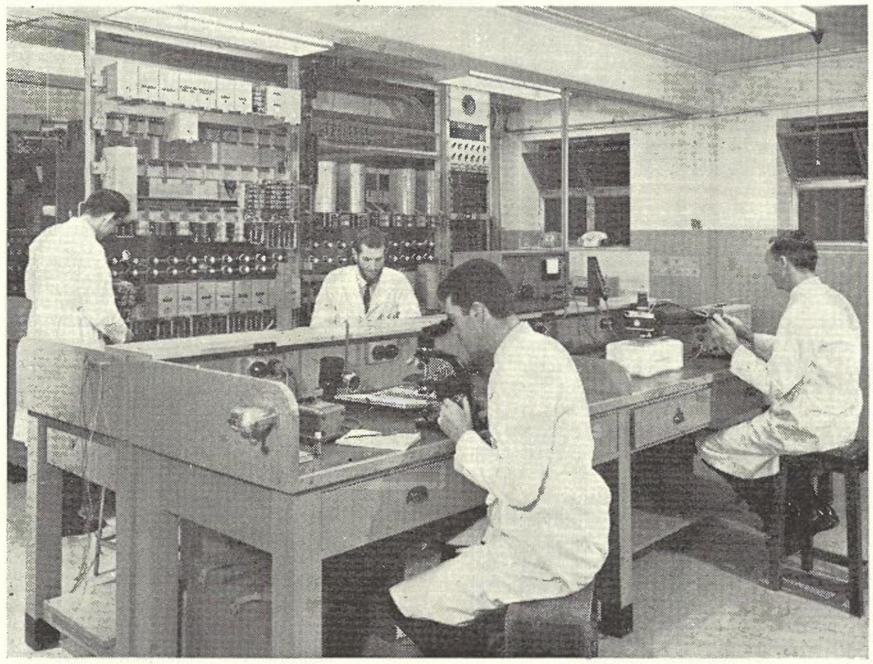

Fig. 9.—Metropolitan Service Laboratory.

Insufficient experience is as yet available to determine the long term effect on the C.A.R.G.O. activities but preliminary indications are that a smaller proportion of faults may be found by C.A.R.G.O. in crossbar exchanges. On the other hand this group still plays a most important part in giving a quick indication of serious troubles in crossbar exchanges, including times when they are unstaffed.

Network Performance and Testing Laboratory

Just as the C.A.R.G.O. group has proved to be an essential part of day by day assistance in keeping the network functioning at a satisfactory level of performance, so a network laboratory (see Fig. 9) has been found most valuable in helping to solve network problems, mostly of a longer term character.

In order to do this work the laboratory is equipped with a model network, consisting of all types of switches and relay sets, which may be interconnected as required by junction cable pairs of required electrical characteristics. The provision of crossbar equipment in this field is not yet complete, but action is in hand to remedy this deficiency at an early date. It is also used as a reservoir for the more critical and sophisticated types of testing gear which may be required from time to time in specific exchange problems. An idea of the scope of the contributions made to improved network performance can perhaps best be judged by listing the more important projects undertaken in the past two or three years, viz:—

(1) Continuous checking of exchange equipment rooms for dust content, using the slide and microscope method.
(2) Design and development of "blink" tester for repeaters and bimotional switches.
(3) Microscopic and photographic examination of switch and relay contacts giving trouble.
(4) Statistical sampling of the electro-mechanical performance of switches and relay sets from various exchanges in the network.
(5) Development of multi-frequency howler suitable for the 800 type telephone.
(6) Examining the impulse repetition performance of various types of "A" relays.
(7) Checking the signalling limits of various types of junction combinations including interworking between step and crossbar exchanges.
(8) Acceptance testing of multi-pen recorder and adapting its use to different types of relays.
(9) Checking the performance over junctions and into different types of exchange equipment of the Subscriber Call Recording Equipment (previously known as Printer Meter Check Equipment). This equipment has recently been obtained primarily as an aid to the investigation of complaints from subscribers of overcharging. It may be connected to a particular service and prints a paper tape record of the time, duration and date of all outgoing and incoming calls together with the metering pulses placed on the meter wire of the service being observed.
(10) Oversighting audio visual work.
(11) Checking the performance of subscribers' equipment such as Public Telephones and P.B.X.'s and trying out modifications as necessary.

(12) Development of annoyance call tracing equipment for step equipment.

(13) Development of precise impulse generators and associated direct reading time interval measuring equipment.

Previously some of the type of work mentioned above would be undertaken by various individuals in the field divisions, often working under restricted conditions, and doing such work on a "side-line" basis. Close liaison is maintained in the working of the laboratory with the Central Office, Research and Circuit Laboratories, as required to avoid duplication of effort in the various projects. In addition, a considerable amount of data and test results are interchanged with the Sydney Metropolitan Service Laboratory, particularly in view of the general similarity of the network problems encountered in Melbourne and Sydney.

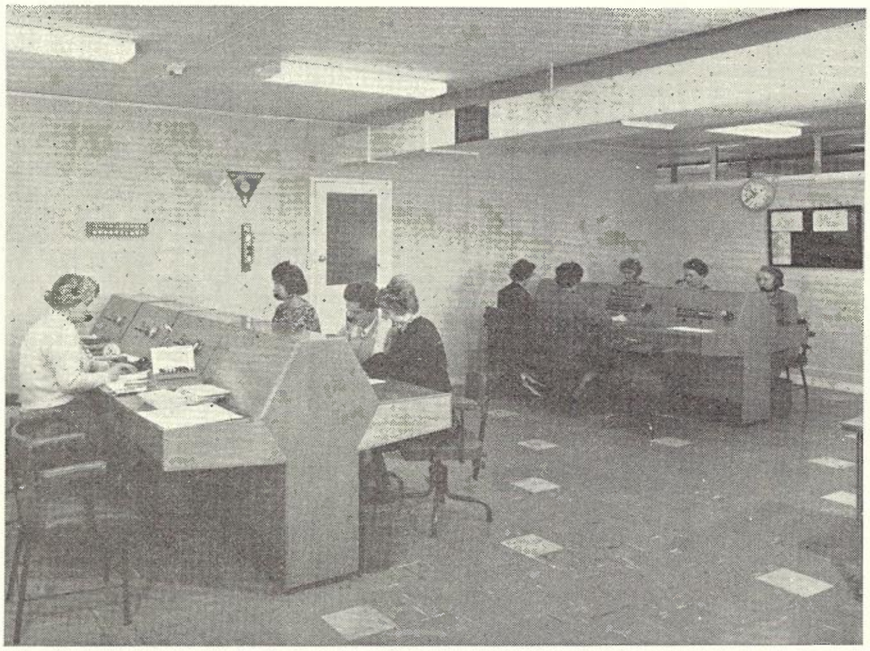

Fig. 11.—Service Observation Room—Russell.

MEASUREMENT OF EXCHANGE EQUIPMENT MAINTENANCE PERFORMANCE

Service Provided

The main criterion of the network performance is given by the results of service observations. These are taken regularly (once a month), on a first selector basis from each exchange in the network, a total of about 18,000 calls being observed per month. Fig. 10 shows the results over the past four years, and it is evident that a steady improvement has been achieved and it is hoped that further improvement will occur as the full benefits of the improvements mentioned in previous paragraphs are felt. New observation equipment has recently been placed in service (Fig. 11) and this should improve the reliability of the observation results. It is planned to introduce automatic data processing into this field, to facilitate processing of the results, and to study the potential advantages in using the observation results when they are related to terminating rather than originating exchanges.

For comparison purposes Fig. 12 shows a summary of the faults found in exchange equipment over the past few years. As explained earlier, the fact that the curve has a downward slope does not necessarily show that the service must be improving, but when read in conjunction with the service observation graph it does indicate a healthy trend.

A second indication of the service provided by the network exchange equipment is given by the number of technical assistance complaints received for every 1,000 calls completed. The complaint rates in the network have not fully settled down due to alterations in the complaints reporting system mentioned earlier. There are also apparent

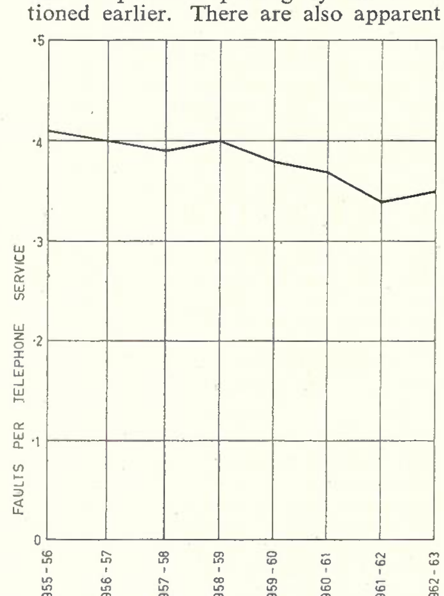

Fig. 12.—Total Exchange Faults Graph.

seasonal effects in trouble reporting rates, so that use of this information as a quantitative indicator of the efficiency of the network is still not fully developed. It is confidently expected that ultimately, difficulties in the use of this indicator will be overcome but in the meantime, its use to indicate individual exchange performances is already of considerable value.

A third indication of service quality is given by TRT results. At the moment this is used mostly in indivi-

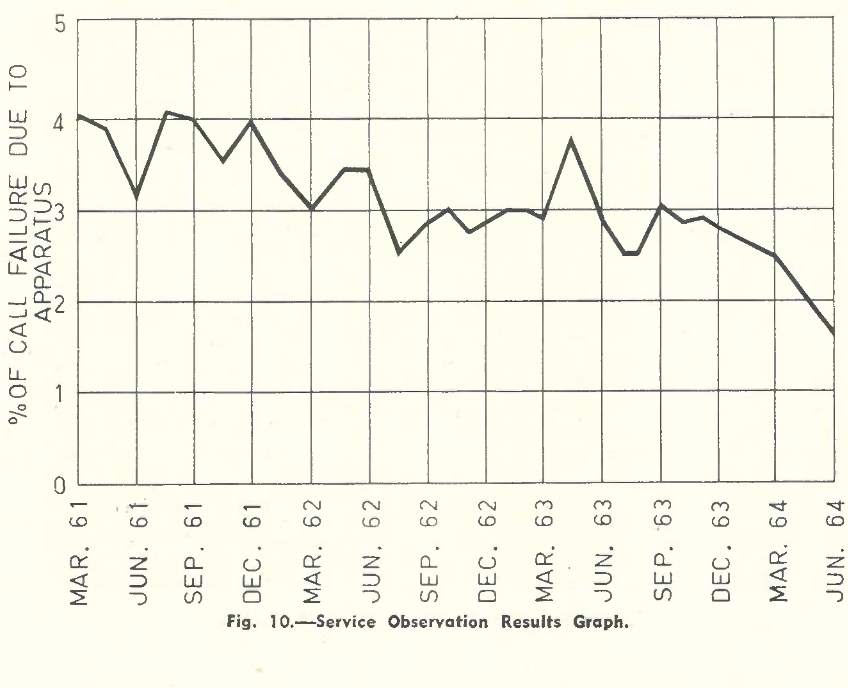

Fig. 10.—Service Observation Results Graph.

dual exchanges or in limited size areas as a service quality indicator, but active investigations are in hand to explore its value on a wider scale. One limitation to be taken into account in this regard is the fact that most TRT's at present in use do not differentiate between plant faults and congestion on "grade of service" runs.

Cost of Providing Service

The aim is to reduce costs and at the same time improve service. The major cost of exchange maintenance lies in the manhours expended, and in this regard the graph in Fig. 13 shows there

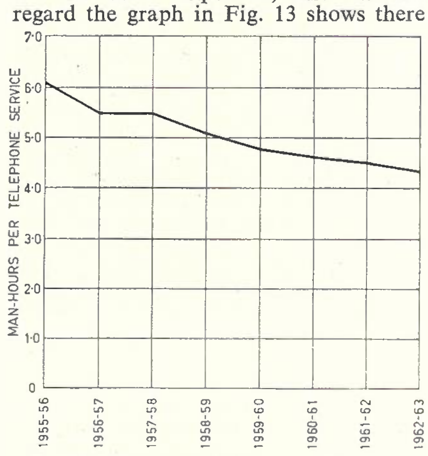

Fig. 13.—Exchange Maintenance Manhours Graph.

has been a gradual improvement in effective productivity. This is obtained by a continuing improvement in equipment design and maintenance methods, including better testing equipment. It is pointed out that the manhours shown in this graph also include all time spent by staff in the exchange in attending to auxiliary equipment such as power and air-conditioning plant, together with test desk and M.D.F. work associated with the connection of new services, transfers and faults on subscribers' equipment and external plant.

SUBSCRIBERS' EQUIPMENT MAINTENANCE

General

Corrective Maintenance is mainly used with substation equipment, with the exception of P.A.B.X.'s. This is because of the continuous oversight by the subscribers of substation equipment performance, and also because of its inherent reliability, which tends also to be improving.

Until recently, substation maintenance activity has been controlled primarily from the associated exchanges during normal week-day operations. Some 10 years ago, however, a Centralised Despatch Scheme was introduced firstly during weekends and then extended to public holidays to control the clearance of "no service" faults including aerial line plant faults. A couple of years ago, a special comparative study of the efficiency of this scheme from a fault clearing point of view was made, and it was shown that its efficiency was superior to the normal decentralised scheme operating on week-days.

It was accordingly decided to launch a full scale Centralised Fault Despatch scheme in the "4" group of exchanges, with a view to extending operations over the whole network if it proved successful. At about this time, information obtained from on the spot checks by Mr. R. C. M. Melgaard, in overseas telephone administrations and companies, had also indicated that such schemes were in successful and wide use. The trial in the "4" group proved that the new practice was a distinct improvement in many respects, and it has now been extended to cover the whole network, on the basis of 6 Fault Despatch Centres located respectively at Collingwood, Hawthorn, South Yarra, Malvern, Russell and North Melbourne.

The main advantages of the centralised fault despatch scheme are:

(1) An overall greater manhour efficiency due to the operation of a large group as against several independent groups.
(2) Better field supervision of work.
(3) More specialised attention can be given to complex faults.
(4) A closer control over the handling of urgent faults.
(5) Stores arrangements are more economical, because of the centralising of main supplies under the control of the Despatch Centre Supervisor, and his headquarters staff.

All of this adds up to the provision of a better fault clearance service at a lower cost, which after all is the main aim of our activities. Fig. 14 gives a general view of the Collingwood Despatch Centre which caters for the repair of 70,000 telephones, involving 15 repair technicians. Although a detailed description of the method of operation is not proposed some features are worthy of mention viz:—

(i) Plotting magnets on a steel-backed area map are used to indicate types and locations of faults and technicians' positions.
(ii) Vehicles with radio telephones are used to good effect in the outer areas and for specialised faultmen who may need to go to different areas frequently.
(iii) The centre has recently been extended to cover the activities of aerial and cable faultmen, a Line Foreman controlling the despatching of 25 faultmen.
(iv) The centre is also used as the control point for after hours service of an evening or weekends and public holidays.

Future Developments—Associated Testing

A centre is to be set up at Malvern which will cater for the repair of 140,000 telephones. This will provide valuable information on the efficiency of large centres. It appears that a greater efficiency could well result with the introduction of completely centralised testing from each of the Despatch centres to all the exchange areas controlled from the particular centre. This also has the advantage of reducing extra handling points for faults, in that details can then be sent direct from the service (complaints) centres to the particular Despatch Centre where testing and despatching functions are under the one close control. Trials have proved the effectiveness of this arrangement, which is now being extended to all the centres. Of interest in this connection too is the recent introduction of test robots, which allows outside staffs to perform their own testing without the assistance of the test desks, thereby further improving overall efficiency. Various ways of using automatic data processing are also being tried with a view to quickly measuring the performance of the centres in regard to fault clearance times, and also checking types of faults, etc.

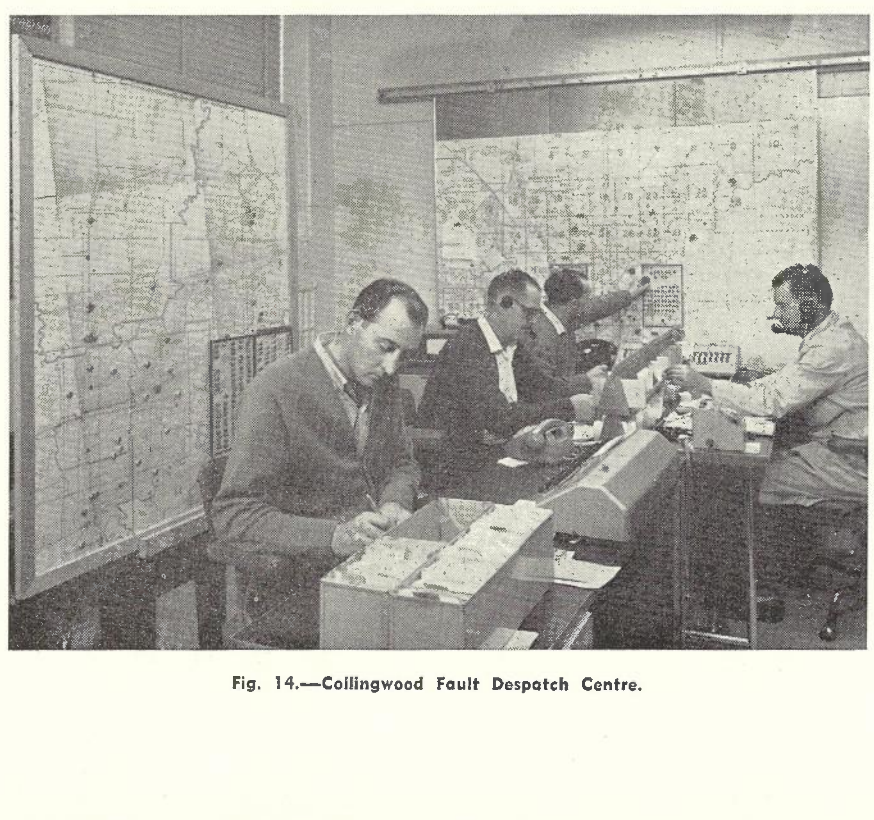

Fig. 14.—Collingwood Fault Despatch Centre.

Public Telephones

Although these in number represent less than 1% of the total number of telephones in the network, they account for over 40% of the faults on all telephones. This is due to the higher calling rate of P.T.'s, the relatively unfavourable housing conditions of the instruments, vandalism and the greater mechanical and electrical complexities due to the coin collecting and associated devices. The fact that some spurious fault reports are received by some users who do not operate the mechanism correctly, or give incorrect information for the purpose of obtaining free calls, adds to the unproductive time which may be spent by the technical staff on this type of instrument. Monitoring at the exchange is used where necessary to check on the service being given by a particular P.T. Another interesting facet of public telephone instruments maintenance is that they are very much cheaper and less troublesome to maintain when they are leased by subscribers, by comparison to being located in street cabinets. In this regard studies are now being made with a view to increasing the proportion of leased instruments, without decreasing the service provided to the public. At present we have 4,300 public telephones, and 1,800 leased coin attachments. Figs. 15 and 16 show the fault rates of ordinary telephones and public telephones respectively over the past six years. An upward trend in the P.T. fault rate coincided with the increase of the unit fee rate from 3 to 4 pennies. It is already clear that the fault rate is starting to fall since the unit fee was changed in February of this year to a single 6d. coin. No doubt the imminent introduction of new P.T. instruments of modern design, made necessary primarily by the proposed change to decimal currency in 1966, will assist also in reducing the fault rate on P.T.'s. In this regard it is pertinent to note that the fault rate on standard telephones has decreased, and this is thought to be due in a large measure to improved design in the telephone instruments in service over the period.

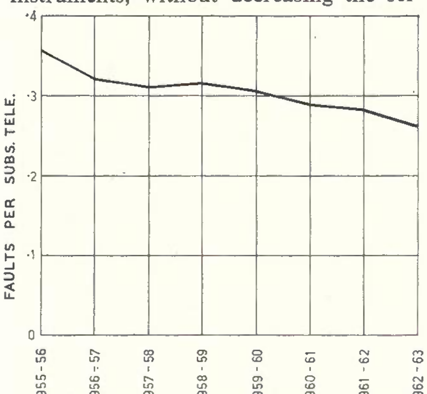

Fig. 15.—Telephones Fault Graph.

P.A.B.X.'s

The methods used in the maintenance of P.A.B.X.'s are in general similar to those practised with the equivalent sized exchanges. As indicated earlier, the largest ones are maintained by a resident technical officer, and the smaller ones are visited as required.

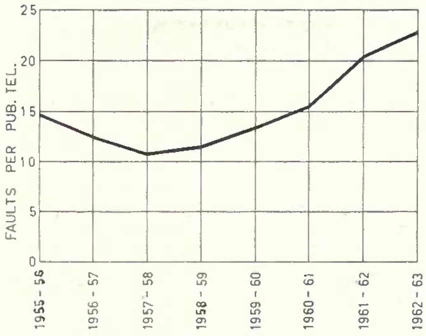

Fig. 16.—Public Telephones Fault Graph.

P.A.B.X. equipment, particularly the more modern types, is relatively complex in its circuitry, which leads to a good deal of the maintenance being performed by staff who specialise in this field. Since the adoption of crossbar switching equipment by the Department, several types of crossbar P.A.B.X.'s have been installed by the approved installing contractors, viz:—

S.T.C.—Pentaconta Crossbar Type.

L.M.E.—Five Ericsson Crossbar Types namely the

(a) ARD.520—2 + 10 size.
(b) ARD.526—3 + 16 size.
(c) ARD.561—Multiples of 30 lines up to 210 lines.
(d) ARD.151—400 lines up to 800.
(e) Special ARF.102—2,000 lines.

T.E.I.—A.T.M. Crossbar Type—basic 80 line multiples.

To date, no attempt has been made to regionalise the installation of this multiplicity of types, the number of which is still being increased. Pending some action along these lines, or alternatively the adoption of a Departmental standard, a considerable amount of effort is being taken in staff training for maintenance of this equipment. At the moment the position is being met to some extent by having "teams" which handle the similar types irrespective of location, even though this increases travelling.

MEASUREMENT OF SUBSCRIBERS' EQUIPMENT MAINTENANCE PERFORMANCE

Service Provided

In the substation equipment the service given is related directly to the number of faults per unit found and also the time taken to clear them, having regard to the type of fault. In the latter regard, for example, it is most important that the power or ringing supply to a P.B.X. or P.A.B.X. be restored quickly, whereas the replacement of a frayed cord on a telephone can be given a much lower order of priority.

The graph in Fig. 15 shows that the fault rate for telephones is steadily decreasing, and this pattern is the same for other types of subscribers' equipment generally, except for public telephones. As indicated earlier, positive improvement in the fault rate of public telephones is in sight. It may be stated, therefore, that in the whole of the subscribers' equipment field, the service is improving.

Regarding the speed of clearance, examination of fault clearance times has indicated an improving performance, particularly in the clearance of faults of the "no service" type, both during and out of normal business hours.

Cost

As with the exchange equipment maintenance, the major expenditure with subscribers' equipment maintenance lies in the manhours expended. It is seen from Fig. 17 that a gradual reduction in manhours per unit has been obtained. This is due also to continuing improvement in equipment and maintenance methods.

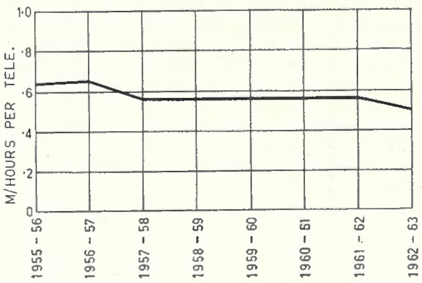

Fig. 17.—Substation Equipment (less P.A.B.X.'s) Manhours Graph.

CONCLUSION

In setting out the improvement in the operation and servicing of the Melbourne network it is clear that in the main a better service is being rendered to the public at a reducing cost. In noting this, however, it is the belief of the writer that with the introduction of better equipment and methods of working, further improvement is inevitable. There is plenty of scope for better performance, and imagination, energy and persistence with good ideas will always be necessary to improve the results which can be achieved. In the complex system we operate, ideas for better performance come from many sources, and I would like to acknowledge the assistance rendered by many people in the Metropolitan Service Section, as well as others in Headquarters and other States.

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TELECOMMUNICATIONS IN CANADA

C. T. BREWER, B.Sc., P.Eng., M.E.I.C.*

Editor's Note: Readers will be interested to compare the Canadian National Telephone plan with that for the Australian system. A brief description of the Australian plan is given in the article. "Australian Telephone and Telegraph Networks" in Vol. 14, No. 2, page 102, of this Journal and more detail is available in the references given there. Points where the comparison is considered of particular interest have been indicated in the article.

INTRODUCTION

Following the second world war, a period of relative stagnation, have come almost two decades of expansion and change in the Canadian telecommunication industry. The growth of basic telephone service can easily be illustrated: in 1946 there were about 12 million people and two million telephones in Canada, eighteen years later, the population has increased by 60 per cent to about 19 million, the number of telephones has more than tripled to 6.5 million. Today, the rate of growth in basic telephone service has become more manageable, but the scope and variety of new types of communications services has begun to increase at a fast pace. And it is to these new services, now that most telephones are dial operated, the telephone industry looks for spectacular growth in the future.

With the emergence of a fast-growing electronics industry, given impetus by the war years and the following boom, changes have been introduced rapidly in every facet of post-war society. Methods of business and of government administration have changed, and are still changing. Methods of production and distribution have altered and many previously neglected areas have sprung to life, with the spread of both primary and secondary industries. The home lives of Canadians have also been transformed, all in little more than two decades. And, in response, the telephone industry has adapted the services it offers and the ways in which it offers them to meet the new needs and the new challenges posed by this developing society.

ORGANIZATION AND OWNERSHIP

In Canada today there are about 2,500 separate telephone systems and companies. The largest, the Bell Telephone Company of Canada, serves over four million of the country's 6½ million telephones. The systems range in size from rural co-operatives serving a few customers to large provincially and privately-owned systems. In this type of organisation, long distance service, whether it is nation-wide, continent-wide or world-wide, demands close co-operation between all the telephone systems whose facilities are inter-connected. For it is a basic premise of the industry that, no matter how many companies may be involved, every call should be handled as speedily and as efficiently as if there were only one telephone organisation. In a country where there are as many as 2,500 separate systems, this calls for co-operation of a high order.

From this basic requirement for co-operation has stemmed the formation of organisations whose purpose is to link the members of the telephone industry. The best known of these organisations is the Trans-Canada Telephone System, formed in 1931 with the aim of developing and maintaining an all-Canadian coast-to-coast long distance network. Today there are eight full members of the System and one associate member:

The Avalon Telephone Company Limited.
Maritime Telegraph and Telephone Co. Ltd.
The New Brunswick Telephone Company Limited.
The Bell Telephone Company of Canada.
Manitoba Telephone System.
Saskatchewan Government Telephones.
Alberta Government Telephones.
British Columbia Telephone Company.
(The Canadian Overseas Telecommunication Corporation is an associate member.)

The members are the principal companies or systems in the provinces they serve, and within the framework of the Trans-Canada Telephone System, work together as partners in a nationwide business, providing a complete network capable of carrying a diversity of communications—television and radio programs, data and defence communications, as well as regular telephone traffic—between the Atlantic and the Pacific. Working to a common plan, each member builds and owns the telephone plant within its own territory, and each shares in the revenues from communications carried into, out of, or across its territory.

An organization of somewhat different character is the Telephone Association of Canada, formed in 1921 to promote the interchange of technical and operating information within the industry. In addition to the eight full members of the Trans-Canada Telephone System, four other companies belong to the Association:

The Island Telephone Company (PEI.)
Okanagan Telephone Company (B.C.).
Ontario Northland Communications.
Quebec-Telephone.

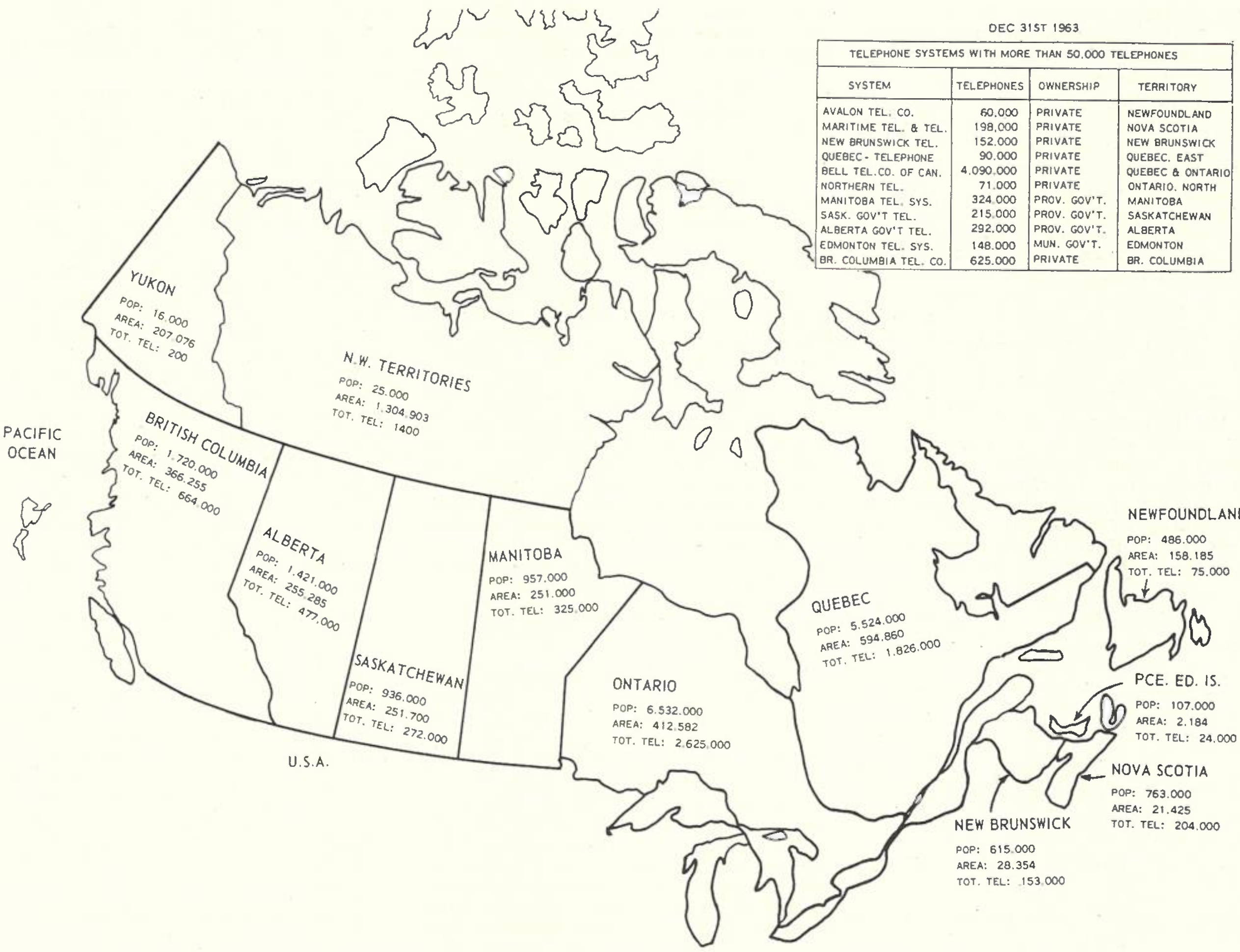
At a time when the industry is not only expanding but also diversifying at a rapid pace, and when technological progress is so fast in so many different areas, the need for sharing technical and operating information is great. Through the medium of the Telephone Association of Canada, the experience of others in the industry is made available to any of its twelve members, and the sometimes painful process of adjusting to new techniques and new developments is often greatly eased. In addition to the larger Canadian telephone systems many smaller systems have formed groups, such as the Canadian Independent Telephone Association, the Quebec Independent Telephone Association and the Saskatchewan Association of Rural Telephone Companies, all of which have aims which are basically similar to those of the Telephone Association.

Co-operation within the industry often extends further. For example, nine companies have separate contracts with the Bell Telephone Company of Canada, through which they can obtain a variety of advice and assistance on both technical and operating matters in return for an annual fee. And the Bell Telephone Company itself has a similar agreement with the American Telephone and Telegraph Company in the United States, which gives it the benefit of the latest information from below the border.

A unique feature of the Canadian telephone industry is its blend of private and public ownership; see Fig. 1. In the prairie provinces, for example, there are three major telephone organizations—the Manitoba Telephone System, Saskatchewan Government Telephones and Alberta Government Telephones—each owned by the provincial government. In Edmonton and Fort William, to name two important cities, service is provided by municipally owned systems. Nova Scotia, New Brunswick and Prince Edward Island are served by privately-owned companies holding provincial charters. Another serves a large portion of Newfoundland. The two largest telephone companies in Canada hold federal charters. The British Columbia Telephone Company serves more than half a million telephones in that province while the Bell Telephone Company of Canada, the first telephone company to be incorporated in this country, operates over four million telephones in Ontario, Quebec and parts of Labrador and the Northwest Territories. Both the British Columbia Telephone Company and the Bell Telephone Company are privately-owned corporations. The Bell, for example, is owned by about 200,000 shareholders, of whom about 97 per cent live in Canada and almost 90 per cent in the territory served by the company. Ninety-three per cent of the Bell's shares are held in Canada.

Because telephone service in a given area can be provided most efficiently by a single company, it is generally agreed that Canada's telephone companies should not compete with each other in providing this essential service. To compensate for the natural regulation of prices that normally takes place through competition, and to fix telephone rates at a level that is fair to both customers and owners, most telephone systems are subject to government regulation. Whether they are federally, provincially or municipally regulated depends on their particular charters or circumstances.

*Mr. Brewer is with the Bell Telephone Company of Canada, Montreal. See page 422.



DEC 31ST 1963

TELEPHONE SYSTEMS WITH MORE THAN 50.000 TELEPHONES			
SYSTEM	TELEPHONES	OWNERSHIP	TERRITORY
AVALON TEL. CO.	60.000	PRIVATE	NEWFOUNDLAND
MARITIME TEL. & TEL.	198.000	PRIVATE	NOVA SCOTIA
NEW BRUNSWICK TEL.	152.000	PRIVATE	NEW BRUNSWICK
QUEBEC - TELEPHONE	90.000	PRIVATE	QUEBEC. EAST
BELL TEL.CO. OF CAN.	4.090.000	PRIVATE	QUEBEC & ONTARIO
NORTHERN TEL.	71.000	PRIVATE	ONTARIO. NORTH
MANITOBA TEL. SYS.	324.000	PROV. GOV'T.	MANITOBA
SASK. GOV'T TEL.	215.000	PROV. GOV'T.	SASKATCHEWAN
ALBERTA GOV'T TEL.	292.000	PROV. GOV'T.	ALBERTA
EDMONTON TEL. SYS.	148.000	MUN. GOV'T.	EDMONTON
BR. COLUMBIA TEL. CO.	625.000	PRIVATE	BR. COLUMBIA

Fig. 1.—Telephone Development in Canada, December, 1963.

SUPPLIERS

The telephone companies are served by a number of manufacturers in Canada. Two of these, the Northern Electric Company, Limited, and Automatic Electric (Canada) Limited, are associated with the two largest privately-owned telephone companies: the Bell Telephone Company of Canada, and the British Columbia Telephone Company, respectively. While both these companies are major suppliers of communications equipment to their parent organizations, much of their business is also obtained from other telephone systems. Several of the other suppliers are subsidiaries of internationally-known telecommunications equipment manufacturers, and some of these maintain only sales and servicing branches in this country.

CANADIAN TELEPHONE SERVICE

Canada has many characteristics that parallel those of Australia. The population density is about five people per square mile—compared with about 800 each in the Netherlands and in England, and about 60 in the United States. The bulk of Canada's population is spread along the fertile southern belt which stretches almost 4,000 miles from the Atlantic to the Pacific, and much of it is concentrated in a few large industrial cities. These cities themselves tend to flow loosely into the countryside, creating ever-growing communities of interest. Quite apart from distance, there are the natural barriers to communications — the Rocky Mountains, the wide plains of the prairies and the scarcely developed northlands; and there is the climate, which for several months of the year does little to encourage travel from one part of the country to another. These are some of the factors which have influenced Canadians in creating standards of values which often differ substantially from those held in other countries; and they are some of the many factors which have determined the development of telephone service in this country.

Canadians rely heavily on their telephone as a means of communication: this is a fact borne out every year in world telephone statistics, which show that Canadians use their telephones more often than any other people. They are also exacting customers: they want to be able to reach all the telephones within their community without paying long distance charges; they want their local calling area to include suburbs and neighbouring towns with which they have a community of interest; they want to feel free to place a great number of calls; and they value the right to talk for just as long as they want on each call.

In North America the practice of supplying goods and services in large lots or "packages" is widespread and the concept of "packaged" telephone service has taken hold. Traditionally, telephone service has been separated into two basic elements: local service and long distance (or toll) service. Local service is usually offered as a "package", for which the customer is charged a fixed monthly rate. For this he is provided with a telephone from which he can call any other telephone within a defined local calling area. The customer can call any number of times, and he can stay on the line as long as he wishes without any extra charge. Long distance service, on the other hand, is usually tailored to the customer's individual needs. He pays for each call he makes, and the charge will depend on how far he is calling and how long he remains on the line. Toll charges are generally based on a three-minute minimum.

In some parts of the country and in some special circumstances, local service is available also on a message-rate or "per call" basis. There is a distinct trend, however, towards both "packaged" long distance service and a substantial extension of the boundaries of local calling areas.

Local calling areas were originally confined to the customer's own exchange. But with the trend toward suburban living near the major cities, and with the gradual merging of many smaller towns, there has been a growing demand for considerable widening of these "flat-rate calling" areas. As a result, many telephone companies have introduced a broader concept of "packaged" local service, known as Extended Area Service.* The object of this is to eliminate long distance charges on calls between certain centres which have a definite community of interest. To compensate for the loss of toll revenue, which is only partly offset by a reduction in operating, billing and other administrative costs, the telephone companies charge a higher monthly rate, based on the number of telephones which can be reached in the extended area. Fig. 2 illustrates a typical EAS complex.

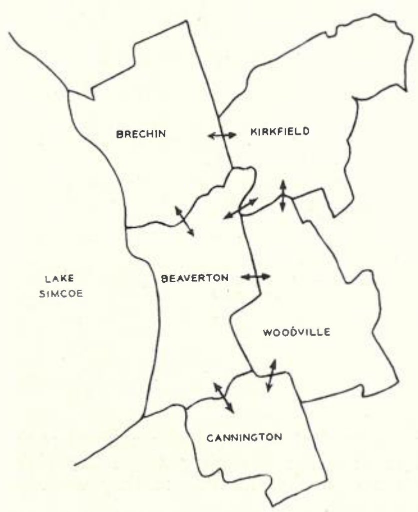


Fig. 2.—A Typical Example of Extended Area Service in Canada: Beaverton Subscribers Can Telephone to Cannington, Woodville, Kirkfield and Brechin, Without Long Distance Charges. Similarly, telephone users in each of these exchanges can place calls to their neighbouring communities with the cost included in the monthly telephone charge.

Some persons in the industry predict that flat-rate calling will one day encompass the whole country, and that customers will merely pay a uniform monthly charge. That day is certainly a long way off, if only because such a service would today be prohibitively expensive for most of the users. A step in this direction, however, was the introduction in 1961 of a new packaged long distance service, known in the industry as "Wide Area Telephone Service". While it is primarily intended for business customers who place a large number of long distance calls, wide area telephone service makes flat-rate calling within any of seven areas available to anyone. These areas range in size from a part of a province to the whole of Canada. Customers subscribe to a wide-area line on which they can dial their calls to any telephone in the area they have selected, calling as often and talking as long as they wish for the predetermined monthly charge.

In practically all urban centres there is a choice of individual-line service or two-party service (at a lower rate) in the area surrounding the telephone company's central office. Some companies offer four-party service but generally there has been a pronounced swing toward a higher proportion of individual lines. Further away from the central office and in most rural areas, where multi-party service is standard, individual and two-party services are available at a higher price. The number of telephones per rural line is gradually being reduced and in the Bell of Canada territory the objective is to have no more than six stations per rural line.

Ten years ago most homes had only a single black telephone. Nowadays, with telephones in about 80 per cent of Canadian homes, many people are prepared to pay a little extra for the greater convenience and attractiveness of extensions and coloured telephones. Small telephones, such as the Starlite and the Princess, have found wide favour, while complete home communications systems are winning acceptance in many larger homes. For the businessman there is a wide variety of key telephones, and call directors, as well as a complete range of automatic, semi-automatic and manual private branch exchanges. Despite this variety in telephone equipment, practically all of it is available at short notice—few residence customers have to wait longer than a couple of days; even the more complex business equipment can usually be installed in a matter of a few weeks.

The change to dial service, which began in the early 1920's, has been accomplished rapidly. By the outbreak of World War II, two-thirds of the system was dial operated. Following the war, large numbers of new dial offices were opened and many manual offices were converted to dial service. Today, nine out of ten telephones are dial operated, and rapid progress is being made in converting the remaining ten per cent. The Bell Telephone Company, for example, expects to virtually complete its conversion program by 1965.

In the case of long distance service, dial operation has been introduced in two stages: the first makes it possible for an operator to complete customers' calls by dialling the distant number; the second, Direct Distance Dialling, allows the customer to dial directly into the continent-wide telephone network.** Today about 80 per cent of all long distance calls are dialled either by an operator or by a customer, customer-dialled calls accounting for roughly 20 per cent; the ultimate objective is to approach, as nearly as practicable 100 per cent.

At the present time, telephone users who have access to the direct distance dialling network can dial their station-to-station calls directly to any of about 85,000,000 telephones in this country and the United States—more than 90 per cent of those in service in the two countries. The only part played by an operator—and even this has been eliminated in many centres—is to record the number from which the call is being placed. Eventually it is planned to introduce direct dialling of person-to-person, collect and other special calls, which will be handled entirely by the customer but supervised by an operator. Automatic accounting equipment, tied in to the direct dialling network,*** times every call and records all the information the telephone company needs for billing. These details are punched in a paper tape, which is later processed by accounting machines.

Lower long distance rates—and in some cases a complete revamping of the long distance rate structure — are direct off-shoots of direct distance dialling and other technological improvements introduced in recent years. A three-minute call between Vancouver and Montreal, for instance, which in 1931 would have cost $8.25, now costs only $3.15. And the Bell Telephone Company has introduced specially low night rates, which permit customers to talk 10 minutes for the price of five, on station-to-station calls, within their territory.

PRIVATE LINES AND SPECIAL SERVICES

Telephone companies lease private lines to many organizations for their exclusive use in carrying voice calls, teletypewriter messages, data, or various combinations of these. For example, mail-order companies often use private circuits to receive daily inventories from their distributing houses; trucking firms use them to keep in up-to-the-minute contact with their branches across the country; and pipeline companies, piping natural gas or oil to users hundreds of miles away, use private lines to gather telemetering information from instruments and gauges along the line. And, of course, with the growth of data transmission, there has come a demand for wide-band circuits, capable of carrying information between large-scale computers.

COMMUNICATIONS IN THE NORTH

Canada's North is a land abounding in natural resources: oil, gas and a great variety of minerals are all to be found. It is a land where one can find scarcely-tapped timber stands; fertile farmlands in the Peace River valley region, quite at odds with the popular image of frozen wastes. It is, too, an area of strategic importance in the defence of North America. But the North is really an empty country by most standards with a population esti-

*Compare ELSA (Extended Local Service Area) in the Australian system noting that ELSA calls are charged as unit fee calls whereas EAS calls in Canada are not individually charged. (Editor.)

**Compare STD (subscribers' trunk dialling) in Australia. (Editor.)

***Compare with the periodic metering used in Australia. (Editor.)

mated to be only about 230,000. For all its natural wealth, the high cost of extracting its riches and transporting them to markets in the south has made full-scale exploitation uneconomical. All but about two per cent of Canadians live in the belt which skirts the southern border; and apart from the small but steadily rising native population of Indians and Eskimos, the inhabitants of the North have tended to cluster in relatively small groups close to trading posts or mines.

Although the North is very sparsely settled, and despite the fact that only a fraction of its resources has yet been extracted, three factors have impelled the members of the telephone industry to carry their communications services northward. The first of these is to provide a much-needed service to remote settlements; the second is the promise of greater economic development in the years to come; and the third is the creation of "early warning lines" for defence, with their need for rearward communications with the south. The economic development of the North will depend mainly on the exploitation of mineral, oil and gas resources. The extent to which these are exploited will depend on a number of factors including improvement in transportation facilities and on the availability of good quality communications.

The enormous distances and the severe climatic and topographic conditions (Fig. 3) in the North generally make it uneconomic to build and maintain landlines and the demand simply does not justify microwave systems for civilian services. High frequency radio, on the other hand, offers a means of giving reasonable coverage throughout the North for some years and is used fairly extensively.

The long-term development of this region will in all probability create a need for permanent back-bone routes, stretching from east to west as well as southward to the Trans-Canada microwave system. These may in part have to be built from scratch. But the extensive northern defence networks, in many cases constructed by the telephone industry itself, could well form the basis for a commercial network—either through direct leasing of circuits from the government, or through provision of additional circuits on these existing routes. Spanning the North, at a latitude of about 70 degrees, is the Distant Early Warning Line. At approximately 55 degrees north is the Mid-Canada Early Warning Line, for which the Trans-Canada Telephone System was management contractor. In both of these systems, the warning "stations" are connected laterally—by tropospheric scatter (Fig. 4) and ultra high frequency networks. Both also have rearward communications facilities, which link them to strategic defence posts to the south. In every case, they are facilities of the very best quality that the telephone industry can provide.

These systems, which have been built primarily for defence, provide complete networks stretching from the Atlantic to the Pacific with connection into the routes of the regular telephone network. Building new communications links in the North is, for obvious reasons, a very costly undertaking. Sharing of communications networks, on the other hand, would considerably reduce costs, not only for the industry but also for the government itself. This has been done to a large extent because, to duplicate communications pathways across such great distances would seriously inhibit and defer the provision of any civilian communications.

THE TELEPHONE SWITCHING NETWORK

Even in the early 1950's, more than four million long distance calls were placed each year from Canada to the United States, and it was clear that it would be to the advantage of both countries to integrate their plans for direct dialling. As a result, there was close co-operation between the telephone companies involved on both sides of the border and an economical method of interchanging international traffic was worked out. In reality, there is today an integrated North American customer-dialling plan, within which the national networks of Canada and the United States carry national traffic entirely within their own borders.

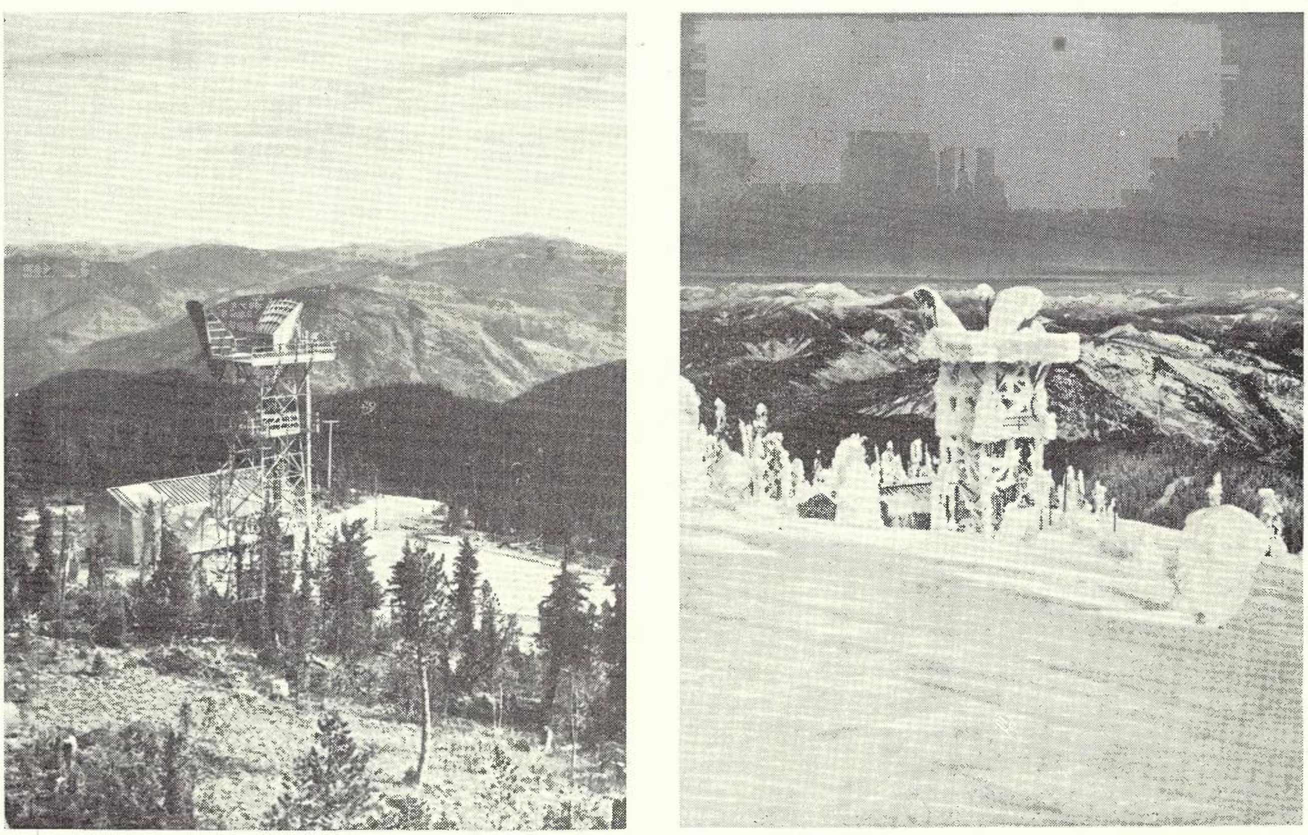


Fig. 3.—The Changing Face of This Microwave Station in British Columbia Typifies the Wide Variations in Working Conditions with Which Many Telephone Companies have to Cope.

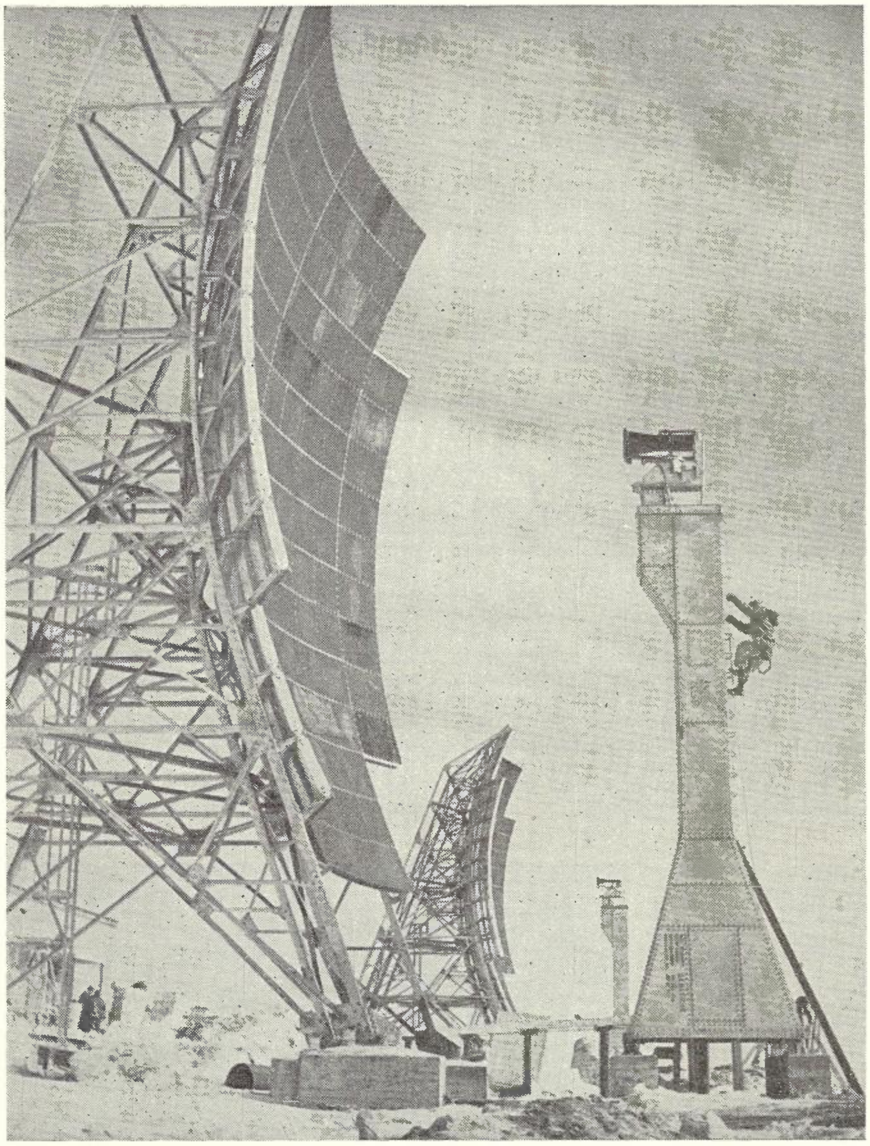


Fig. 4.—Tropospheric Scatter Station in Northern Canada.

The basic ingredients of the customer-dialling plan—or Direct Distance Dialling—were a uniform system of telephone numbering and a hierarchy of switching machines connected by a network of high-usage and final trunks. (See Fig. 5*). The hierarchical-network principle, with its inherent high efficiencies for handling small or modest amounts of traffic, has served the North American continent very well. With it, Canada and the United States have been divided into about 120 numbering plan areas, each distinguished by a special three-figure code. Fig. 6 shows the numbering plan areas and the control switching points.** Within each numbering plan area, every telephone which can be reached by direct distance dialling has been assigned a different seven-digit telephone number. Originally, two letters and five figures were standard; now a seven-numeral system is being introduced because it provides a larger number of central office codes. Taken together, the area code and the seven-digit number provide a unique telephone number not duplicated elsewhere in North America.

Generally, the first three digits of the continent-wide telephone number—the area code—are examined by a switching machine in a long distance centre to determine the route of a call to a distant numbering plan area. The next three digits are examined by machines in the distant area to determine the route of the call within the area. The last four digits route the call through the local switching equipment to the specific telephone desired. If a call is placed to another telephone in the same numbering plan area, the area code is not needed for routing purposes and therefore need not be dialled.

If a switching machine has more than one direct route for calls to a distant numbering plan area, it needs to examine both the area code and the next three digits to determine the route. For example, Regina has direct circuits to both Edmonton and Calgary which are in the Alberta numbering plan area, and the machines obviously could not choose which route to take by examining only the area code "403". If the next three digits were 424, the call would be routed to an Edmonton office; if they were 277, to a Calgary office. Area codes have been assigned at random throughout North America — the only premise that has governed the assignment is that a numbering plan area should not normally extend over a provincial or state boundary.

SWITCHING SYSTEMS

The switching systems are dealt with under two categories: Exchange or local systems and trunk tandem or toll systems. There are about 2,000 local dial central offices in Canada mainly of the Strowger step-by-step variety supplied by Automatic Electric (Canada), the Northern Electric Company, and Siemens-Edison-Swan. While step-by-step apparatus has met the telephone companies' needs for many years, its heyday is now past, and there is evidence that much of the equipment will either have to be replaced or modernized within a few years. About ten years ago, cognizance was taken of the need for more versatile local switching equipment that would handle more economically and more rapidly the bulk telephone traffic that stems from increasing usage and wider flat-rate calling. There was also a growing need for equipment to keep pace with the latest demands for more data services, switched-teletype service, etc. This demand is now to a large extent being satisfied by common-control, crossbar systems.

Crossbar systems made it possible for the telephone companies to offer a variety of services which are difficult or expensive to provide with step-by-step. Touch-Tone Calling, in which the telephone dial is replaced by a set of push-buttons, is one of these; others are Wide Area Telephone Service, which offers large flat-rate calling areas at a fixed monthly rate; and Centrex service, which enables callers to by-pass the customers' switchboards and dial directly to extension telephones. Even modern crossbar switching systems, however, do not provide all the features which will be required in the future, and most companies are trying to get electronic central offices as soon as possible. The electronic central office will provide an economical means of handling heavy loads of telephone traffic and will make feasible an impressive array of optional service features.

These include:

1. Automatic transfer of incoming calls from one home telephone to another. This can be arranged by the customer, who merely dials a special code.

*Note the similarity in the switching plans of the two systems. See Fig. 6 in Vol. 14, No. 2, page 106, of this Journal. (Editor.)

**Compare with the Australian Numbering Plan, Fig. 5, Vol. 14, No. 2, page 105, of this Journal. (Editor.)

2. Two-digit dialling (instead of the usual seven) to reach frequently called telephones.
3. Camp-on feature—calls to a busy number are held automatically, and the called telephone rings as soon as it becomes free.
4. Conference calls involving other telephones are set up by the customer, and additional telephones can be connected to a conference in progress. And so on.

The telephone companies expect that electronic switching systems will be in operation in some of the major cities before the end of the present decade. The first in Canada is being installed in Montreal for the World's Fair in 1967. The telephone companies are faced with major decisions as to how far they should go in modernizing their present equipment, and as to how much of it should be replaced with electronic systems. The Bell Company has completed a long range study into the modernization and replacement of existing dial systems and finds that it is economically feasible to replace their step-by-step equipment over a period of about 25 years. The study has been approved in principle, and a program of planned replacement, starting with the older and larger central offices, is expected to start by 1967.

Toll switching has seen many more dramatic advances in post-war years than has its older and less up-to-date relative, the local central office. In the past decade the network had undergone virtually complete modernization, to provide for the introduction of direct distance dialling. Crossbar equipment is used in most of the principal toll switching centres. In a few, the switching machines are basically of step-by-step design with associated "register control". Fig. 6 shows the locations of the main Canadian toll switching points.

For all the efficiency and versatility of present-day toll switching systems, there is no doubt that electronic switching will eventually be used for toll routing — though probably not before the 1970's. The real need for electronic systems is in the field of local switching, and it is here that development is being concentrated. It is possible that a good deal of the existing toll equipment will be replaced—even though a major toll switching machine represents a large investment.

Two main types of automatic equipment are used to record billing information on calls placed by direct distance dialling: Automatic Electric's SATT (Strowger automatic toll ticketing) and the Northern Electric Company's CAMA (centralized automatic message accounting). The billing information is now recorded on paper tape or cards. The paper tape is later converted into punched cards which, together with cards originated by operators on calls which they have handled, are machine-processed at accounting centres. This paper process is being replaced in Montreal and Toronto this year by two electronic computors. Several cities have Automatic Number Identification, and there are active plans to extend ANI throughout Canada as soon as possible. The Bell Telephone Company, for example, expects that the calling number will be recorded automatically on the majority of customer-dialled calls by 1965.

Billing information on calls handled by an operator is now recorded on "mark sense" cards—the operator marks the called and calling numbers and the time elapsed on a business-machine card, using a special pencil with magnetically sensitive graphite lead. This type of card, which can be processed by machine, is gradually replacing the handwritten toll ticket which requires expensive manual processing. Person-to-person, coin and credit card traffic will be automated and customer dialled, starting in the early 1970's.

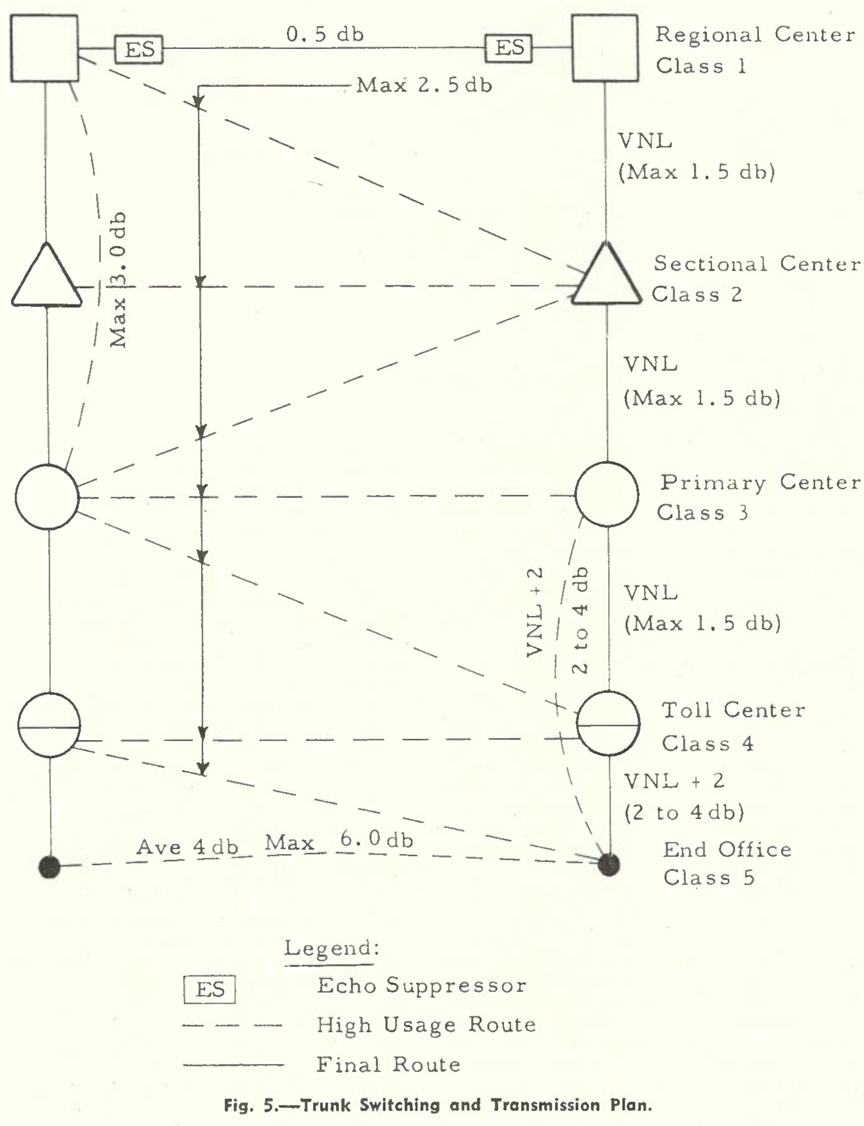


Fig. 5.—Trunk Switching and Transmission Plan.

LINES OF COMMUNICATIONS

The backbone of the telephone network is the Trans-Canada microwave system, which stretches 3,900 miles from the Atlantic to the Pacific. In all, the telephone industry owns and operates some 10,000 miles of microwave routes —in several places the main system is reinforced by parallel networks, and there are sizeable spur lines which feed the backbone route in every province. A microwave route linking Newfoundland to the mainland network is operated by the Canadian National Telegraphs who also are building a network across the country.

The Microwave system was designed and built by the members of the Trans-Canada telephone system at a cost of some $40,000,000. On its completion in 1958, it made available for the first time, coast-to-coast television as well as hundreds of long distance circuits. There are currently two television networks carried on these facilities: the CBC which is publicly owned and the privately owned CTV network. In all, about 18,000 channel miles are used for television. The inter-toll facilities that feed into the backbone structure are mainly cable-carrier systems using frequency-division multiplex. These cables are virtually all paired cables, and are buried where the geology permits. Until

Fig. 6.—National Numbering Plan and Control Switching Panels.

now, coaxial cable systems have not been used to any extent, mainly because of higher cost than for comparable microwave systems under the conditions we encounter. For example, trenching and cable construction would be very difficult through the Rocky Mountains or in long stretches north of the Great Lakes between Manitoba and Eastern provinces. Here the terrain is rocky and until recent years there was no adequate road system to facilitate cable construction and maintenance. In the future, however, we expect that intermediate length and cross-section coaxial systems will play an important role as the radio frequencies get used up. Because of storm damage and sleet, and the need for improving the reliability and quality of service, open-wire systems are generally not satisfactory for long-haul toll circuits. Consequently, the companies are relegating their open-wire to other uses or replacing it. By 1970 the bulk of the toll open-wire will be replaced or reinforced by microwave and cable.

A number of significant trends in the design of customer plant are now becoming apparent. Improvements in the supervision limits of central office equipment, for example, have made it possible to use wire of finer gauge. At the same time, the transmission quality of telephone sets has improved so that advantage can be taken of the increased signalling limits. The supervision limit of the electronic central office will be 2,500 ohms and in order to take advantage of this and meet transmission standards, a simple economical way has to be found for further transmission improvement of telephones or the loops. As wires become finer and finer, more and more of them are being put into a single cable and a standard full-size cable, for instance, now contains 2,700 pairs of No. 26 (4 lb. per mile) gauge conductors. On the rural scene, long cables are gradually displacing the familiar steel wire rural lines which were at one time the staple of the industry.

If the wires which make up telephone cables have changed in the past few years, so too have the cables themselves. Once, paper insulated conductors and lead sheaths were standard; now the wires in many cables are insulated with polyethylene. Larger sizes still use paper conductor insulation and the cables themselves have plastic sheaths. One of the more obvious developments in the field of customer loops is more and more cable is being placed underground, both for aesthetic reasons and because buried cable is better protected and is expected to have a longer life than its aerial counterpart.

TRANSMISSION PLAN

The present overall transmission objective is to provide a grade of service that is rated by subscribers as Good in at least 95% of connections; Fair in no more than 5%, and Poor in a negligible percentage of cases due only to specific trouble conditions. The transmission loss objectives (at 1,000 cps.) for subscriber loops, interlocal trunks, toll connecting trunks and intertoll trunks are shown in Fig. 5 and amplified below. It might be noted that this is essentially the routing plan with transmission loss objectives superimposed.

Subscriber loops are designed on the basis of assigning the minimum amount of copper wire necessary to meet the limitations imposed by the signalling, pulsing and supervision requirements of the central office switching equipment. For the most widely used types of switching systems, satisfactory operation can be obtained with d-c loop resistances up to about 1,200 or 1,300 ohms. Electronic systems will have a 2,500 ohm limit as previously mentioned. To equalize voice frequency transmission performance over a comparatively wide range of loop lengths, loading coils are applied to the longer loops which are also equipped with modern highly efficient telephone sets. With the loop plant designed on this basis, calls between any two telephones connected to the same switching office, or through the local or long-distance trunk networks, are given a "good" rating by the vast majority of subscribers.

Interlocal trunks which provide the connection between two local offices located in a large metropolitan area or multi-office exchange area, are designed to meet an objective of 4 db average with a maximum of 6 db. This objective applies whether the connection is by means of a single direct trunk or two interconnected tandem trunks.

The trunks which connect the end offices to the long-distance network are operated at losses ranging between 2 and 4 db. The objective is to provide a loss of Via Net Loss + 2 db with a maximum of 4 db.* VNL is defined as the lowest loss in db at which it is desirable to operate a trunk facility considering limitations of echo, crosstalk, noise and singing. From a knowledge of the various types of facilities employed, it has been possible to specify the VNL for each type of facility on a per mile basis. The minimum loss of 2 db is required to ensure stability of overall connections. In the case of short toll connecting trunks; i.e., less than 2 db, this requirement is met through the insertion of attenuators.

The final trunk groups linking the toll centres and higher ranking switching centres, are designed to operate at VNL with a maximum of 1.5 db. In the case of final trunk groups between Regional Centres the objective is 0.5 db. To operate these trunks at such low loss, it is necessary to insert echo suppressors on the trunks since the circuit loss alone would be inadequate to control echo. High-usage intertoll trunks within a region are also operated at VNL. In the case of high-usage trunks between regions, operation is at VNL but with a maximum of 2.5 db. Echo suppressors are inserted on inter-regional high-usage trunks, permitting operation at any loss up to 2.5 db while maintaining echo control. From Fig. 5, it is apparent that the average loss of a connection between two end offices is about 4 db if the connection is made via interlocal trunks. On connections between end offices via the long-distance network, the loss will be greater but generally not much higher since more than 80% of long-distance connections involve only one intertoll link.

Circuit noise objectives are comparable to those currently recommended by the CCITT. However, because of the very long connections encountered within Canada and on calls to the United States, consideration is being given to the implementation of more stringent objectives.

*Compare the Australian loss allocation as shown in Fig. 7, Vol. 14, No. 2, page 107, of this Journal. (Editor.)

LINES OF COMMMUNICATION OVERSEAS

Telephone calls can now be placed to 165 overseas countries, via the facilities of the Canadian Overseas Telecommunication Corporation (COTC). In the past, most overseas telephone service has been provided by means of radio. Today, cables provide direct circuits between Canada and Britain and between Canada and continental Europe. Last year the final section of another cable was laid across the Pacific, to link this country with Australia, New Zealand and a number of intervening points. Still more dramatic are the advances which have been made in the new field of satellite communication. It is likely that satellites will eventually carry much of the intercontinental communications. The COTC is the official government agency responsible for this country's participation in any satellite program designed to provide overseas communication; and COTC is currently participating in engineering and other studies with the objective of securing a proper place for Canada in the development and use of satellites for communications purposes. Plans are now fairly definite for establishing a satellite tracking station on the Atlantic coast by 1965.

RESEARCH AND TECHNOLOGY

The telephone industry serves its customers best when it remains responsive to change, and much of its progress has come from frequent interchange of ideas between the people of the industry and those engaged in research and development work. Much of this co-operation has been international in scope. Through its service agreement with the American Telephone and Telegraph Company, for example, the Bell Telephone Company of Canada has access to the progress made within the A.T. & T., including the inventions and developments of the Bell Telephone Laboratories. The Bell of Canada pays an annual fee for information of all kinds—on new service concepts, on new equipment, and also on operating and administrative matters. The British Columbia Telephone Company, through its parent, the General Telephone & Electronics Corporation, has access to the results of research and development work within the General Telephone System.

At home, the Northern Electric Company, which is the manufacturing associate of the Bell Telephone Company, has established Research and Development Laboratories on the outskirts of Ottawa. The Northern research centre (Fig. 7), which was officially opened late in 1961, comprises some 100,000 sq. ft. of space in two buildings, plans call for the eventual construction of two additional buildings to provide space for the expansion of these laboratories. Construction has started on one of these buildings which will add 120,000 sq. ft. of space. There are at present about 400 scientists, technicians and supporting staff at the Northern Laboratories. Development work, much of it designed to produce equipment suited to Canada's specific needs, is concentrated in the fields of telephone and data transmission, microwave radio, communications switching, audio and video broadcasting, wires, cables and subscriber apparatus. The Laboratories are also working on fundamental studies in the new arts of electronic circuitry, and on basic research in such fields as micro-miniaturization and solid state physics.

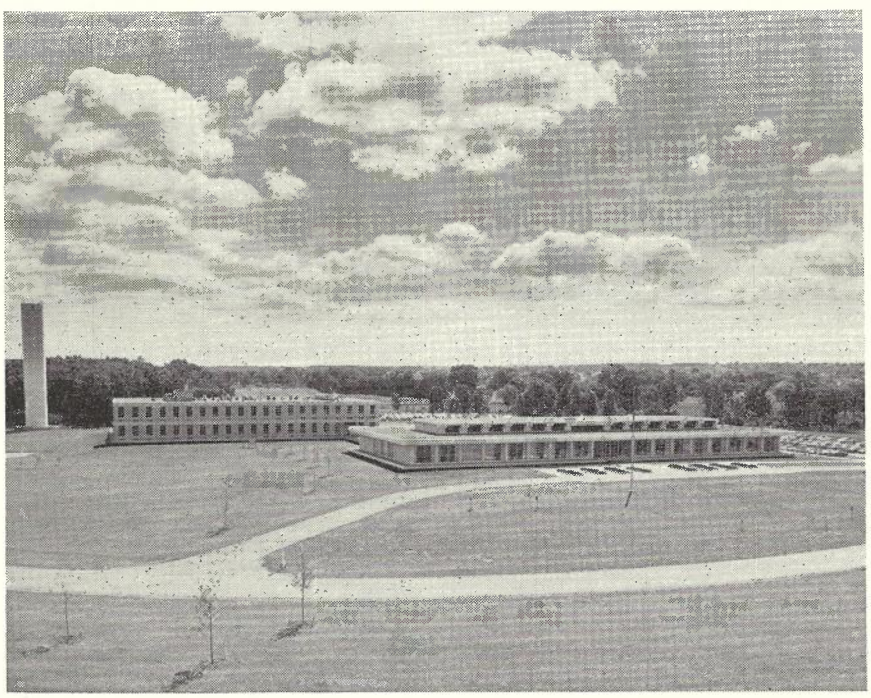


Fig. 7.—Northern Electric Laboratories, Ottawa.

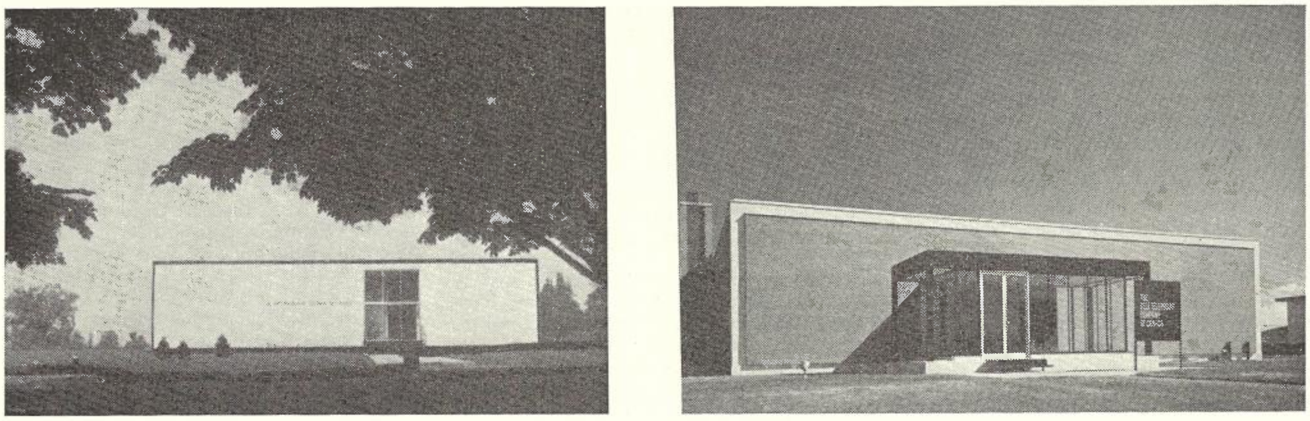


Fig. 8.—New Exchange Buildings, Toronto.

An important development in the field of engineering education took place in 1963 when the Bell Telephone Company opened a regional engineering school to provide post-graduate courses in communications technology for young engineers. It is affiliated with Queen's University in Kingston, Ontario, and all instruction is conducted by the faculty of the university.

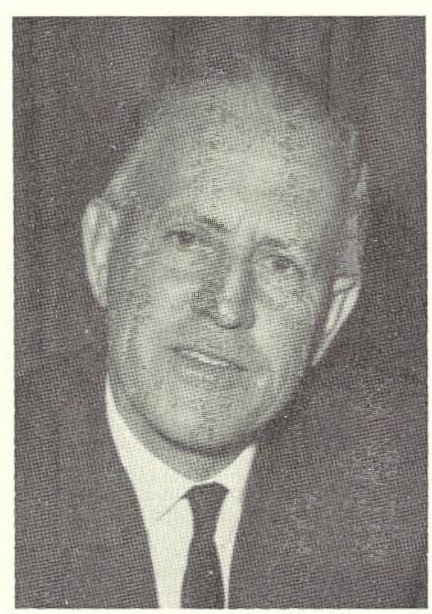
CONCLUSION

The Canadian industry's primary aim has been to provide highly efficient telephone service — easy to use, available virtually everywhere at short notice, and offered at the lowest possible price. At the same time the industry has made a substantial investment in research, and in the development of a wide variety of new communications services.

In the years ahead the telephone industry will continue to increase both the scope and the quality of its communications. Telephone service will be carried to the furthest reaches of this country; more steps will be taken to enhance the value of service in both rural and urban communities; and the industry will extend the convenience of automatic long distance dialling to many more people. But telephone service, for all its importance, is but one component in the increasingly diversified range of communications that is being offered by the industry. The telephone companies plan to provide a complete communications service — transmitting over the regular telephone network virtually every kind of information that can be translated into suitable electrical signals. With the introduction in recent years of methods of carrying handwritten messages, printed text, and data between business machines, the industry is already well on its way towards the achievement of this aim.

The reader will have noted the numerous parallels that can be drawn between Australia and Canada with regard to size, rate of expansion, telephone trunking plans and so on. Both countries are expansive from a geographical standpoint with vast undeveloped and virtually uninhabited areas. Opposite extremes of climate and geography make the countries look different to the casual observer, but the effects of these extremes on building and maintaining a communications network are probably very similar. Heating a central office (Fig. 8) can be as much of a problem as cooling one. Similarly, our objectives and degrees of achievement are probably not too different.

The future will, of course, bring many changes—some of them probably more sweeping than any that have been made in the past. Of these, one of the most significant will be the introduction of world-wide automatic communication—an event which will open impressive new horizons and strengthen the bonds of friendship within the Commonwealth Family of Nations and, we hope, between all mankind.



Mr. P. M. HOSKEN, B.Sc., A.M.I.E.Aust.

Congratulations are extended to Mr. P. M. Hosken, B.Sc., A.M.I.E.Aust., on his promotion to Assistant Director, Engineering, Queensland. Mr. Hosken joined the P.M.G.'s Department in Melbourne as a Cadet Engineer in 1926. He qualified as an Engineer in 1931 and graduated Bachelor of Science from Melbourne University in the same year. In 1944 he transferred to Queensland as Divisional Engineer, Transmission Planning, and in 1950 was appointed Supervising Engineer. He was promoted to Superintending Engineer, Country Branch, in 1962. Mr. Hosken has been particularly active in the power co-ordination field and has been the Convenor of the Queensland Power Co-ordination Committee since its inception in 1954.

In 1935, Mr. Hosken visited Europe and U.S.A. for 10 months, three of which were spent working with various communication authorities in the U.K. and U.S.A. He is a past Chairman of the Queensland Division of the Telecommunication Society and has contributed articles to the Journal. Mr. Hosken was President of the Queensland Branch of the Professional Officers' Association for many years, is a Fellow of the Royal Institute of Public Administration, and is Vice-President of the newly formed Electrical and Communication Branch of the Institution of Engineers, Australia (Queensland Division).

MULTI PAIR PLASTIC SUBMARINE CABLE—MORETON BAY QUEENSLAND

K. L. HAFFENDEN, B.Sc., A.M.I.E.Aust. and H. J. RUDDELL, A.M.T.C.***

INTRODUCTION

North Stradbroke Island, enclosing the southern end of Moreton Bay, near Brisbane, is some 20 miles long and seven miles wide and includes the small townships of Dunwich, Amity Point and Point Lookout. Settlement on the island dates back to before 1850 when a Government quarantine station was established at Dunwich. The cemetery at Dunwich contains many graves from this time of immigrants and medical staff who died of typhus and other serious diseases contracted during the long voyage by sail from England. With Federation and the transfer of quarantine responsibilities to the Federal Government, Dunwich ceased to be a quarantine station, but was later established as a State Aged Persons' Home. Following World War II this was also closed and there is currently no major Government Institution on the island.

The island is rich in mineral sands which are mined and treated in gravity separators on the Pacific Ocean beachfront and transported across the sand mountains of the island by rope roadway to Dunwich where electrostatic and magnetic separators complete the processing into the various component sands. Recently a second large mineral sands lease has been gained by another mining company who intend to truck the sands to their own treatment works over a network of 60 miles of new road. The island's second major activity, which has begun to develop rapidly, is tourism, particularly at and near Point Lookout. Thirty miles of first-class surfing beaches, excellent fishing and the scenic location of Point Lookout have led, in the last two years, to the first formed road across the island from Dunwich to Point Lookout, the first hotel (located on a headland at Point Lookout) and a regular landing barge service from the mainland to Dunwich for transport of cars and trucks. As a result of this industrial and tourist development, the island appears to be at the start of a new period of development. Since existing telephone trunk line facilities have been close to fully occupied for several years a proposal was prepared in 1960 to provide additional trunk circuits to the island from the mainland via a new 74 pair cable. The submarine sections of this cable were laid in November, 1963.

The present article reviews briefly the submarine cable facilities which have serviced the island for the last 50 years. A description then follows of the planning and installation of the submarine sections of the new cable including details of the type of cable, the development of a new method of jointing this cable and cable laying procedures.

* Mr. Haffenden is Engineer Class 2, District Works, Brisbane. See page 421.

** Mr. Ruddell is Chemist Class 2, Research Branch, Headquarters. See Vol. 12, No. 6, page 466.

PREVIOUS SUBMARINE CABLES

For many years telephone connection between the mainland and Stradbroke Island was provided by two single core submarine telegraph cables. One was direct from Cleveland to Dunwich (on the Moreton Bay side of the island) and the other from Cleveland to Dunwich via Peel Island where a Government Lazaret was in operation up to about five years ago. Numerous repairs and replacements of sections of cable were needed over the years, but, operating as earth circuit telephone lines, the cables did provide good quality connections. The last section of original single core cable was abandoned in 1963.

To replace one of the original cables and provide additional circuits an eight pair 40 lb. conductor Double Wire Armoured P.I.L.C. cable was laid in 1942 between Cleveland and Dunwich, a distance of eight miles. Drum lengths of 8/40 cable were laid up on a vessel near Scarborough and jointed into one length prior to laying. All pairs of this cable are currently in use and in addition a 1 + 4 carrier system is operating over two of the pairs. The first failure of this cable occurred in December, 1960, when 440 yards of new cable were pieced in. The cable has since been inspected over approximately half of the route and seems to be in reasonable condition with the outer layer of armouring missing at a few locations.

Over the years the maintenance of the above cables and the several other submarine cables in Moreton Bay has developed along fairly clear lines:—

(i) Adequate stocks of single core cable have been stored underwater in cable tanks in Brisbane. In the early days this was gutta percha insulated cable, but since 1945, stocks have been mainly V.I.R. insulated cable. Stocks of 8/40 cable are held under cover at the Main Store, Brisbane.

(ii) In 1918 the Department designed and had built a boat for under-running and repairing submarine cable. It was essentially a whale boat with stem and stern sheaves. A new improved boat, equivalent in size, replaced the original vessel in 1959. Since then various facilities have been added to the boat to expedite cable repairs. The most recent is the addition of two coupled outboard engines, mounted in the stern compartment of the boat, and operating through two wells in the bottom of the vessel. This enables the boat to under-run cable under its own power. The practically instantaneous steerage action of the outboards means the boat can be steered along the somewhat tortuous paths which the cable may take up thereby reducing the chances of damage to the cable.

(iii) The normal methods of repairing and jointing submarine telegraph cables (1) have been modified slightly to suit shallow water conditions, rubber insulation and double wire armouring.

(iv) The earth circuit lines provided by the single core cables possess a waterproof insulant of substantial thickness and remain workable even after the armouring and outer brass tape have completely disintegrated. It is only when the insulation wears through or the inner conductor is broken due to boating activities that repairs need to be instituted. In the case of the 8/40 PILC cable a continuous gas pressure of 25 lbs. per sq. in. is maintained at the two ends. For faults due to normal wear and tear the operation of the gas alarm gives fair warning of the need for repairs while the gas pressure inhibits the ingress of water to a reasonable degree. These factors have assisted in keeping the maintenance costs on submarine cable in Moreton Bay low.

NEW CABLE ROUTE

Following the decision to supplement and replace existing submarine cables to North Stradbroke Island with a new 74 pair cable, a detailed survey of alternate desirable routes was made. Factors bearing on the choice of the route and the type of cable were:—

(i) Experience with existing cables had shown that areas of living coral, which are fairly common in the vicinity of Moreton Bay, should be avoided due to the wear and tear on the protective armouring. This, of course, also applied to exposed rock.

(ii) There was no clear information available as to make up of the Bay bottom. Discussions were had with experienced Bay fisherman and officers of the Department of Harbours and Marine in an effort to determine the most suitable route.

(iii) To assist future maintenance of existing cables it was desirable to keep the new route well clear of them.

(iv) The State Government has under consideration the sub-division of Peel Island into a farming and tourist area and it is likely that additional circuits to the island will be required within 10 years.

(v) Location of future faults in the new cable would be simplified if it could be sectionalised by a crossing of Peel Island.

With the above in mind, various shore approaches at Cleveland, Peel Island and Dunwich were investigated above low water line. Reasonably satisfactory approaches were found for the Cleveland-Peel Island section consisting of mud and sand over a bed of dead coral and outcrops of growing mussels.

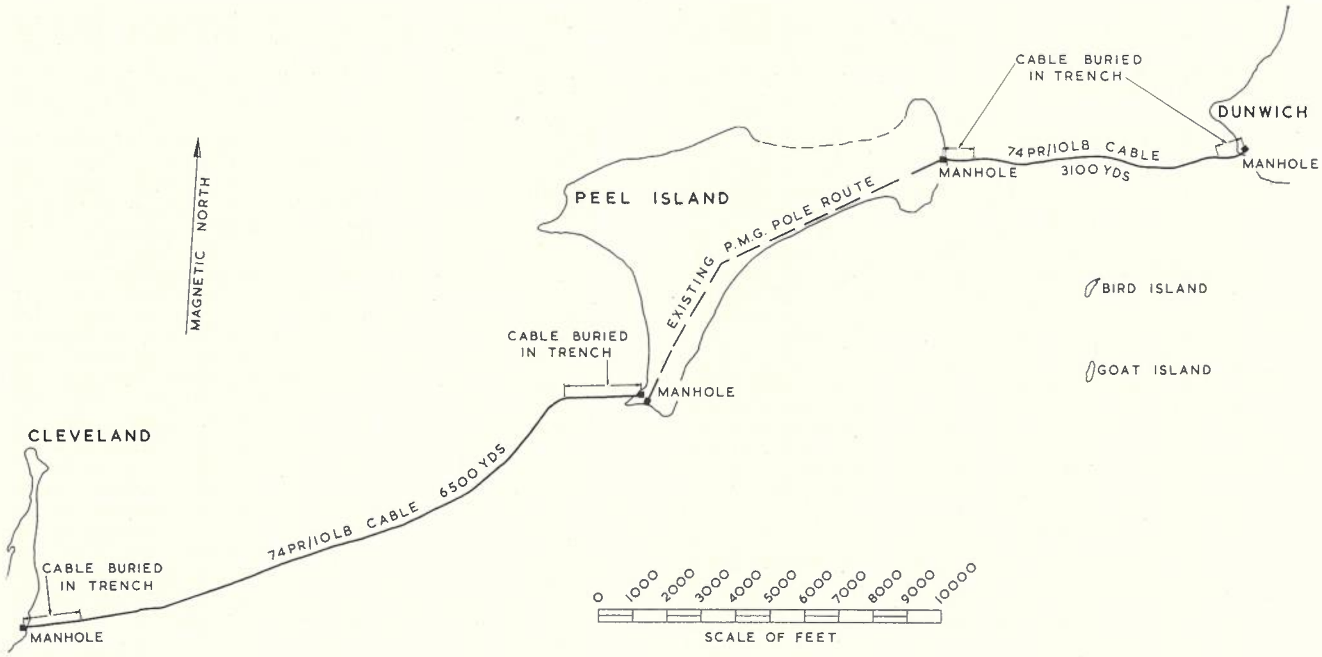


Fig. 1.—Locality Map and Route of Cable.

Rock shore approaches had to be accepted for the Peel Island-Dunwich section. Below low water line, alternative routes across the Bay were inspected using a glass-bottomed viewing box, an echo sounder and a lead line in an attempt to determine both the depth and type of bottom. The route selected appeared to be clear of major outcrops of live coral and rock though probably in several spots dead coral existed below a thin layer of silt or sand.

The route finally chosen was very close to the path followed in the later laying of the cable and shown in Fig. 1.

DESIGN OF CABLE

Developments in the field of multipair plastic cable in recent years indicated that a further trial of submarine cable of this type would be economic and informative. Reference (2) gives details of a previous multipair plastic submarine cable installed between Townsville and Magnetic Island.

From experience with previous cables in Moreton Bay it appeared that the most effective protection for the new cable would be Double Wire armouring. However, overseas trials suggested that if a sand or mud bed could be chosen for the cable route then an outer polythene jacket would provide substantial protection against abrasion during movement of cable on the Bay bottom. With this in mind the plastic multipair cable was overlaid with a single layer of armour wires of gauge approximately half that specified for normal Heavy Wire Armouring (H.W.A.) (3). Over this was laid a fairly thick outer polythene jacket. The actual make-up of the submarine cable was as follows. (See also Fig. 2):—

Core: 74 pair 10 lb. per mile conductor with 15 mil insulation of Grade 0.3 polythene to BS 3234.
Core Sheath: 0.1 in. grade 2BC polythene to BS 3234.
Brass Teredo Tape: 0.004 in.
Middle Sheath: Reprocessed polythene 0.020 in. Grade 2BC to BS 3234.
Single H.W.A.: Wires of 0.128 in. diam. to Specification 6.
Outer Jacket: Reprocessed polythene 0.08 in. Grade 0.3C to BS 3234.

The intermediate brass tape between cable and armouring wires was included to deter any action by teredo worms or termites and in addition provide a metal sheath which would be useful in the future maintenance of the cable. If the tape in later years should become earthed, a normal Varley Loop location could be made and action taken to repair the cable before cable damage reached the stage of ingress of water into the inner sheath.

The choice of plastic submarine cable was a controlling factor in several other facets of the proposal for these reasons:

(i) Previous and current experience with plastic cable indicated that there would be at least some blemishes in the wire insulant, and, that it was important to keep the cable core dry for satisfactory operation of the trunk circuits. In addition, water in the core of a cable would lead to a substantial increase in transmission losses.

(ii) It was unlikely a gas pressure system on the cable would be an effective inhibitor of water passage along the cable for any except the smallest sheath holes since the plastic insulation on the wires would not swell when wet as is the case with paper insulation. In preference to the gas system it seemed more appropriate to firstly try and ensure the cable was repaired before water entered the core—hence the alarm on the brass tape. Secondly, if water did gain access to the core due to say major mechanical damage it would be best to contain it by sectionalising the cable with water barriers installed at drum length intervals (1,000 yards).

(iii) The submarine cable joints would need to be proof against water entering the joint from outside the joint sheath and from along the core. Details of the method of jointing developed to accomplish this are discussed later.

(iv) The vagaries and severity of weather conditions in Moreton Bay precluded completing the nine sub-

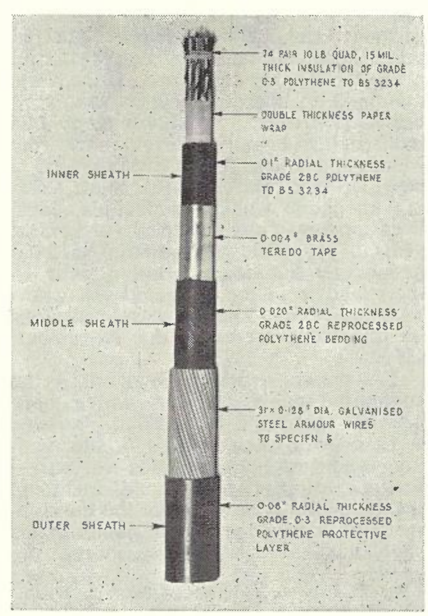


Fig. 2.—Make-up of Cleveland-Dunwich Submarine Cable.

marine joints after laying of the cable if the method of jointing required considerable time. As discussed later the method finally developed required the elapse of a period of some 24 hours between start and finish of each joint. As a result it was proposed to lay up the cable on the cable laying vessel and joint into one length of six miles prior to laying.

(v) The finished joints, if rigid, would need to be reasonably short and close to the diameter of the cable to ease the problem of paying out the cable into the water.

SUBMARINE CABLE JOINTING METHOD

Basically the union of cable drum lengths consists of resin encapsulated conductor joints within a polythene sleeve welded to the inner sheath, around which teredo tape is bound for electrical continuity across the joint. This is surrounded by joined armour wires also embedded in epoxy resin within a larger polythene sleeve welded to the outer sheath. (See Fig. 3).

Conductor jointing was carried out in a sheath opening of 7$\frac{3}{4}$ ins. using a modified hot-twist method. This technique was adopted because the resulting continuous insulation eliminates the problem of air entrapment in the conductor jointing sleeves normally associated with resin encapsulated sleeved joints. The over-all length of the conductor wire joint was confined to 1$\frac{1}{2}$-1$\frac{3}{4}$ ins. to permit four banks of joints in the first and second layers and five banks in the outer layer. The twists were tip-soldered to ensure complete electrical reliability, and the polythene "blob" made in exposing the wires for soldering was reformed around the soldered end by moulding in a shaped tool attached to plier handles. This ensured a complete and ample coverage by the original polythene insulation around the soldered twist for maximum protection against ingress of moisture. All heating of the polythene insulation was done with hot nitrogen gas delivered from industrial gas welding guns. Nitrogen was used to prevent degradation of the polythene by oxidation.

After spark testing of the hot twist joints and testing of the conductors for continuity, the conductor joints were laid pointing away from the tight-fitting polythene slip-sleeve. This prevented fouling of the joints by the sleeve when it was moved over the joint opening prior to carrying out the hot-tool welding of the sleeve to the polythene spacer pieces. These spacer pieces had previously been welded to the inner sheath by the hot-tool technique. In this position the welded sleeve completes an unbroken sheath over the conductor joint to provide another barrier against moisture, in addition to functioning as a mould during the resin encapsulation. At approximately 1 in. from each end of the sleeve was installed polythene adaptors for the thin-walled bottle of the Standard Epoxy Resin Field Pack (4) and a $\frac{1}{8}$ in. diameter hole. These were to function as the filling port and air escape hole respectively during injection of the contents of a single epoxy pack into the cavity of the sleeve to encapsulate the conductor joints. This was performed by compressing the thin-walled mixing bottle in a specially designed ratchet type injection gun when connected to the sleeve. When resin appeared at the air escape hole, it was temporarily closed with a wrapping of P.V.C. tape and injection continued to force resin along the cable for approximately 4-5 ins. on either side of the sheath opening. On completion the gun was removed and the collapsed bottle pierced and left attached to the sleeve to act as a resin reservoir. After a minimum curing period of eight hours, the adaptor and tape were removed from the sleeve and $\frac{3}{4}$ in. diameter polythene patches hot-tool welded over the openings.

Brass tape was then soldered to one of the exposed teredo tapes and wound spirally around the sleeve to completely cover it before soldering to the other teredo tape. It was found necessary to build-up the brass tape at each end to overcome the large difference in diameter between the teredo tape and sleeve. The function of the brass tape is to protect the joint from teredo worm attack and to provide electrical continuity of the tape throughout the length of the cable. As it was desired that the armour wires also be made electrically continuous through each joint, connection between wires of adjacent cable ends were individually made using 200 lb. G.I. press-type sleeves. The wire joints were further strengthened by embedment in epoxy resin within a 23$\frac{1}{2}$ ins. long, 3 ins O.D., 3/16 in. thick polythene sleeve, hot-tool welded to the outer polythene sheath. More information on hot-tool welding may be obtained from reference (5). Insulation between the teredo tape and armour wires was provided by a single half-lap lay of kraft paper followed by two half-lap lays of 1$\frac{1}{2}$ ins.-wide glass tape. All polythene sheath surfaces within the joint area not covered by the paper and glass insulation were treated with an oxy-acetylene flame (a blue, not yellow flame) until the surface appeared glossy. This action permits a chemical bond to be made between the otherwise chemically inert polythene sheath and epoxy resin (6).

The outer polythene sleeve was filled with epoxy resin whilst inclined at an angle of approximately 15°, through one of two 5 ins. x $\frac{1}{8}$ in. I.D. polythene tubes, held in place by caulking compound over holes in opposite ends of the sleeve. The resin was poured into the lower tube to displace air as it flowed up the cylinder and into the upper tube. When full, the sleeve was returned to the horizontal and a head of resin maintained in the tubes to compensate for flow-out of air bubbles, shrinkage and resin penetration into voids adjacent to the armour wires. After a minimum cure of six hours, the tubes were removed and 1$\frac{1}{4}$ in. polythene patches were hot-tool welded over the openings to complete a watertight outer jacket.

COMPOSITION OF CASTING RESINS

Past experience has shown the liquid types of epoxy resin to be the most suitable casting resin for this type of application, mainly because they are easy to handle, can be modified to meet a range of properties and cure or set by exothermic polymerisation without evolution of water or other volatile materials. This latter property is responsible for the low shrinkage obtained during casting. The formulation chosen for the conductor joint encapsulation was one which has already been proved satisfactory for this type of application and made available as the components of the Standard Epoxy Resin Field Pack. Its properties are such that at approximately 100°F. its viscosity permits penetration of the conductors and cable voids without excessive flow along the cable, and gelation occurs rather rapidly without damage to the polythene insulation by excessive exotherm.

The purpose of the second epoxy resin pour was to combine the armour wires of the two cable ends in such a manner as to produce a union at least equal to the strength of the cable itself, in addition to sealing the teredo tape to provide yet another barrier against moisture. The most important

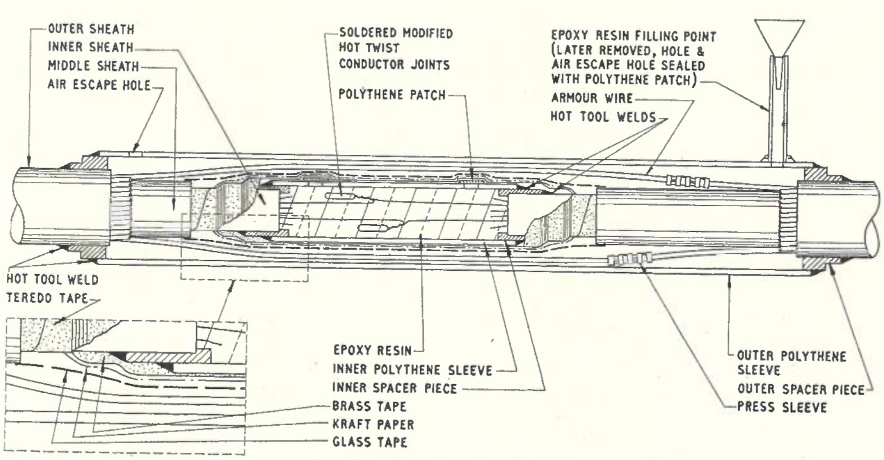


Fig. 3.—Cross Section of Joint.

property required of the resin, therefore, is a high tensile strength. However, as it is encased only in a thin-wall polythene sleeve, it is preferable that it should also have a reasonable impact shock resistance to avoid damage by contact with boat anchors, etc., and be resistant to marine life found in subtropical sea water that may penetrate the polythene sleeve.

Previous experience (7) has shown that thiokol modified amine cured epoxy resins have the strength and impact resistance required, whilst literature (8) indicates that although unfilled epoxy resin suffered borer damage, glass laminated epoxy resin showed no attack after one year exposure. On this admittedly limited evidence, the epoxy resin compound was filled with 25% of glass powder as a possible teredo worm deterrent. This had the desirable effect of reducing peak exotherm by bulk displacement of the other resin components, thereby reducing shrinkage.

Laboratory tests have shown that encapsulated sample cable joints containing only half the number of armour wires laid back over the joint to give a full overlap, had tensile strengths comparable with that of the cable. The actual joints containing the full complement of wires joined by press-type sleeves and embedded in resin will, therefore, constitute the strongest parts of the cable length.

CABLE LAYING VESSEL

The type of vessel required was determined mainly from the desire to prejoint the cable prior to laying. This meant the most suitable vessel should be:—

(i) Capable of carrying 40 tons of cable and fittings.
(ii) Shallow draught to ease the prolems of laying the shore ends and laying across sand bars near Dunwich.
(iii) Powered, preferably in such a fashion as to proceed at a slow speed and still maintain steerage way.

After various approaches were made to find a suitable vessel it was found the Army had assembled a powered barge, 70 ft. x 20 ft., made out of rectangular steel pontoons (and designated NLE). Fig. 4 illustrates some of the features of this barge which include a load capacity of 70 tons for a draught of 5 feet; a clear, flat deck 63 ft. by 20 ft.; and independently controlled inboard-outboard 115 h.p. Chrysler engines with propellors which are capable of being raised and lowered while driving and of turning through 360° for steering purposes. The barge and a crew of four were made available by the Army.

Experience on the job has shown this vessel to be almost ideal for laying shallow water submarine cable since:—

(i) It is sturdy and almost unsinkable (36 individual sealed tanks make up the barge).
(ii) It can travel at up to six or seven knots or down to one to three knots while still maintaining steerage way (under reasonable weather conditions).

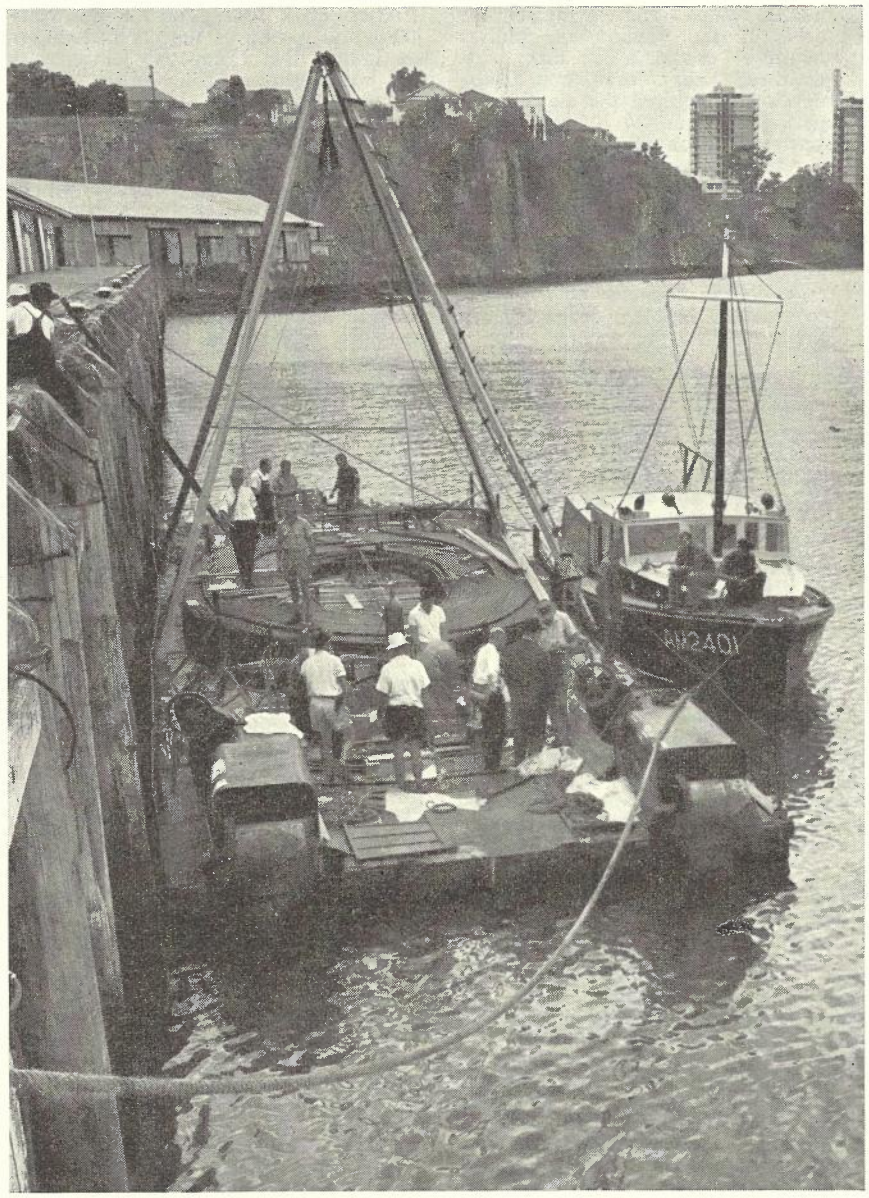


Fig. 4.—Cable Jointing Proceeding on Army Barge N.L.E. Note in foreground two inboard outboard 115 h.p. engines with propellors which can be raised through 180° and rotated through 360°.

(iii) It travels backwards so that cable may be paid over the trailing end with no dangerous propellors near by.
(iv) Its draught fully loaded with a 40-ton load is 3 ft. 8 ins. near the engines and 2 ft. 8 ins. near the bow.
(v) It may be beached with no danger to the vessel or crew and refloated on the next appropriate tide. To operate in the shallows the propellors are raised while still driving.

WORK SCHEDULE

The selection of early November for the laying of the cable was governed by the delivery date of the last drums of cable into Main Store, Brisbane, and the development of a satisfactory submarine cable joint. At this time of the year the area of Moreton Bay between Cleveland and Dunwich is subject to unexpected sharp storms and cyclonic disturbances. The weather during the four days on the job down the bay was fortunately most favourable for the work. However, within two days of completing the work a fairly severe cyclonic disturbance built up quickly causing severe winds and seas and closing all boating activities over the route of the cable for several days. The specific dates for cable laying (11th-13th November) were chosen in order to obtain reasonably good high tides at a suitable time of the day—this reduced considerably the work involved in getting the cable ends ashore.

Prior to the start of the job a detailed works schedule and list of duties for all staff was prepared. It was planned the job would take approximately three weeks as follows:—

(i) Two weeks from 28th October to 8th November for—
   (a) Team of three men (later five) to excavate shore approaches from low water to high water.
   (b) Team of six men plus Line Inspector and Line Foreman and welder to fit out barge and load cable.
   (c) Team of five jointers to be trained in new jointing technique and then complete nine joints on barge while loading of cable proceeded.

(ii) Four days commencing 11th November to land shore end at Cleveland, lay cable to Peel Island, lay cable from Peel Island to Dunwich and tidy up shore ends.

Apart from some small variations the work of fitting out, loading, jointing and laying proceeded as planned.

EXCAVATION OF SHORE APPROACHES

Based on maintenance experience with previous submarine cables it was decided to excavate a trench and bury the cable for some distance below high water line. Over this portion of the route the armour and outer jacket are subject to considerable weathering and to damage from fishing vessels, vandals, etc. The trenches, which would be in coral and rock, were to be excavated using explosives. At the start of the actual work it was decided to extend the trenches out to below low water as the outer plastic jacket of the cable was softer than expected and very susceptible to scoring by any item with a sharp edge, for example, mussels, broken coral, sharp rocks, etc; further, the armour was much lighter than previous submarine cables laid in the same general area of the Bay.

The extension of the trenching in this way led to approximately $1\frac{1}{2}$ miles of excavation on the four shore approaches. Apart from approximately 300 yards at the Cleveland shore end (excavated by Gofor Ditcher) all the trenching was completed with the use of explosives. Due to the rapid in and out of the tides on the shallow shore approaches, giving a maximum "out" of no more than three hours, the original gang of three men (including Powder Monkey) was increased to five to six men. Full sticks of gelignite ($1\frac{1}{8}$ ins. x 8 ins. AN60) were placed approximately 9 ins. below surface at intervals of 3 ft. using instantaneous Cordex fuse to fire runs of approximately 100-120 yds. of trench at a time. Any greater spacing of charges resulted in a discontinuous trench. The trench obtained in this way was particularly suitable for cable laying being approximately 2 ft. 6 ins. deep (with a slush bottom), 3 ft. wide at the top and clear of any backfill. The method proved expeditious, for example, 350 yds. were excavated through a 12 ins. thick coral shelf at Peel Island by six men in approximately $2\frac{1}{2}$ hours. A total of 525 lbs. Gelignite and 9,000 ft. of Cordex were used on the job.

LOADING CABLE

Ten drums, each holding 1,050 yds. of submarine cable, were loaded on to Army vessel NLE at a wharf in Brisbane. Briefly, six miles of cable were laid up in a flat elongated coil (Fig. 5) approximately 30 ft. x 18 ft. with a 6 ft. wide lay of cables. The height of this coil was slightly under 3 ft. Turns were laid down close to each other and feathering boards were, in the main, needed only where the cable fed from the inside to the outside of the coil or where the ends were brought out for jointing. No ties were needed to hold the turns of cable down during loading. Only in the first drum of cable was any trouble experienced. With this drum it was found necessary, due to the accumulation of a twist every few turns in the cable, to lay up three or four reverse loops to cancel the twist. This, of course, necessitated considerable timber feathering and slowed down the rate of loading. After changing the laying techniques slightly no trouble was experienced with later drums, for example three drums of 1,050 yds. each were laid up by nine men in one working day. The total loading time for the full six miles of cable was four days.

From this and previous jobs of a similar nature it is clear that time spent in carefully laying up the cable during loading is more than recouped when paying out the cable on the water. Hurried loading with improperly coiled cable leads to long delays during laying and serious hazards to the staff (particularly if the vessel cannot be slowed down immediately trouble occurs). The features in loading drums of cable on to a flat deck are:—

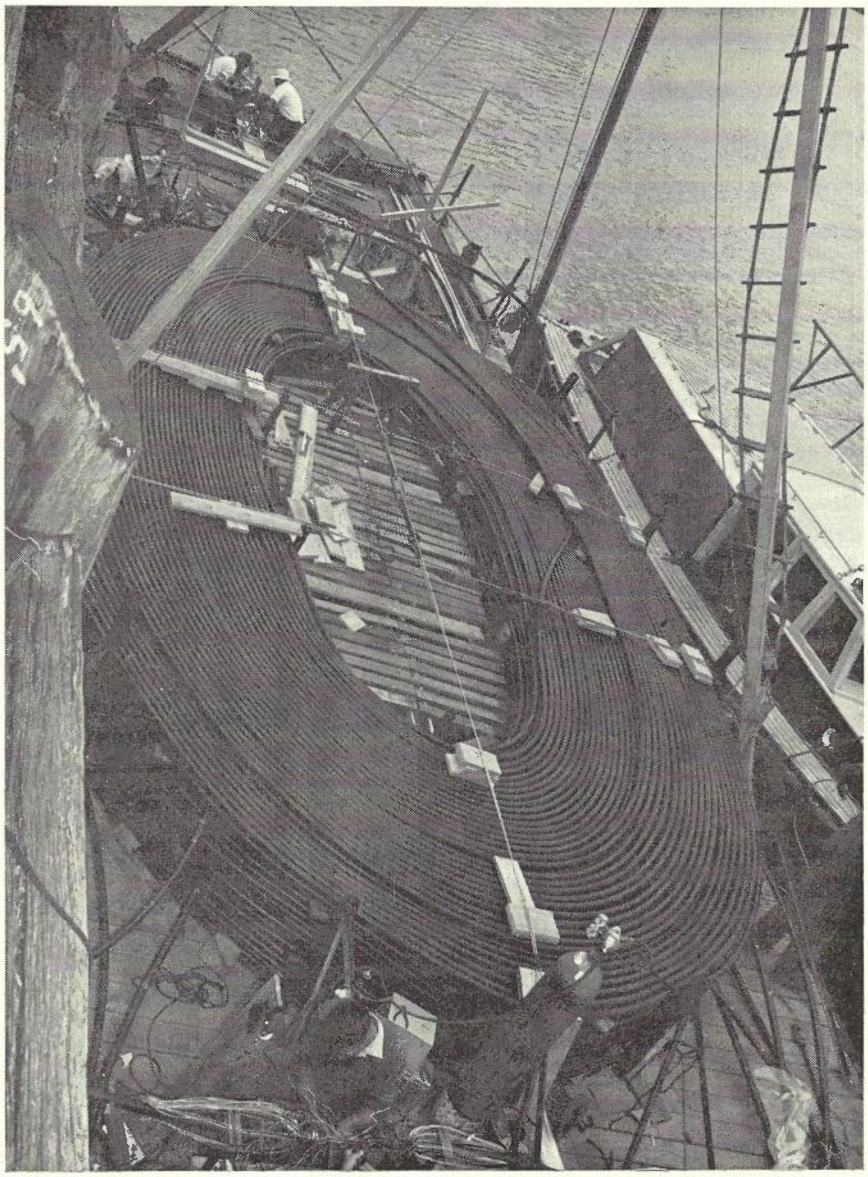


Fig. 5.—Six Miles of Cable Laid up on Barge. Note jointer working in foreground.

(i) Keep the cable running free from the drum.
(ii) Feed it through a central paying out sheave approximately 12 ft. to 15 ft. above the flat coil.
(iii) Pull the cable down from the sheave direct on to the coil—do not pull down immediately below the sheave and then feed out to the cable coil.
(iv) Hold the running end down as it is laid up on the coil to prevent the twist accumulating.
(v) Provide feathering boards wherever cable crossovers occur and wherever there are gaps between turns of cable. This latter is important, since, if turns from above should slip down in the gaps, real problems can occur when paying out the cable later.

During and following the loading of the cable onto the vessel the five jointers completed the nine submarine joints at either end of the vessel. Fig. 6 shows two joints at different stages of completion and three completed joints.

LAYING CABLE

No difficulties were experienced in paying out the cable. The actual time to run from Cleveland to Peel Island, a distance of 6,500 yds., was 2 hours while the 3,100 yds. from Peel Island to Dunwich took $1\frac{1}{4}$ hours. Fig. 1 shows the route of the cable as laid.

The cable laying vessel proceeded at a speed of approximately three knots, the cable was fed up into the central cable sheave (approximately 15 ft. above the coil) and down and out through the cable brake—in the deeper channels slack was increased. As each joint was approached the barge was slowed down, the central sheave lowered, cable brake opened and the joint lifted free of the ramp on which the joints were mounted. No difficulty was experienced in paying out the joints. Towards the end of the second submarine section two of the reverse loops, which had been placed in the first drum length loaded on the barge, were paid out. The first was paid out with the barge travelling at approximately three knots. This allowed little time for the cable to be "flipped" to get rid of the reverse loop. For the next loop the barge was slowed down (actually losing some steerage way) and the cable paid out without incident. This supports the earlier remarks that proper laying up of cable in the vessel is the secret in ensuring cable pays out into the water easily.

At the end of the Cleveland-Peel Island run (Tuesday, 12th November) the cable barge was brought in to Peel Island on the high tide, adjacent to the trench previously excavated, and grounded some 200 yards from high water line. The cable was cut and caps hot-tool welded on to the ends ready for one end to be taken ashore.

Excavation of the trench through the mangroves then proceeded. As the tide approached low water the cable end was carried ashore over the mussels (and exposed pieces of coral left after the blasting) and laid in the trench. A similar procedure was followed at the end of the Peel Island-Dunwich run on Wednesday, 13th.

On Thursday, 14th November, the digging in and tidying up of the shore ends at Peel Island was completed. This work included the injection of epoxy resin into the capped ends of the cable on both shore ends at Peel Island to ensure a positive open circuit; all pairs were cut to staggered lengths. This was to allow for the later testing of the Cleveland-Peel Island section from Cleveland and the Dunwich-Peel Island section from Dunwich with a T.M.C. Pulse Echo Tester.

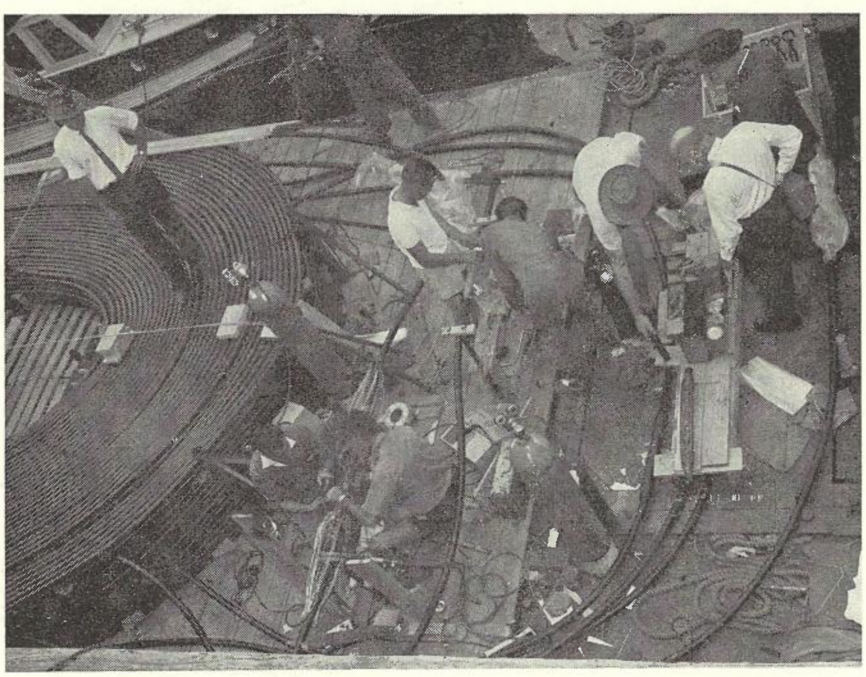


Fig. 6.—Jointing in Progress on Barge. On left, hot twist jointing of conductors; on right, armouring wires being laid up and jointed. A completed joint is visible just to the right of the gas cylinder in the foreground.

FUTURE MAINTENANCE OF CABLE

As mentioned earlier the multipair plastic submarine cable requires a somewhat different maintenance approach from that of previous cables. In an attempt to prevent waterlogging of the cable core it is proposed to adopt the following practices:—

(i) Provide polythene sleeved joints at the four points where submarine cable meets land cable, these to be capable of being opened and resleeved several times—a suitable joint has been developed. This should assist in proving the two submarine sections in case of a fault occurring.
(ii) Provide epoxy resin water barriers at the four ends of the submarine cable and set in these barriers an accessible 1 pr. block electrically connected to the brass tape and the armouring of the cable. Extend these connections back to Cleveland and Dunwich exchanges respectively via a separate cable pair and provide a permanent alarm on each at the exchange.
(iii) If the alarm on the brass tape operates, complete a Varley Loop location on the fault from the end of the submarine cable using a spare cable pair as the good wire. As soon as convenient after the location, underrun the cable out to the location of the fault.
(iv) Repair, by epoxy resin encapsulation and split polythene moulds any cases where the armouring is substantially damaged and/or the brass tape is exposed. If necessary piece in armouring wires before encapsulating.

If the above practices are followed there should be little need to piece in a new length of cable. However, if this becomes necessary:—

(i) A check of the water-logged section can be made using the Pulse Echo Tester. Fig. 7 shows the artificial balance line which has been developed to balance either of the two sections of submarine cable. Test traces for selected pairs through the cable, using this network, have been recorded. Fig. 8 illustrates a typical trace on the 6,500 yard submarine section.
(ii) Spare submarine cable is on hand to replace the water-logged section.
(iii) The method of jointing, detailed earlier, has been modified somewhat to reduce the time of completing a joint on the water.

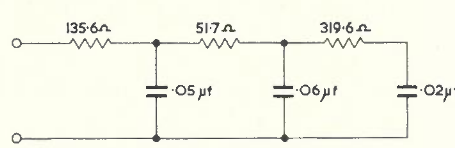


Fig. 7.—Artificial Balance Line.

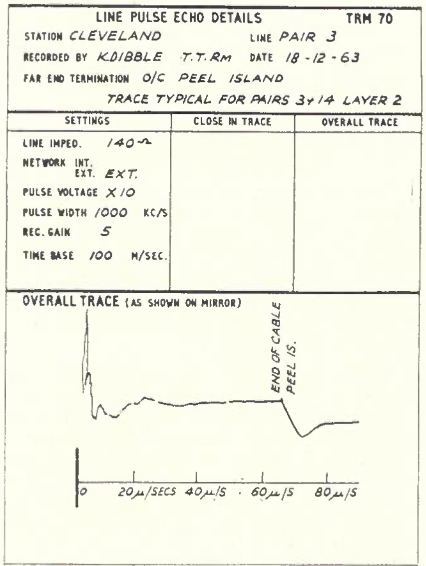


Fig. 8.—Typical Pulse Echo Trace Record.

CONCLUSION

Experience with the installation of the six miles of 74 pair plastic submarine cable has shown it is easy to handle and lay if normal care is taken. Provided an adequate cable laying vessel can be obtained (preferably one with the features possessed by Army Vessel NLE) and certain simple loading and laying techniques applied, several miles of cable can be loaded on the vessel in a continuous flat coil with no complications of "reverse loops" or "figure eights" and paid out speedily with little hazard to staff or cable.

The jointing techniques used on the job include several new approaches to the jointing of armoured plastic cable designed to safeguard the electrical and mechanical properties of the joints during the future life of the cable. As a result it is expected the joints will not be a point of weakness in the future. Several of the techniques used are simple and effective and likely to have application in the jointing of normal plastic cables, e.g., hot-tool welding a continuous polythene sheath over a joint.

Despite care in the selection of route, handling of the cable and excavation of shore approaches, damage to the outer plastic cable occurred during laying. It would appear normal plastic jackets, such as polythene, may provide mechanical protection where the cable bed is sand or mud, but provide little protection in the presence of rock, coral or mussels. There is no doubt the polythene jacket eases the handling of armoured cable (particularly when compared with bitumen impregnated jute serving) and for this reason should be retained. However, until substantial progress is made in the development of new plastics with more appropriate mechanical properties, it is considered the armour wires should be relied on to provide the required mechanical protection.

Experience over the last decade has shown multipair plastic cable is somewhat sensitive to the ingress of water into the cable core. Careful consideration has, therefore, been given to the future maintenance procedure for the new cable. It is proposed to make use of the insulated brass tape laid up outside the inner cable sheath to indicate the presence of water prior to the water entering the cable core. In normal cases of wear and tear on the cable corrective action at this stage should prevent further damage. Pulse traces on selected pairs, in the presently dry cable, have been recorded to assist in the location of water-logged sections if sudden and substantial damage should occur to the cable. For repairs under these circumstances the jointing method has been modified to suit piecing in of new lengths of cable on the water.

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Mr. G. R. LEWIS, B.E. (Hons.), A.M.I.E.Aust.

Congratulations are extended to Mr. G. R. Lewis, B.E. (Hons.), A.M.I.E. Aust., previously Superintending Engineer, Country Branch, N.S.W., on his appointment as Assistant Director, Engineering, N.S.W. Mr. Lewis joined the Department as Cadet Engineer in 1929 and has occupied a number of positions in the Transmission, Equipment and Long Line Sections of the Country Branch. He has been connected closely with the introduction of a number of major developments of the telecommunications system in N.S.W. over the years, such as the introduction of specialised equipment for overseas radio circuits, trunk dialling systems, trunk repeaters and signalling systems, multiplex telephone and telegraph systems and junction carrier systems. He also played an important part in the initial installation and operation of major projects including the Type J1 and J2 carrier systems, the Sydney-Melbourne Coaxial Cable System, the Sydney-Dalley Trunk Exchange and the re-establishment of telephone services in Canberra after the disastrous Civic Exchange fire.

Mr. Lewis is a graduate of the University of Sydney, with an Honours Degree in Mechanical and Electrical Engineering. He has taken a particular interest in the activities of The Institution of Engineers, Australia, where he has occupied the positions of Secretary and Chairman of the Sydney Division, Electrical and Communications Branch and is currently a Committee member.

Mr. Lewis has been active in Society affairs in N.S.W., serving as a Sub-Editor of the *Journal* since 1957. Members of the Society will no doubt join with the Board of Editors in congratulating Mr. Lewis and in assuring him of every support in his new sphere of activity.

GFELLER LINE CONCENTRATOR UNIT

B. P. DEW and J. D. MATHER, Dip.E.E., Dip.Mech.E., A.M.I.E.Aust.***

INTRODUCTION

A line concentrating device for subscribers' services has been sought by most telephone authorities since the turn of the century. Many telephone authorities in an endeavour to keep the costs of their outside line plant to a minimum adopted a shared or party line system using code ringing or multi-frequency ringing, but this did not give the secrecy required by the subscriber.

After the second world war the Australian Post Office, in its endeavour to meet the heavy demand for telephone service and the need of secrecy for the subscriber as well as conserve line plant, introduced on a wide scale the duplex service. This service gives satisfactory service to the "average" residential, two subscribers using a single cable pair, but in practice it is nearly impossible to find two "average" subscribers whose telephone habits do not clash.

By the early 1950's a Subscriber Auxiliary Unit (S.A.U.) was developed by the Australian Post Office, this unit accommodated 10 subscribers on 2 exchange pairs. The main disadvantage with this unit was that 10 residential subscribers could originate and terminate more traffic that 2 cable pairs could handle at a reasonable standard of service.

Morris (1) has described a concentrator unit which was designed and built by the Australian Post Office in 1959. It consisted of uniselectors and relays commonly used in 2000 type telephone exchanges and had a capacity of 23 subscribers on 5 exchange lines.

Because of the demand for line concentration equipment various telephone equipment manufacturing companies are offering various types of subscriber line concentrators and the Australian Post Office has purchased a number of different types of line concentrators for field testing in selected locations where expensive cable relief would be required to give telephone service to waiting applicants.

The Swiss-made Gfeller line concentrator unit is only one of the types undergoing tests, and to date it appears to be the most attractive type on the market. This article will only deal with the Gfeller Line Concentrator as the A.P.O. have on order a number of these and similar A.T.E. units and it is felt that a circuit description will be of some assistance to the installing and service staffs in the near future.

A Gfeller Line Concentrator Unit capable of serving 49 subscribers and using 11 cable pairs was selected for use in the Hawthorn (Vic.) Exchange area to serve two adjacent blocks of flats, in all a total of 49 new residential flats.

The Gfeller Line Concentrator uses a Trachsel-Gfeller crossbar switch and it is designed to accommodate 49 subscribers using 9 (2 wire) junctions or links and 4 control and marking wires. Both the exchange end unit, Fig. 1, and the subscribers end unit, Fig. 2, can be either wall mounted or rack mounted. The switching and marking equipment is similar in both exchange and subscriber units but there are a larger number of common control relays in the exchange unit.

THE TRACHSEL-GFELLER CROSSBAR SWITCH

The principle of the Trachsel-Gfeller switch is shown diagrammatically in Fig. 3. The switch consists of nine vertical switching bars of a transparent plastic material into which are fitted three nickel silver strips having inclined teeth on one edge to engage the horizontal cross links.

Each subscriber on the concentrator has one cross link or horizontal bar. The subscriber cross link carries three twin nickel silver wires which correspond with the strips in the vertical bars, and the three twin sets of wires are multiplied across the switch nine times and can be engaged by any one of the nine vertical bars.

When all the vertical bars are at rest the teeth are clear of the cross link wires even if a cross link is operated. With the vertical bar in the operated or raised position the wires on the horizontal bar are moved beneath the teeth of the vertical bar, then when the vertical bar is dropped or released the inclined teeth on the vertical bar trap the twin wires on the subscriber's cross link horizontal bar thereby making an effective contact.

LOADING

The connection between the connector bar elements and those of the horizontal bar is a physical connection. This means that at the completion of the call, the horizontal bar wires are maintained in an operated position by the contact with the connector bar, although the horizontal operating magnet coil is not energised. This is termed "LOADING". The horizontal bar remains

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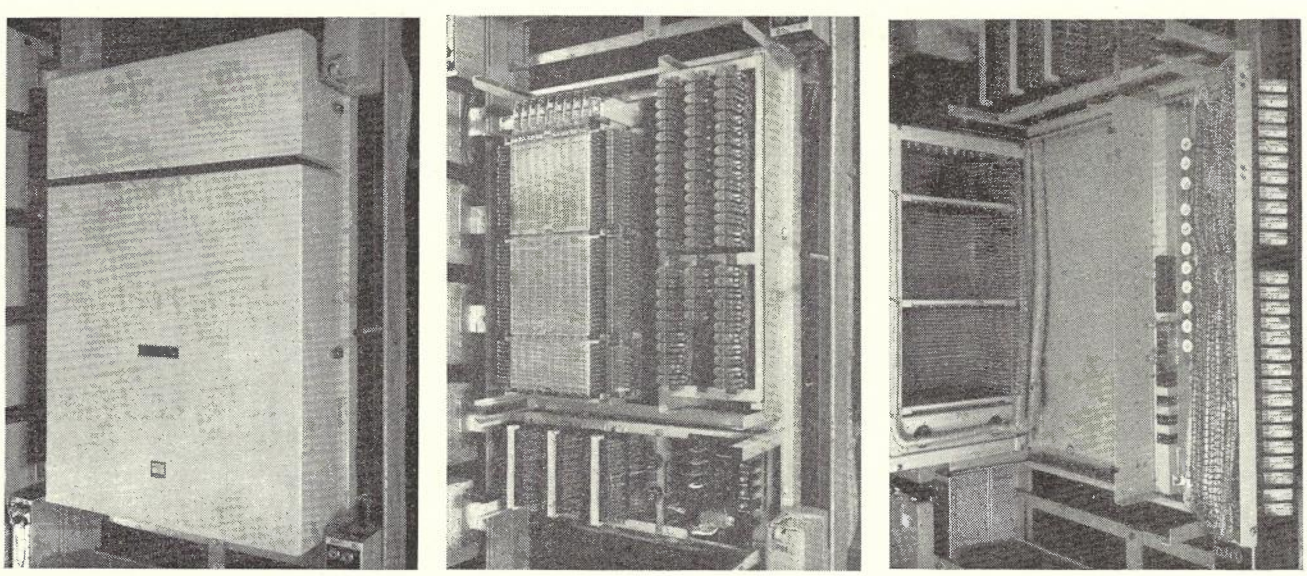


Fig. 1.—Exchange End Unit. Centre: With covers off. Right: With gates open showing how accessible the equipment is for maintenance.

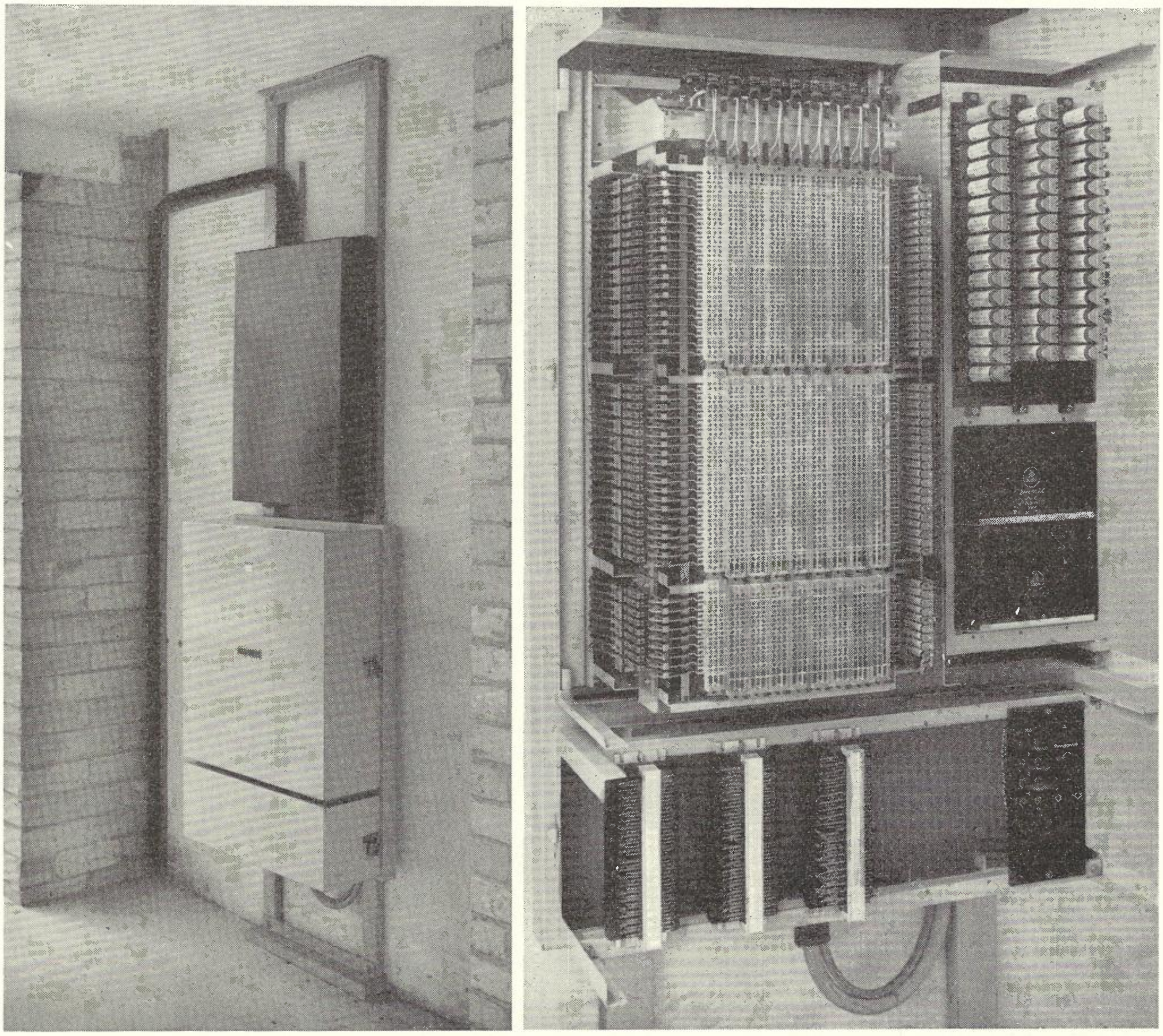


Fig. 2.—Subscribers End Unit. Right: With covers off.

"loaded" to the connector bar until such time as the connector bar is raised when selected by "LINK ALLOCATION".

This loading feature enables a subscriber making frequent calls to use the same link circuit on subsequent calls, thus obviating unnecessary setting up of the equipment.

LINK ALLOCATION AND TESTING

Unless all link circuits are simultaneously busy, a corresponding connector bar in each unit is maintained in a raised position.

This is a link circuit which has been tested and found free and so raised to enable its connection to the next subscriber requiring a link circuit. The raised connector bar circuit is said to be "ALLOCATED". Link allocation is dependent on the link being free and the testing always takes place in sequence from the previously allocated link, i.e., if link circuit No. 5 was previously allocated, then, when it is taken into use, the No. 6 circuit would be tested for busy, then No. 7, 8, 9, 1, 2, 3, 4, in that order, till a free link circuit is found, which would then be allocated. In practice, each link circuit, except the allocated circuit, would be loaded onto a subscriber circuit, and so the testing circuit is arranged to regard a link circuit with battery on the private or "C" wire as being free, and an earth or no potential on the "C" wire busies the link. Thus a "loaded" (to sub.) link circuit is tested according to the condition of the loaded subscriber's private wire in the exchange. Testing for free links only takes place in the exchange unit. Since absence of potential on the "C" wire of a link circuit will cause it to be tested as busy, an additional horizontal bar (Bar 50) is provided in the exchange unit, the "C" wire multiple of this is connected via 600 ohms to battery. This bar 50 is always maintained in an operated condition so that during initial setting up of the units or the subsequent "unloading" of any link (for any reason) the link circuits will be loaded onto bar 50 to enable them to be tested as free.

CIRCUIT OPERATION

Link Allocation in Exchange Unit (Fig. 4)

The sequence testing of links is controlled by a chain relay circuit of nine relays VB1-VB9 and interacting relays M and N. Initially, all VB relays are unoperated, and W relay operates via Battery, 3,750 ohm coil W, VB1/1 normal, VB2/1 normal, etc., to VB9/1 normal, 2,000 ohm R15, VB9/2 normal, to earth. VB1 relay operates via battery, 2,000 ohm coil VB1, W/1 operated, M/1 operated to earth. VB1/1 releases W. Initially, all connector bars in the exchange unit are loaded by hand onto "bar 50". Therefore, BSU operates via earth, 12,000 ohm coil BSU, VB1/3 operated, "C" wire of connector bar 1, "C" wire of "bar 50", AK/2 (disconnect key), 600 ohm R.10 to battery. BSU/1 holds relay M. M/3 holds relay N. PD operates via battery, 2,000 ohm coil PD, BSU/2 operated, V/3 normal, C/1 operated, D/2 normal, to earth. PD/1 opens the holding circuit of relay RD in relay group RA-RF (normally operated). Relays RS2 and RS3 operate via earth, RF/1 operated, RE/2 operated, RD/4 released, A2/1 normal, 2,000 ohm coil RS2 and 2,000 ohm coil RS3 in parallel, PD/3 operated, 570 ohm coil PIRS, SCH/2 normal (SCH previously released at RD/4), R2 to battery. Connector bar No. 1 is raised by lifting coil S1 via battery, R5, KO1/1 normal, RC/1 operated, RB/2 operated, RA/4 operated, RS2/1 operated, 56 ohm coil S1, PIRS/2 operated, V/2 normal to earth. The connector bar holds via earth, A2/3 normal, M/2 operated (also from earth, A/2 operated if A relay has operated.) 300 ohm coil S1, S1/3 operated, C/4 operated, 450 ohm R13, 265 ohm coil A1 to battery until required for a call.

Subscriber's Unit (Fig. 5)

When relay RD released in the exchange unit, relay RD released in the subscriber's unit, since they were holding in series. The release of relay RD in the subscriber's unit promotes the marking and operating of the corresponding connector bar in the subscriber's unit thus, RS2 relay operates via earth, RF/1 operated, RE/2 operated, RD/4 released, A/1 normal, RC/3 operated, 3,750 ohm coil, RS2, PIRT/2 normal, SCH/1 released (SCH previously released at RD/4, 50 ohm R2 to battery. Connector bar No. 1 is raised by S1 lifting coil via battery, R1, PIRT/1 normal, RC/1 operated, RB/2 operated, RA/4 operated, RS2/1 operated, 56 ohm coil S1, ABS/1 normal, PIRS/1 operated, A/2 normal, to earth. Connector bar holds via earth, 100 ohm coil A, 300 ohm coil S1, S1/2 operated, "B" side of junction No. 1, 1/2 operated in exchange unit. C/2 operated, MK5 terminals, 600 ohm R14, 60 ohm coil A to battery.

Exchange Unit

The raising of the connector bar breaks the connector bar/bar 50 contact and releases BSU relay. BSU/1 releases M relay. BB2 operates via earth, M/1 released, VB1/2 operated, 2,000 ohm coil VB2 to battery. VB2/1 releases VB1 relay which had been holding via battery, 2,000 ohm coil VB1, VB1/1 operated, and chain contacts VB2/1 to VB9/1 normal, 2,000 ohm R15, VB9/2 to earth. VB2 relay holds via the same chain contact route as VB1 through VB2/1 operated. BSG relay operates via earth, 12,000 ohm coils BSG, VB/2 operated, "C" wire of connector bar No. 2, "C" wire of bar 50, AK/2, 600 ohm R10 to battery. N relay holds via battery, 7,800 ohm coil N, X/2 normal BSG/1 operated to earth. At this stage, link No. 1 has been tested, found free, and the corresponding connector bars raised in both units, while link No. 2 has been tested and found free. Relays N, BSG, and VB2 are holding while M relay remains released. If link No. 2 had tested as busy, i.e. if BSG failed to operate, then N relay would have released when contact M/3 opened during release of M. M would then reoperate via N/1 released. N would reoperate via M/3 operated, and at N/1 open the circuit of M. VB3 would operate via earth, M/1 operated, VB2/2 operated, 2,000 ohm coil VB3 to battery. BSU relay would test link No. 3 for busy via earth 12,000 ohm BSU, VB3/3 operated, "C" wire of connector bar 3, "C" wire of bar 50, AK/2, 200 ohm R10 to battery. From this it is seen that the VB relays under the control of interacting relays M and N will test the link circuits in sequence until testing is stopped by the operation of either BSU or BSG. When a link is allocated, relay A1 holds in series with the 300 ohm holding coil of that S magnet. Relay V holds via earth, A1/1 operated, V relay to battery. Since release timing of V controls the delay between subsequent operations of connector bar lifting coils, it has a slow release controlled by 100 μF capacitor and 500 ohm resistor R3. This delay ensures that the 3,500 μF capacitor in the subscriber's unit is sufficiently charged before each lifting coil operation. When the allocated link is taken into use, C/4 opens the circuit of A1 relay and S magnet holding coil. A1/1 releasing, opens the holding circuit of V which releases slowly via V/1 and capacitor/resistor circuit. Until V releases, the relay group PA-PD is inoperative, being open at V/3 so no marking of the next free link can take place.

Basically, the VB relays controlled by interacting relays M and N cause BSU and BSG to test link circuits in sequence till a free link is found, when a combination of operated BSU or BSG, together with an operated VB relay, operates relays in the group PA-PD. These relays in turn release relays in the group RA-RF. Relays in the group RS1-RS3 operate, and these, together with relays RA-RC, determine the path for the operation of the lifting magnet coil of the required link circuit.

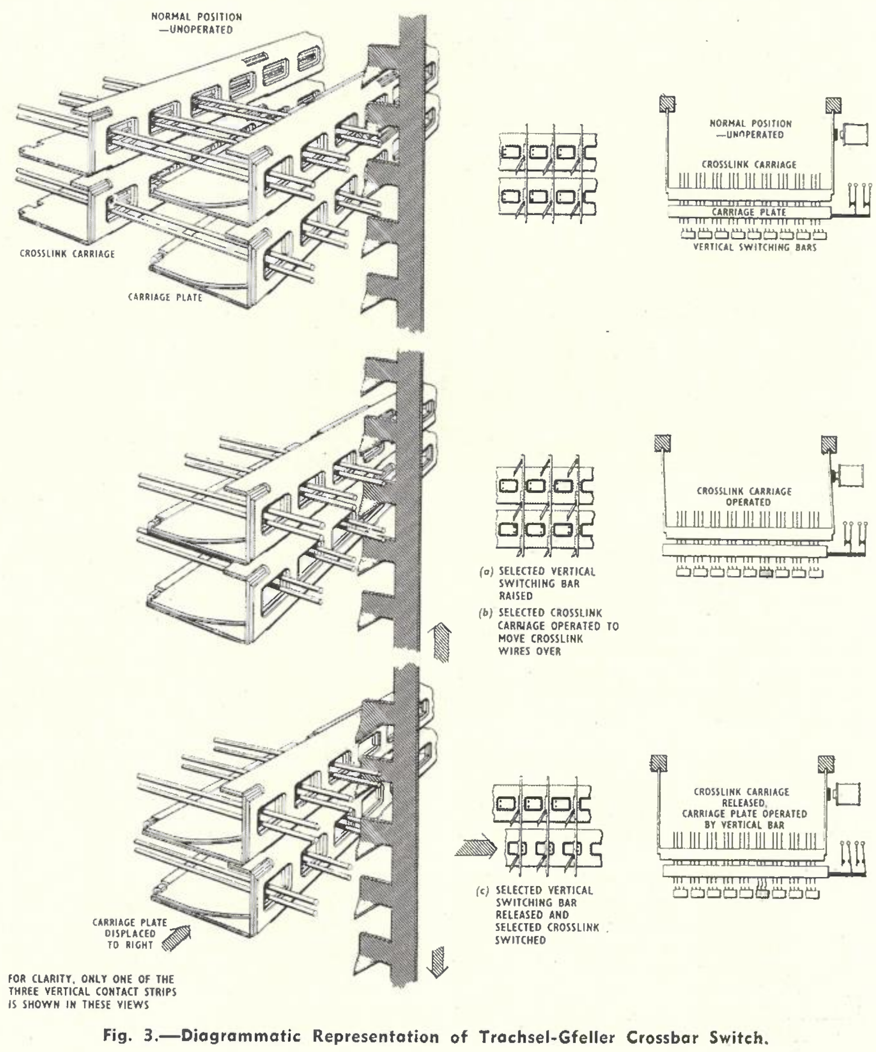
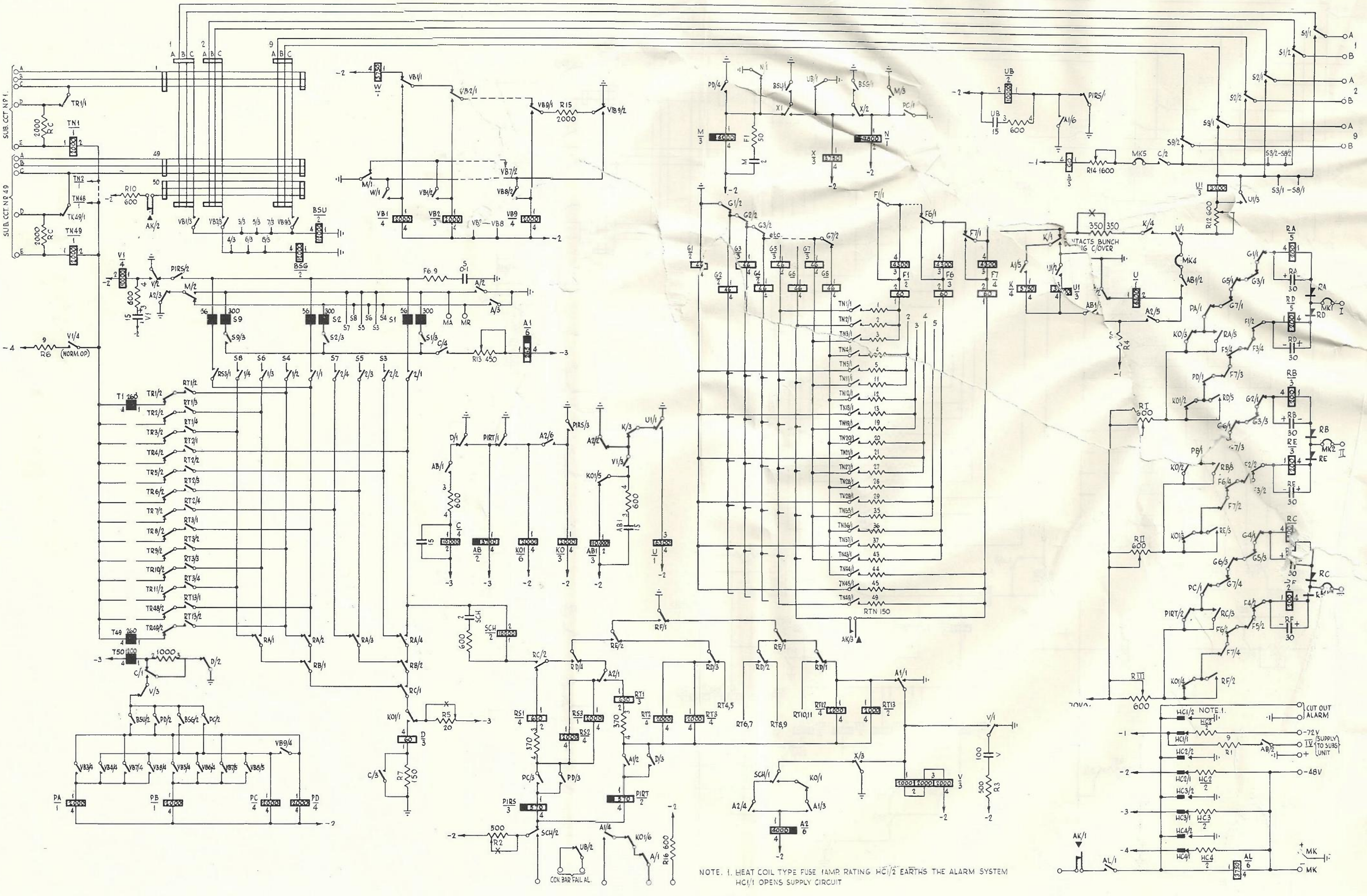


Fig. 3.—Diagrammatic Representation of Trachsel-Gfeller Crossbar Switch.



NOTE. 1. HEAT COIL TYPE FUSE 1AMP. RATING HC1/2 EARTHS THE ALARM SYSTEM HC1/1 OPENS SUPPLY CIRCUIT

Fig. 4.—Exchange End Unit Circuit.

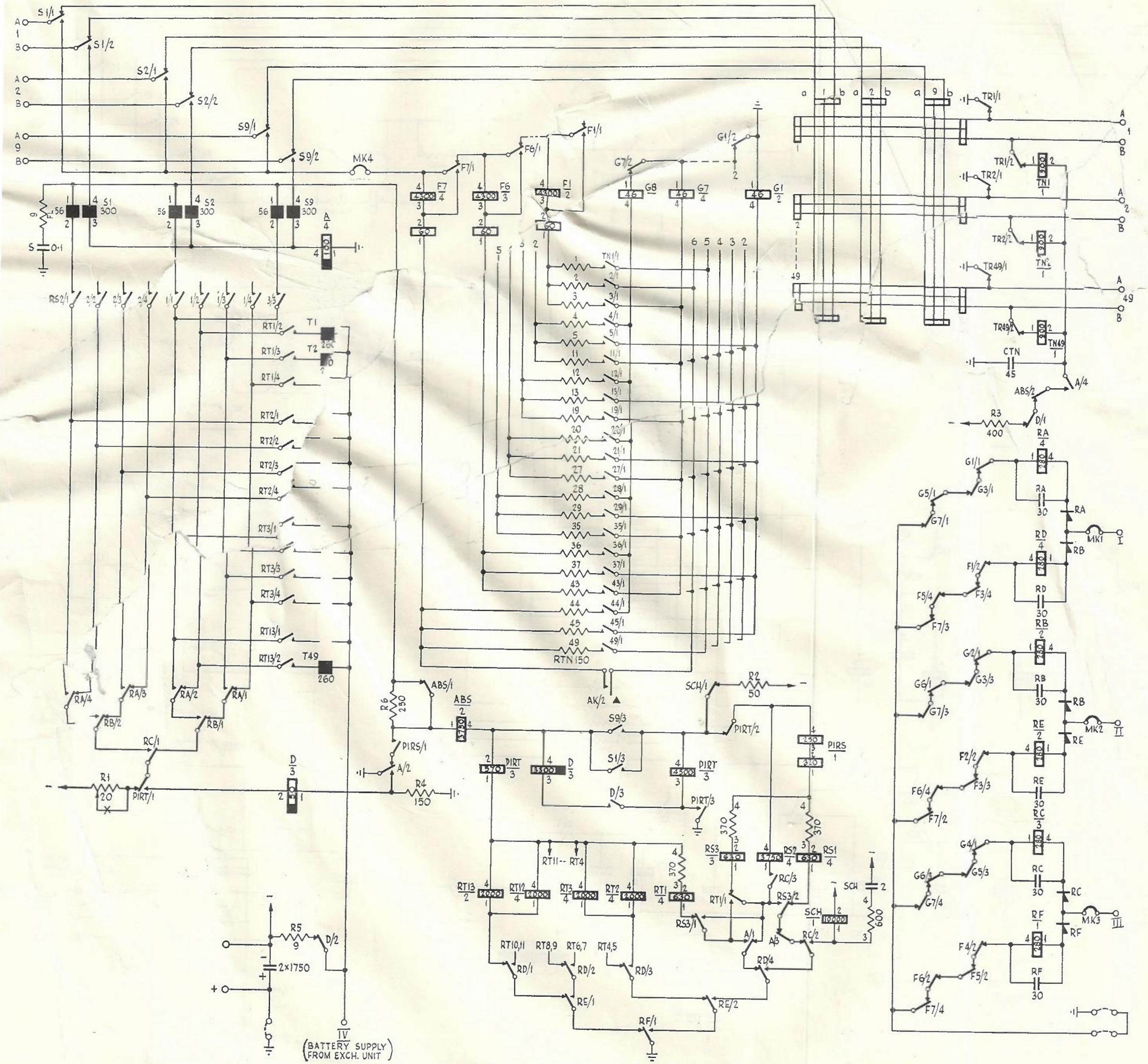


Fig. 5.—Subscribers End Unit Circuit.

Call Through Parent Exchange to Concentrator Subscriber

The calling final selector earths the private wire of the called subscriber's final selector multiple. This earth is extended to the "C" wire of the corresponding concentrator subscriber's circuit. If the subscriber is not already loaded to a link, then a TN relay (individual to subscriber) will operate. Assuming concentrator subscriber No. 1 was called, then TN1 relay operates via earth on "C" wire, horizontal off normal springs TR1/1 normal, 2,000 ohm RC, 2,000 ohm coil TN1, V1/4 operated, 9 ohm R6 to battery. Relay K operates via earth, chain contacts G1/2 to G4/2 normal, 46 ohm coil G5, TN1/1 operated, 150 ohm RTN1, 60 ohm and 4,300 ohm coils F1, chain contacts F2/1 to F7/1 normal, K/1 normal, A1/5 operated, 3,750 ohm coil K, AB1/1 operated 20 ohm R4 to battery. K operates and locks via K1 to earth. K/4 extends F and G circuit via U/1 normal, MK 4 terminals, AB1/2 operated, A2/5 operated, 20 ohm R4 to battery. This low resistance path allows G5 and F1 to operate. Three relay holding circuits are opened, viz. RA at G5/1, RD at F1/2, RC at G5/3, RT1 operates via earth, RF/1 operated, RE/2 operated, RD/4 released, A2/1 operated, 630 ohm coil and 370 ohm resistance of RT1, A1/2 operated, 570 ohm PIRT, SCH/2 released, R2 to battery. Horizontal magnet T1 operates via earth, C/3 operated 60 ohm coil D, KO1/1 operated, RC/1 released, RB/1 operated, RA/2 released, RT1/2 operated, TR1/2 normal, 260 ohm coil T1, V1/4 operated, 9 ohm R6 to battery.

Subscriber's Unit

Following release of RA, RC and RD, RT1 operates via earth, RF/1 operated, RE/2 operated, RD/4 released, A/1 operated, RS3/1 normal, 630 ohm coil and 370 ohm resistance of RT/1, 570 ohm coil PIRT, contact S1/3 to S9/3 (dependent on which link is allocated), SCH/1 released, 50 ohm R2 to battery. Horizontal magnet T1 operates via earth, 150 ohm R4, 50 ohm coil D, PIRT/1 operated, RC/1 released, RB/1 operated, RA/2 released, RT1/2 operated, 260 ohm coil, T1, to battery from MK4 and 3,500 μF capacitor through D/2 and 9 ohm R5. Relay D operates in series with T1, and holds on 3,300 ohm winding via earth, PIRT/3 operated, D/3 operated, 3,300 ohm D, S1/3 to S9/3, SCH/1 released, 50 ahm R2 to battery.

Exchange Unit

Relay D operates in series with T1, Relay C releases when D/1 operates. The allocated link releases when C/4 releases. T50 releases when D/2 operates. The allocated link in the subscriber's unit releases when C/2 releases. The two connector bars release simultaneously, and load to the operated subscriber's horizontal bar. This action causes the operation of the horizontal bar "off normal" springs. TN1 relay circuit is opened at TR1/1. The T1 magnet coil circuit is opened at TR1/2. The loaded subscriber's multiple restores, except for the loaded contact wires held by the connector bar elements. D relay releases when TR1/2 opens, and D/1 allows "C" relay to reoperate. D/2 allows T50 (bar 50) to reoperate. The release of the connector bar releases relays A and A1, A1/1 opens circuit of relay V (slow release). A1/5 opens circuit of relay K. A1/2 opens circuit of relays RT1 and PIRT. The circuit of F and G relays is opened at K/4 and A2/5, and they release. This reoperates RA, RC and RD. SCH reoperates via earth, RF/1 operated, RE/2 operated, RD/4 operated, RC/2 operated, 10,000 ohm coil SCH, RA/4 operated, RB/2 operated, RC/1 operated, KO1/1 released, R5 to battery. SCH/1 releases relay A2. When V releases, the allocation of the next free link takes place as previously described.

Subscriber's Unit

The subscriber's unit connector bar released when its holding circuit was opened at C/2 in the exchange unit. Relays RA, RC and RD reoperate in series with RA, RC and RD in the exchange unit. RF/1, RE/2 and RD/4 reoperated, release RT1, and together with RC/2, reoperate SCH. RC/1 and RA/2 reoperated, release T1 magnet and relay D. The next free link allocation takes place as described, under the control of the exchange unit.

Basically, the calling final selector earths the private of the called sub, operates a TN relay which causes a combination of G and F relays to operate. G and F operating, release marking relays in the group RA-RF. These relays released, permit operation of an RT relay in the group RT1 to RT13 and the subsequent operation of the desired subscriber's circuit horizontal magnet.

CALL FROM CONCENTRATOR SUBSCRIBER VIA PARENT EXCHANGE

Assume Subscriber No. 1 Calling

TN1 operates via earth, TR1/1 normal, subscriber's loop, TR1/2 normal, 900 ohm coil TN1, A/4 operated ABS/2 normal, D/1 normal, 400 ohm R3 to battery. G5 and F1 operate via earth, chain contacts G1/2 to G4/2 normal, 46 ohm coil G5, TN1/1 operated, 150 ohm RTN1, 60 ohm and 4,300 ohm coil F1 in series, chain contacts F2/1 to F7/1, MK.4 terms. S-/1 contacts of allocated link, "A" side of link, S-/1 contacts of allocated link in exchange unit, 3,200 ohm coil U1, 600 ohm R12, U/1 operated, MK.4 terms, AB1/2 operated, A2/5 operated, 20 ohm R4 to battery. In marking group RA-RF, RA is opened at G5/1, RC at G5/3 and RD at F1/2. Relays RA, RC and RD are also released in the exchange unit, and the subsequent operation is similar to that for an incoming call to subscriber.

A subscriber remains loaded onto a link circuit at the completion of a call, until the link is reallocated. A call to or from the loaded subscriber cannot actuate a TN relay circuit, since they are opened in both units by the subscriber's horizontal off normal springs.

Terminating Call

Since the loading of a subscriber to a link commences when the final selector earths the private, a slight delay (500 m.s. approximately) will be present between the time the final selector switches and feeds ring forward and the actual time when the subscriber receives the ring. This is, however, of little significance, since a normal subscriber may have a delay of two seconds for the same conditions, due to the "quiet" period in the ring cycle.

Originating Call

Also due to the loading time, (500 milliseconds) a concentrator subscriber would experience a similar delay when calling out, between the time of lifting off and the time of receiving dial tone, as compared to a normal subscriber.

In the case of the call to or from an already loaded subscriber, no switching takes place in the concentrator, and no additional delay would exist, as compared to a normal subscriber.

GENERAL

No special treatment of exchange equipment is required for the operation of this system, apart from the extension of the required subscriber's Final Selector multiple P, — ve, and + ve wires to the exchange unit. Testing (from a test desk) of the subscriber's equipment can proceed normally, as the test final selector earths the private of the required subscriber, causing the unit to connect via a link circuit to the distant end.

Concentrator subscribers may call each other, although this requires the use of the two links (trombone trunking). If simultaneous calls are made through the system, chain relay contacts (G1/2. F1/1 etc.) prevent incorrect marking and also give preference to one of the required subscriber's circuits.

The maximum junction (link) loop resistance between exchange and subscriber's unit is 780 ohm. The theoretical maximum loop resistance between the subscriber's unit and the subscriber may be 3,500 ohm. However, the combined subscriber's and junction loop must not exceed the normal limits laid down for subscribers and exchange equipment, i.e., a combined resistance of 1,000 ohms with a 400 type telephone and 2,000 type exchange.

If all junctions (links) are busy, the following applies:—

(1) A subscriber calling out will not receive dial tone until a link becomes free.

(2) An incoming caller will receive ring tone from final selector, but ring will not be fed to the called subscriber till a link becomes free. This second condition could lead to D.N.A. complaints and a modification can be made to busy idle subscribers under all links busy condition.

In the above two cases when a link circuit becomes free, it is immediately loaded to the concentrator subscriber required for the uncompleted call, which then proceeds normally. Contacts in the exchange unit are extended to two meters mounted externally, which record the number of times the "all links busy" condition exists, and also the duration of the condition. The occupancy meter is fed by six second pulses. Thus 10 meterings indicates a total "all links busy" duration of one minute. Alarms are connected to the unit to indicate:—

(1) Fuse alarm (4 heat coil type fuses are in the exchange unit).
(2) Open condition of any one of the three marking wires, MK I, II, III.
(3) Open condition of the pilot wire supplying 72 volt D.C. to the subscriber's unit or failure of a subscriber's unit connector bar to operate and hold. (This could be due to the corresponding link pair being open).
(4) Failure of an exchange unit connector bar to operate and hold.

Power Supply

The exchange unit is supplied with 48 volt D.C., 72 volt D.C. and 70 volt A.C. The 70 volt A.C. is used to operate the marking relays RA-RF in both units, but is supplied directly only to the exchange unit. The 48 volt is distributed via 3 (1 amp) fuses in the exchange unit. The 72 volt D.C. is fed from the exchange unit over a pilot wire (MK IV) to the subscriber's unit, where it is used to operate the lifting coils of the connector bars. Since this pilot wire could be of considerable resistance and the lifting coil requires a relatively high operate current, the pilot wire at the subscriber's unit connects both to the lifting coil circuit and also a 3,500 μF capacitor (2 x 1,750 μF in parallel.) This capacitor charges over the pilot wire and provides a "reservoir" to be tapped during short periods of high current drain.

To ensure that this capacitor is reasonably charged between subsequent calls, a slow releasing relay V is used in the exchange unit to provide a delay between successive calls. The slow release is effected by using V relay with three windings in series and a release shunt path of a 100 μF capacitor in series with a 500 ohm resistor.

Subscriber Circuits Not in Use

In the units these circuits have the "C" wire strapped to battery via 600 ohm resistor R16 in the exchange unit. This strapping is done on the terminal strips in the exchange unit only. This ensures that a connector bar being accidentally or incorrectly loaded to a spare circuit, may be tested as free and "allocated" by the presence of the "C" wire battery during testing.

Link or junction circuits may be busied by opening the testing circuit of the particular link. To busy link No. 1, insulate contacts VB1/3 to busy link No. 2, insulate contacts VB2/3 to busy link No. 3, insulate contacts VB3/3, etc It is important before busying a link circuit, to unload it from any subscriber. This must be done electrically, thus, links should be taken into use until the junction to be busied is "allocated", this unloads the subscriber. The appropriate VB contact is then insulated and the "disconnect" button operated. This releases the link and another free link is then allocated.

Once a subscriber is loaded to a link circuit, no electrical component or potential of any kind is applied to either wire (A or B) of the subscriber's speaking circuit, nor to the private wire in the exchange by the concentrator. The through connection consists only of two relay type contacts (connector bar off normal springs, S-/1, S-/2), and the connector bar to horizontal bar connection in each unit. The subscriber may therefore be regarded as working normally over a temporarily allotted cable pair.

JUNCTION (LINK) FAULT CONDITIONS

As the "A" and "B" legs of the preselected (allocated) link are used for marking and holding purposes, various fault conditions on the link pairs will cause differing reactions in concentrator operations. Examples are discussed below.

Link Pair—Open "B" Side. Open "A" and "B"

Under these condtions, the holding (B) leg is open and the link when allocated fails to hold and step on occurs, that is, the sequence testing progresses to the next link circuit. If a calling subscriber's circuit is loaded to the faulty junction before the fault occurs, the subscriber cannot make or receive calls until such time as the sequence allocation raises the connector bars of the faulty link and releases the subscriber's horizontal bars.

Open "A"

With this condition, the link may be allocated, and will hold (on B side) but a concentrator subscriber calling out cannot obtain battery over the "A" leg to operate the F and G marking relays. Therefore, the allocated link will not be loaded to the calling subscriber. This means that no concentrator subscriber can call out except those already loaded to other links.

However, a call through the parent exchange to a concentrator subscriber other than those already loaded will cause loading of the faulty link to the called subscriber. This will cause sequence allocation of the next free link and calls will proceed normally until the faulty link is again allocated. Any subscriber loaded to the faulty junction will be out of service until freed by link allocation.

Ground "B" Side. Short Circuit. Ground "A" and "B" Side

Under these conditions the subscriber loaded to the faulty link becomes a "P.G" in the parent exchange and the busy condition on the private ("C") wire prevents sequence allocation of the faulty link. Thus the loaded subscriber remains out of service until the link is artificially unloaded.

Ground "A" Side

A subscriber loaded to this link would be out of service until the link was allocated again in sequence. Dependent upon the combined resistance of the earth fault and the wire resistance to that point, various conditions occur:—

(i) If above approximately 20 ohms the line may appear noisy to the subscriber and may prevent subscriber tripping incoming ring.
(ii) If a very low resistance fault, e.g., a heat coil on the "A" side of the link in the exchange, then the subscriber's fuse (1 amp) in the exchange unit may operate. The nature of the fault on the "A" will determine:— Whether the circuit is noisy but usable. Whether the ground will shunt the battery supply to the subscriber's F. and G. relays and prevent calls out. Whether the incoming ring cannot be tripped, because of the shunting effect on the ring return battery.

CONCLUSION

Concentrator working permits a number of low calling rate subscribers to have access to the parent exchange, using a greatly reduced number of cable pairs to the parent exchange than would be necessary under normal subscriber working.

It is felt that the use of line concentrators should not be planned for in exchange line networks, but concentrators will prove a suitable method of providing telephone service in areas where severe line congestion exists and rapid residential development is taking place.

The concentrators should then be used as an interim measure to provide service to potential subscribers who would otherwise be denied a telephone service for many years.

Connection of subscribers to concentrator units must be closely supervised to prevent overloading of the units and should overloading occur, selected heavy users should be removed from the concentrator and given an exclusive service which can be accomplished without a change of numbers.

Line concentrators should preferably be mounted in weatherproof cabinets adjacent to line distributing pillars rather than within buildings. This arrangement would permit the reallocation of concentrators to other areas without disturbing the subscriber's premises, and the cost of subsequent reinstallation would be much less. The Gfeller Line Concentrator was extensively tested to determine its reliability in service and a total of 115,000 simulated terminating and originating calls were made through the concentrator requiring a complete switching operation for each call. These calls were distributed evenly over 10 of the 49 subscriber circuits and the 9 link circuits, which represented a wear equivalent to approximately 10 years' service assuming an average of 3 calls per subscriber per day.

There were no detected failures in the unit and the only noticeable effect resulting from the test was a discoloration and very slight pitting of some relay contacts which was corrected by a light burnishing with a contact cleaning tool.

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2. H. V. Paris, "Subscriber Line Concentration"; A.T.E. Journal, Vol. 15, No. 4, page 313.

SLOW SCAN TELEVISION BANDWIDTH REQUIREMENTS

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INTRODUCTION

The bandwidth of a television signal generated by the orthodox X-Y scanning method is dependent on the three systems variables:

- N_E Number of elements per line, defining horizontal spatial resolution.
- N_L Number of (horizontal) scanning lines, defining vertical spatial resolution.
- F Frame frequency, the number of complete pictures per second each containing N_E N_L picture elements.

For F in c/s the signal bandwidth, B, i.e., the maximum frequency component the television signal is considered to contain, is then given by

$$B = \frac{N_L N_E F}{2000} \text{ Kc/s} \qquad \ldots\ldots (1)$$

Inspection of equation (1) immediately suggests that within a given bandwidth the three variables are interchangeable and can be chosen to match the functional purpose of the system. For example, for the presentation of slowly moving or stationary events, or when only still movement-phases will suffice F can be chosen to be low and thus N_L N_E high. Moreover, depending on the major dimension of the displayed objects, the aspect ratio given as the vertical to horizontal dimension of the image, may be chosen to obtain optimum utilization of the image area in conveying the important information. It is then appropriate to match the ratio N_L/N_E to the aspect ratio.

DESIGN CHART

In order to more easily evaluate equation (1) and determine the choice of values for the three variables a design chart in the form of a nomogram has been prepared (Fig. 1). The ranges of variables contained in this chart were chosen specifically for low frame rate, i.e., slow scan, television signals as would be suitable for transmission over industrial TV channels equivalent to one, three (Subgroup), twelve (Group) or 60 (Supergroup) telephone channels. This is indicated by the figures on the right side of the B-scale.

The usage of the chart should be self-explanatory, but some comments are in order on modifications of the actual value of the variables.

Bandwidth: The bandwidth obtained from equation (1) is the maximum frequency component of the "base band" signal, generally denoted as "video" signal. Its minimum frequency component would be zero or, with appropriate equipment techniques, F c/s. For that reason it is generally impracticable to transmit the video signal in its original form over ordinary (switched) telephone lines. (Equalizing techniques are known, however, by which it is possible to do so over private lines). Therefore some form of modulation process is usually involved resulting in the required channel bandwidth B_c being greater than the video bandwidth B, i.e.,

$$B = mB_c \qquad \ldots\ldots (2)$$

where

$$m = \frac{B}{B_c} < 1 \qquad \ldots\ldots (3)$$

is the channel utilization factor. Moreover, because there are limits on the permissible phase delay distortion in order to achieve satisfactory waveform

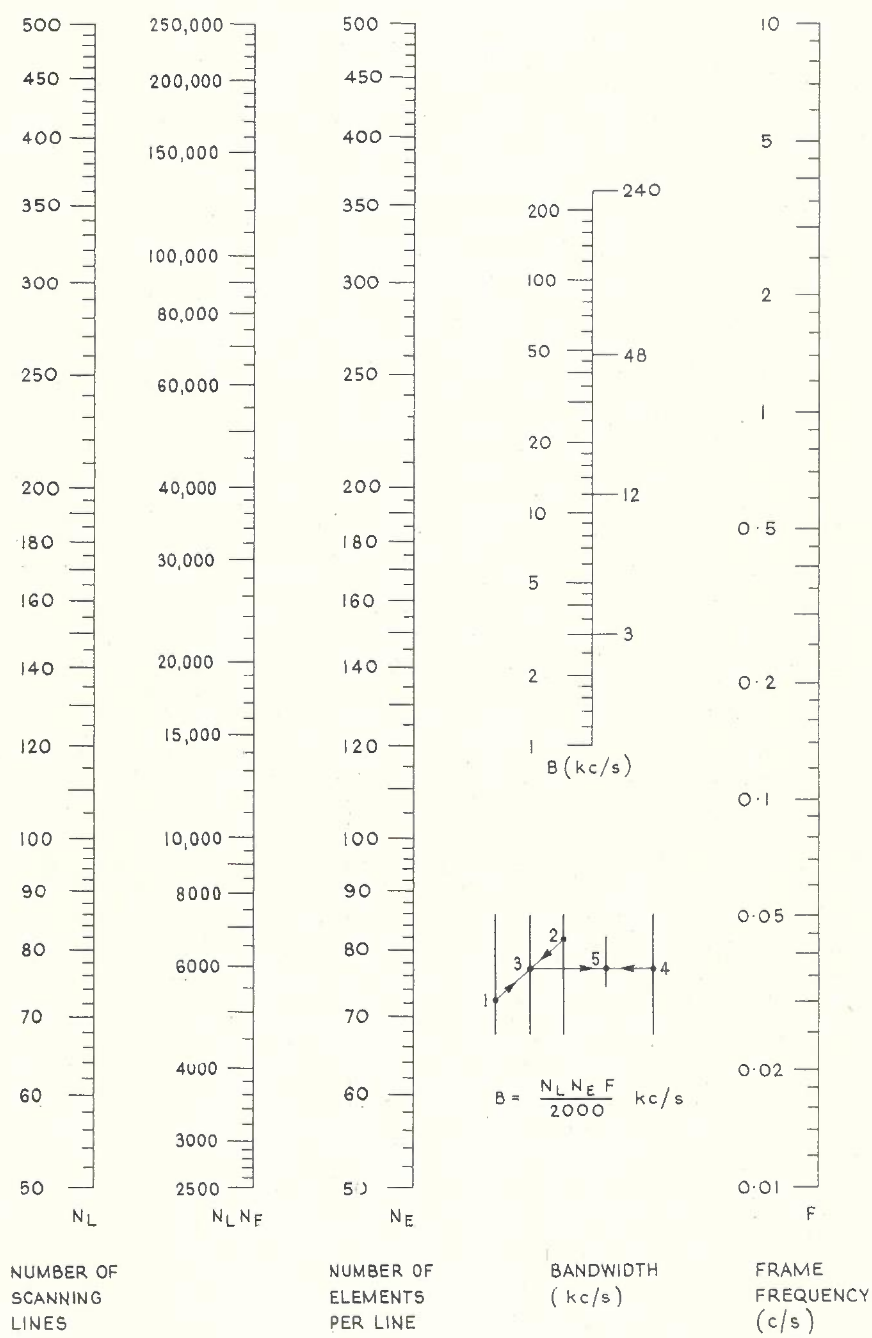

Fig. 1.—Design Chart for Slow Scan Television Bandwidth Requirements.

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response of the channel, m may also be affected by this limitation. As a rule of thumb, borne out by experience, an unequalised phase-delay dispersion of some two picture elements, i.e., $\Delta\tau = 1/B$ would be tolerable. For the one-telephone-channel equivalent these considerations lead to a practical figure for m between 0.6 and 0.65 for switched telephone lines, i.e., approx. B = 2.5 Kc/s. It would be expected that m will be somewhat greater for the Subgroup, Group and Supergroup equivalent channels, say, 0.7 to 0.75 depending on the respective filter and modulation characteristics and the permissible degree of pre-equalization compatible with S/N ratio and crosstalk. Thus, tentative values for B in those cases would be 9, 36 and 180 Kc/s respectively.

Number of Elements per Line: The number of elements per line N_E, being an electrical signal-variable, would be about 20% greater than the number of active picture elements N_H resolvable (usually referred to as N_H lines resolution) over the horizontal dimension. The 20% by which N_H is smaller than N_E is required to accommodate the horizontal synchronizing signal and the finite fly-back time of the scanning beam.

Number of Scanning Lines: For reasons similar to those valid for the relationship between N_E and N_H a reduction of the active number of scanning lines N_V in the picture must be accepted compared to the electrical signal quantity N_L. But N_V is generally only about 3% smaller than N_L. Thus, the product $N_V\ N_H$ must for practical purpose be assumed to be equal to 0.78 $N_L\ N_E$.

Furthermore, when considering vertical resolution R_V as a subjective viewing criterion of the displayed picture, this becomes a rather undetermined quantity due to the discrete nature of the scanning line structure affecting the reproduction of horizontal contours in the displayed objects. The ratio $R/N_V = k$ is a statistically defined quantity known as the Kellfactor, and for TV-broadcasting systems an average value of $k = 0.75$ is generally used. However, for the design of utilitarian slow scan systems under consideration here, the introduction of the Kellfactor may be an unnecessary complication because the variety of picture content for any given application would be much less than in the case of entertainment type systems and the system-variables can be more specifically matched to the pictorial information to be transmitted.

Frame Frequency: The free choice of the frame frequency is the most significant feature of narrow band industrial TV-systems. In the entertainment type system this variable is primarily determined by the flicker criterion of the displayed image in order to minimize the cost of home receivers. In the industrial slow scan system, the flicker criterion can generally be satisfied by using some kind of image storage at the receiving end, either in the form of storage display tubes or electronic respectively magnetic signal storage devices. Thus, frame rate can be more freely manipulated to match the dynamic characteristics of the information to be displayed. The necessity of using such devices naturally increases the cost of the receiving terminal by from about £300 for the simplest display storage tube to £1,500 and more for other storage devices which are preferred when the received signals are to be displayed on a multitude of screens in various locations (e.g. Stock Exchange, Hospitals, etc.). Storage devices are indispensable for frame times exceeding, say, 2 to 3 seconds, as applicable for the one telephone channel and possibly Subgroup equivalent. However, for higher frame rates, realizable on Group and Supergroup channels, the method of pseudo-random dot-interlace scanning together with the use of long-persistence display screens seem to offer lower cost terminals. (This method is presently being studied by the Research Laboratories to define the applicable range of variables and economic equipment techniques.)

CONCLUSION

The usage of the nomogram is probably best demonstrated by an example for which the Videx system, being offered by the I.T. & T. Group, is chosen. This system, designed for transmission over a single standard telephone channel, operates with a video bandwidth of B = 2.5 Kc/s and offers a choice of frame times of 10, 20 and 40 seconds. (F = 0.1, 0.05 and 0.025 respectively.) Entering these parameters in the chart yields values for $N_L\ N_E$ of 50,000; 100,000; and 200,000 respectively. It is then possible to choose N_L and N_E which is shown by way of example. Letting N_L be 400, N_E would assume values of 125, 250 and 500 for the three frame rates (and vice versa when choosing $N_E = 400$). As a rough approximation, one would prefer $N_L > N_E$ for display of objects having predominantly vertical extent and containing mainly horizontal contours, whereas $N_E > N_L$ would be chosen for horizontally orientated objects and emphasis on resolving vertical contours.

TABLE I: STANDARD TV-SYSTEM PARAMETERS

	F c/s	N_L	$N_L\ N_E$	B Mc/s
British	25	405	240,000	3
U.S.A.	30	525	267,000	4
C.C.I.R.	25	625	400,000	5

As a matter of interest and for general reference, Table I lists the parameters of equation (1) for the three main standard TV-systems.

ACKNOWLEDGMENT

The author is indebted to Mr. J. K. Lynch for the preparation of the Nomogram.

TECHNICAL NEWS ITEM

EXPERIMENTAL TV-PHONE

During a Science Exhibition held in Melbourne from the 7th to the 15th August, 1964, an experimental TV-phone was displayed to the public by the Research Laboratories of the Australian Post Office. The purpose of the TV-phone is to provide visual and aural communication between persons or groups of persons. To provide such a facility using the 5 Mc/s base-bandwidth channel, which is required to satisfy the picture standards laid down for the Australian television service, would impose prohibitive costs on its installation and operation. Therefore the experimental system displayed to the public has been engineered to use a considerably reduced bandwidth by taking into account the type of material to be transmitted. Since basically when we talk to another person it is only necessary to be able to see the conversation partner in a head and shoulders view, it is possible to change the picture format from the 3 by 4 used in the home receivers to a 4 by 3 format. Similarly a modification of the scanning standards can be made so that, all in all, a video base-bandwidth of 800 kc/s can be achieved whilst still preserving the resolution necessary for faithful reproduction of the human face. A picture of 375 lines is used and spot wobble techniques are applied to reduce the line visibility. A "Crispener" circuit improves the sharpness of outlines.

The experimental system has been developed from normal industrial television equipment using a minimum of additional instrumentation and modification. One of the problems involved in the development of the system included the provision of a "mirror image" facility so that the calling or called party can view his own image preparatory to the connection of the call and see himself as he normally does when looking in a mirror. If this facility is not provided, quite disturbing effects are experienced.

As at present designed, the experimental TV-phone is suitable for use in a special booth and provides a reasonably natural image of the conversation partner on the standard 14" monitor when viewed from a distance of about 4½ feet. As yet, plans have not been made to bring this facility into operation. If introduced in Australia it would probably be provided initially on a booked call person-to-person arrangement between special terminals established in say Sydney and Melbourne.

TECHNICAL NEWS ITEMS

EXPANSION OF RADIO RELAY NETWORKS IN THE AUSTRALIAN TELECOMMUNICATION SYSTEM

The Australian Post Office is currently engaged in a large programme of providing microwave radio relay bearers for both telephony and television purposes, the extent of which is indicated in the table below.

Major radio relay projects currently under construction include:—

	Completed July, 1963	Under Construction as at June, 1963	Programmed for Construction by June, 1965	Totals
Microwave Projects .	11	28	22	61
Route Miles	647	3,098	1,593	5,338
Radio Bearer Miles ..	2,896	9,222	9,260	21,378
Installed Cost (excluding buildings)	£1.42M.	£4.98M.	£4.22M.	£10.62M.

Brisbane - Cairns — 300 channel telephony and television system for completion during 1965.

Sydney - Lismore — 960 channel telephony system for completion during 1964.

Melbourne-Adelaide — 960 channel telephony system for completion during 1966.

Melbourne-Launceston—300 channel telephony system for completion during 1966.

The programme involves the use of radio relay equipment operating in the 2000, 4000, 6000 and 7000 Mc/s frequency bands, manufactured in the United Kingdom, Germany, Italy and Japan.

AIR FORCE COMPUTER TO USE POST OFFICE TELEGRAPH CHANNELS

Conforming to modern trends in business management techniques, the Commonwealth Defence and Service Departments are installing computers to handle many of the routine administrative functions of their Departments.

These computer systems will include communication networks linking the computers with the remote establishments. The first of these will link RAAF airfields, depots and other centres throughout Australia with a computer in Canberra and will utilize long distance voice frequency telegraph channels rented from the Postmaster-General's Department.

At each depot information will be prepared on perforated paper tape, using Friden Flexowriters supplied by a commercial firm. The information is then transmitted to Canberra through line sending equipment. At the Canberra computer centre, line receiving equipment will produce a perforated tape which will be fed into the computer. Some of the results of the computer processing will again be in the form of perforated paper tapes which will be transmitted to the bases where it will be reproduced as paper tapes. These will then be converted to printed information by the Flexowriters.

Arrangements have been made for the Postmaster-General's Department to procure, install and maintain the line equipment used to send and receive the data tapes between the bases and the computer centre. This equipment will handle seven or eight level tape and will employ the familiar start-stop principle using an 11 unit time cycle per character. To conform to the transmission capabilities of the trunk telegraph network, the equipment will operate at 50 bauds.

The line sending and receiving equipment will comprise tape transmitters and reperforators manufactured by an American company and ancillary controls and mountings of Australian manufacture.

RELAY DEVELOPMENTS

The Components Group of G.E.C. (Telecommunications) Ltd. have recently announced development of the following new relays.

A New Sub-Miniature Relay

This new relay is being developed to give reliable operation within subminiature assemblies while being suitable for many general purpose applications including mounting on to printed circuit cards. It has a volume of less than .04 cu. in. and has a mechanical life expectancy of 50 million operations. The relay has a single changeover contact action and contact reliability is achieved by using solid precious metal contacts and a contact pressure of 10 grms. All organic compounds are excluded from the sealed contact compartment.

Ratchet Relay

This comparatively small and inexpensive device is invaluable in pulse-operated circuits for the counting or absorbing of pulses. It provides the equipment designer with a device retaining much of the flexibility of the uniselector while occupying no more mounting space than a single G.E.C. P.50-type (B.P.O. 3000-type) relay. The ratchet relay operates on the reverse-drive principle and is essentially a uniselector mechanism in which the wipers have been replaced by a cam and ratchet assembly and the contact bank has been replaced by long-life springsets of the relay type.

Seven-Cam Ratchet Relay

This relay was developed from the 2-cam version to provide an even greater range of applications in pulse-operated circuits, being particularly useful for decimal and binary coding.

One such case is the transmission of decimal information in the 2 out of 5 code form which is widely used in modern data transmission and data handling techniques. Five cams may be used for this purpose, the other two providing an off-normal impulse for a "start-from-zero" check and a "carry-over" impulse to the next decade counter. The relay has all the attributes of the original ratchet relay, has the same mountings and occupies two relay positions.

ACTIVITIES OF THE SOCIETY

The following extracts from the Annual Reports of the State Divisions of the Telecommunication Society of Australia highlight activities of the Society for the period 1963/64.

NEW SOUTH WALES

The "Statement of Receipts and Payments" for the year ended 30th April, 1964, shows this Branch of the Society to be in a sound position financially. This has been achieved with a current membership of 1,050 and an overall Journal distribution of some 1,200 per issue, depending somewhat on the content of individual issues. The development of the Society hinges largely on the popularity of the Journal for there are no real alternatives with any permanence to attract members and maintain their interest. On occasions the Society fulfils a very real need in augmenting the normal Departmental facilities. A particular case was the organisation of the crossbar and coaxial lectures to introduce the staff to the new developments. For most of the time however, it is the Journal which is the reason for the Society's existence. Provided an intact organisation exists which can immediately rise to an occasion such as the presentation of the crossbar lectures its existence is well justified along these lines.

We have experienced one period of intense interest and activity, the introduction of crossbar and the coaxial cable, and the next could well be the advent of electronic exchanges. In between these events we are left largely with the Journal to sustain membership. The Council of Control is also aware of this and is continuously striving to make the Journal more attractive. In this regard we feel your Committee has played an active part over the past year.

To make the Journal attractive is one thing, to sell it is another. On this latter point the Committee took advantage of the need to revise accounting procedures to incorporate in the changes a more direct access to the staff. A comprehensive system of field representatives is being set up designed to introduce the maximum of personal contact in stimulating membership of the Society and Journal sales. This system will be introduced shortly when up-to-date representatives' lists of members have been compiled and it is the Committee's view it will serve to restore membership to a level much closer to that applying at the height of the crossbar lecture series than presently applies.

We are fortunate that New South Wales authors figure prominently in the compilation of the Journal but there are as yet many untapped resources particularly from amongst the staff in the field. Who better to appreciate the needs of the man on the job, and do something about it, than those actively engaged in the relevant sphere.

You will already be aware of the Society's decision to issue the Journal on a three volume per calendar year basis. Allied to this decision is a current examination of the desirability of having the Society's financial year also coincide with the calendar year. The outcome of these current considerations will be made known through the Journal but it is worth mentioning in this report to forewarn you of impending changes.

An interesting series of visits was arranged during the year to 402 Signals Regiment "Signal Transmission Reception and Distribution" centre. Three well-attended tours were arranged and as a reciprocal gesture a party from the Regiment inspected our TRESS installation in the G.P.O.

There has been a steady demand during the year for the New South Wales Division printed notes, both from within and without the service. A further set of notes treating the subject of TV Receivers is shortly to be issued to members of the Society.

The Society was pleased in November, 1963, to publicise a lecture in Sydney organised by the Institution of Radio Engineers. The guest speaker was Professor Guelke, Dean of the Faculty of Engineering at the University of Capetown, who spoke on "The Transmission of Information by Means of Speech."

During the year the Committee instituted the award of Telecommunication Society prizes to trainees. Prizes were awarded for the best performance during the first two years of training by a Technician-in-Training in "Telecommunication Theory" and by a Lineman-in-Training in "Practical Application." A similar prize for Traffic Officers-in-Training was considered but deferred to this coming year as it was not appropriate to award such a prize at the time the Committee considered the matter.

The Committee is hopeful that the proposed procedure of having active field representatives will better cater for the wants of our country members. In the meantime however it is pleasing to note that the Wagga/Albury Branch remains active and that a Branch is being formed in Goulburn. Lectures were held at Wagga and Albury and introductory crossbar lectures were held in Canberra with the able assistance of the Training School.

VICTORIA

Members and Journal Subscribers: These for the year were 949 and 1,393 respectively compared with 1,033 and 1,525 for the previous year.

General Meetings: General meetings of the Division were conducted bi-monthly, except December, 1963, in Radio Theatre, Royal Melbourne Institute of Technology. Attendances have been excellent in the range of 80-100. The following lectures were delivered:—

Impressions of Telephone Exchanges in U.S.A.—C. M. Lindsay.

Electronic Exchanges—H. Wragge.

New Developments in Subscribers' Equipment—K. B. Smith.

Current External Plant Network Considerations—J. C. Sloss, B. P. Howard, F. Lowenthal, K. Potter.

One of the General Meetings consisted of a tour of City West Exchange building.

During the year the practice was established of showing a short film on a subject related to the main lecture prior to the commencement of the meeting. The large attendances in time to view the films indicate that the innovation is appreciated.

Tour of Volkswagen Plant: The Division arranged a tour of the Volkswagen Plant, Clayton. There was an overwhelming response to the tour, more than 950 applications being received to attend. With the co-operation of Volkswagen (Australia) Pty. Ltd., a total of 790 were shown over the plant over three dates, 13th, 27th November, and 4th December, 1963.

Country Lectures: During the year a total of thirty-two lectures was held at fifteen country centres. The lectures were:—

Television—J. Wilkinson.

Pentaconta Crossbar—B. Carroll.

Exchange Services Overseas—C. M. Lindsay.

E.M.D. Exchanges—B. Worden.

Ericsson Crossbar—R. Burbury.

The attendances at these lectures has been very gratifying, and arrangements are in hand to conduct a yearly programme of at least two lectures at each of the fifteen centres (Ararat, Ballarat, Bendigo, Colac, Croydon, Dandenong, Frankston, Geelong, Hamilton, Mildura, Sale, Shepparton, Swan Hill, Wangaratta, Warrnambool).

Information Cards: Following the practice established in the previous year, the committee again distributed to all members and subscribers a quality finish card giving information of the 1964 Lecture Programme.

Prizes for Technicians and Linemen-in-Training: Commencing with the year 1963 the Division has made available the following prizes:—

Technicians-in-Training:

A total of five prizes, each consisting of one year's Society membership and Telecommunication Journal of Australia subscription to the best Technicians-in-Training in each of the 1st, 2nd, 3rd, and 4th years of training and to the Dux at the completion of the course. Prize winners to be determined by the Principal of the Technicians' Training School based on the highest total marks in theory over the year's work.

Linemen-in-Training:

A total of two annual prizes (as above) to the Dux from each quota of Linemen-in-Training as determined by the Principal of the Linemen's Training School.

The Prize winners for the year 1963 are:—

Technicians-in-Training:

First Year: D. R. Appleton.

Second Year: R. W. Collins.

Third Year: K. J. Pannam.

Fourth Year: N. E. Robinson.

Dux: T. L. Guy.

Linemen-in-Training:

July, 1963: B. V. Potter.

December, 1963: A. R. Kealey.

QUEENSLAND

General: Due largely to the activity of the Society's agents and the committee, there has been a further increase in membership and journal subscriptions during the year:—

	April 1961	April 1962	April 1963	April 1964
Members	436	463	524	613
Journal subscribers	580	572	608	717

General Meetings: Seven general meetings and the annual general meeting were held during the year. Guest speakers and "gadgets" at these meetings were:—

25/6/63 — Annual general meeting. Modern Training Methods.—Mr. P. L. Dubois. Films — "Seven Letters a Second", "More Than Meets the Eye".

23/7/63 — Development of Marine Electronics.—Mr. S. Grantham. Gadget —A miniature two-way radio.—Mr. D. Roberts.

24/9/63 — Electronic Equipment and Meteorology.—Mr. W. R. Wilkie, Gadget—A Light Sensing Device for Blind P.B.X. Operators.—Mr. G. A. Fooks.

22/10/63—Multi-frequency Signalling. —Mr. J. K. Petrie. Gadget — The "Victa" Red Public Telephone.—Mr. G. Gahan.

26/11/63—The Moonie Oil Pipe Line. —Mr. A. J. Etingen. Gadget—An auxiliary battery for N.B. power plant.— Mr. A. Box.

28/1/64—Radio Communications for Antarctic Exploration. — Mr. K. McDonald. Gadget—A test desk tutoring machine.—Mr. W. C. Harris.

24/3/64—National Subscriber Dialling. —Mr. L. J. Lumb. Gadget—The new multi-coin P.T.—Mr. W. Trudgian.

26/5/64—The Microwave Radio Route for Seacom.—Mr. V. J. Griffin. Gadget —The Ericophon.—Mr. W. Trudgian.

Field Outings: Two well attended outings were held during the year and proved of great interest to members and friends. We are indebted to the D.C.A. and members of their staff who acted as guides for an inspection of the operations of that Department at Eagle Farm Airport.

Thanks are also due to organisers and guides for the visit to the Central Telegraph Office to inspect the operation of TRESS and the associated No-break power equipment.

Summary: The Queensland Division of the Society continues to grow in membership and the bi-monthly lectures are well attended. This situation is due in no small measure to the activity of the programme sub-committee who arranged the year's programme of lectures covering topics from within the Department's activities as well as interesting and informative topics from other authorities. The interest shown by members is to be commended and augurs well for the future of the Society.

SOUTH AUSTRALIA

The membership of this Division stands at 323, a decrease of 10% on last year's figure. At last year's Annual General Meeting also, a slight decline in membership numbers was reported, and this trend has continued; this matter may need to be given some attention by the Committee during the forthcoming year.

On the other hand, the attendances at meetings have indicated that there is no waning of interest on the part of those who have held membership over the past year. The seven General Meetings have had average attendances of forty, no meeting had less than thirty present, and the highest attendance was fifty-five at the January meeting. It has been particularly pleasing to the Committee to see a number of country members attending.

The following lectures were presented at the General Meetings:—

June, 1963: Compac — the Sydney-Vancouver Submarine Cable System.— Mr. J. McLeod.

July, 1963: The Changing Pattern of the Adelaide Automatic Exchange Network.—Mr. O. G. Bartlett.

September, 1963: Broadband Carrier Equipment for Telephony Transmission.—Mr. H. G. Nowotny.

November, 1963: Subscriber Distribution Systems in England, Europe and North America.—Mr. H. T. Davis.

January, 1964: The Introduction of A.R.K. Crossbar Equipment into Country Areas.—Mr. K. M. Bartsch.

March, 1964: The Role of the C.C.I.T.T. in World Telecommunications.—Mr. E. R. Banks.

May, 1964: Physical Properties of Materials used as Contacts and Insulators.—Mr. G. Flatau.

Subscriptions to the Telecommunication Journal numbered 434. While most subscribers are in the P.M.G.'s Department, there are approximately seventy in other Commonwealth and State Government Departments (chiefly the Department of Supply and the S.A. Railways), and ten in private industry.

Sales of odd single copies of the Journal have taken the total quantity of the past year's three issues distributed in this State and the Northern Territory to 1,350, an average of 450 copies of each number. This is a slight increase on the previous year's distribution.

WESTERN AUSTRALIA

During the past year of activities, the Society has continued to prosper and the membership list and total number of Journal subscribers has again increased.

Over the year, six General Meetings and six Committee Meetings were held and the average attendance was maintained similar to past years. A new undertaking was fulfilled — our first country lecture — and this was held at Bunbury, with a talk on Transistors. It was gratifying on this occasion to have had about 50 in attendance, and it is hoped that we can cover other country centres in the future.

The lectures conducted throughout the year were:—

June, 1963—The Tellurometer, by D. Lee and A. Faulkner.

August, 1963—External Plant aspects of the Perth-Bunbury Coaxial Cable Project, by B. Pember and R. Kelly.

October, 1963—Some Aspects of Television Servicing, by J. Cook of Hills Television Services Ltd.

December, 1963—The Negative Impedance Amplifier, by A. Timmins.

February, 1964—Cable Protection, by R. Green.

April, 1964 — Visit to Wanneroo Transmitting Centre with descriptions by J. Mead.

Where possible, the Gadget of the Month has been retained at General Meetings, and this has continued to be of interest to all. The official Society Journal, "The Telecommunication Journal of Australia", has been maintained at a high standard and the variety of subjects covered in the articles have been sufficient to keep the interest of all. The number of Journals distributed in this State has increased 20% over the past year, and we hope that it will continue to expand in the future.

During this year, Society Agents have been established throughout the country and metropolitan areas, to conduct business on behalf of the State Division. This includes collecting subscriptions and distributing Journals, and has proved to be of benefit to both members themselves and to the Committee. A closer liaison is obtained between members and the Society because of a 'live wire' representative on the spot, thus providing a personal contact which was missing beforehand.

Our future programme includes lectures on the Telecommunications Administration of Turkey, Some aspects of Traffic Signal Controllers, and a talk giving a general and practical outline of Crossbar Telephone Equipment.

TASMANIA

The Society and its Division in this State have now been in existence for four very active years. The progress evident in the early stages has continued. Development through the years is shown in the following figures:—

	Members	Subscribers
*1959/60	—	80
1960/61	300	250
1961/62	305	295
1962/63	315	292
1963/64	319	308

*Prior to formation of State Division.

Six General Meetings were held in Hobart, and the lectures covered a wide variety of subjects. In addition, three Special General Meetings were held to cover subjects interesting primarily to particular groups of members.

A visit to Cadbury's computer was also arranged, and thirty-five members took the opportunity to get first-hand knowledge of a modern electronic computer.

Details of the year's programme are:

11/6/63. Annual General Meeting. Annual Report and Films.

13/8/63. Computers — Theory and Application.—Mr. K. L. Briggs, B.E., B.Econ., A.M.I.E.Aust.

17/9/63. Egypt—Past and Present.—Mr. H. L. Greener.

8/10/63. TV Transmitters. — Mr. K. Newham, A.M.I.E.Aust., A.M.I.E.E.

12/11/63. Emergency Power.—Mr. K. Adams, B.E., A.M.I.E.Aust., Mr. R. Hanson, Dip.E.E., Grad. I.E.

10/12/63. Space Flight. — Mr. L. Edwards.

12/2/64. Communications in New Guinea.—Mr. G. W. Clark, A.M.I.E. Aust., S.M.I.R.E.E.Aust.

16/3/64. A Review of Electronic Development. — Mr. B. Brodie, B.E., B.Sc., A.M.I.E.Aust., A.M.I.R.E.E. Aust.

14/4/64. The Future of Broadband in Tasmania.—Mr. A. Traill, B.E., A.M.I.E. Aust., Mr. J. Macey, B.E., Grad. I.E.

12/5/64. Crossbar Comes to Tasmania. —Mr. A. Head, Dip.E.E., Grad.I.E., Mr. R. Wyatt.

1/10/63. Inspection of Cadbury's Computer.—Mr. C. Chenoweth of I.C.T.

The average attendance at General Meetings improved to forty-one, compared with thirty-eight for the previous year. The three Special Meetings attracted an average of twenty-two members—very satisfactory for topics of interest to specialist groups only.

Contributions and Letters to the Editors

may be addressed to:

the State Secretaries or the General Secretary at the following addresses:—

The State Secretary,
Telecommunication Society of Australia,
Box 6026, G.P.O., Sydney, N.S.W.
Box 1802Q, G.P.O. Melbourne, Vic.
Box 1489V, G.P.O. Brisbane, Qld.
Box 1069J, G.P.O. Adelaide, S.A.
Box T1804, G.P.O., Perth, W.A.
Box 246C, G.P.O. Hobart, Tas.

The General Secretary,
Telecommunication Society of Australia,
Box 4050, G.P.O. Melbourne,
Victoria, Australia.

Agent in New Zealand: E. C. Cheyne, c/o Engineer-in-Chief, G.P.O., Welllington, C.1.

Agent in Europe: P. S. Bethell, B.Sc., Dip.P.A. Australia House, Strand, London, W.C.2, England.

OUR CONTRIBUTORS

B. P. DEW

J. D. MATHER

L. M. WRIGHT

B. P. DEW, co-author of the article, "Gfeller Line Concentrator Unit", joined the P.M.G. Department in 1950 as Technician-in-Training subsequently qualifying as Technician and later as Senior Technician in 1956. After the Technician-in-Training course he was allocated to Country Installation, and transferred in 1959 to Metropolitan Exchange Installation where he is now acting Supervising Technician. At Hawthorn Exchange he was responsible for the installation and testing of the Gfeller Line Concentrator.

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J. D. MATHER, co-author of the article, "Gfeller Line Concentrator Unit", commenced his training as an Apprentice Electrical Mechanic with the State Electricity Commission of Victoria in 1948, where he was engaged on a variety of heavy industrial electrical installations, including Power Station, Briquetting, and coal winning equipment. On completion of a Diploma course he was transferred to the Electrical Test Laboratory, and carried out field testing of electrical equipment in the power stations at Yallourn. He joined the P.M.G. Department as an Engineer, Grade 1, in 1954 and after experience in the Traffic and Trunking Division he was transferred to the Metro. Service Section as Group Engineer, in 1955. Since 1958 he has been employed in his present position of Group Engineer, Metropolitan Exchange Installation. Mr. Mather holds the Diploma of Electrical Engineering, Diploma of Mechanical Engineering and is an Associate Member of the Institution of Engineers, Australia.

K. L. HAFFENDEN, co-author of the article, "Multipair Plastic Submarine Cable—Moreton Bay, Queensland," is Engineer Class 2 in Queensland, but currently on temporary transfer as Engineer Class 3 in the Fundamental Planning Section, Planning Branch Headquarters. He commenced his service in the Postmaster-General's Department as a Technician-in-Training in 1948. Following promotion as Cadet Engineer, he qualified as Engineer in March, 1955. His subsequent experience was 15 months as Grade 1 Engineer in Outer Metropolitan Division, Brisbane, three years as Group Engineer, Professional Training, Brisbane, eight months relieving as Divisional Engineer, Technical Training, at Headquarters and four years as Group Engineer, District Works No. 2, Brisbane.

K. L. HAFFENDEN

In the latter position, he was responsible for the provision and maintenance of line plant over a major portion of southern Brisbane and the rural area adjacent to Moreton Bay, including numerous islands in and around the Bay. At Headquarters Planning Branch, he is currently investigating the economics of rural automatic networks, the development of possible new equipments and the application of line concentrators in urban areas.

Mr. Haffenden possesses a Bachelor of Science Degree from the University of Queensland and is an Associate Member of the Institution of Engineers, Australia.

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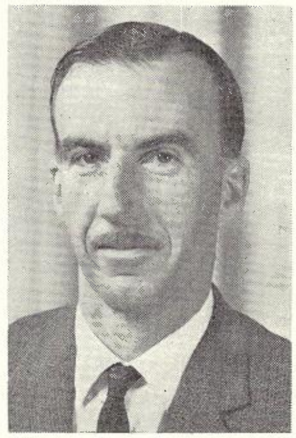
L. M. WRIGHT, author of the article, "Crossbar Trunk Exchanges for the Australian Network", joined the Postmaster-General's Department in Adelaide in 1940 as a technician-in-training. Following service in the R.A.A.F. from 1943 to 1945 he resumed duty early in 1946 as a cadet engineer and qualified as engineer early in 1950. During the next few years he worked mainly on the installation of long line and telephone exchange equipment and also worked for eight months in the Headquarters Circuit Design Laboratory. In 1956 he was promoted as Divisional Engineer in charge of one of the two Long Line and Country Equipment Installation Divisions in South Australia. During the next 6½ years he was responsible for equipment installation over a wide area of South Australia and in this period he was the State's Circuit Liaison Officer. In 1962

A. J. SEYLER



G. A. DOBBINS

M. O'CONNOR

he was promoted to the Switching and Facilities Planning Section at Headquarters where as Sectional Engineer, Application Standards, he was responsible for specifying switching and signalling facilities in the light of future needs, system compatibility and cost considerations. Early in 1964, Mr. Wright spent two months in U.S.A., Europe and India including two weeks in Stockholm, finalising the facility requirements for the ARM trunk exchanges currently on order from L M Ericsson. Mr. Wright is a science graduate of the University of Adelaide and an Associate Member of the Institution of Engineers, Australia.

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A. J. SEYLER, author of the article, "Slow Scan Television Bandwidth Requirements," was born and educated in Germany where he received the degree of Diplom Ingenieur in Electrical Engineering from the Technical University of Munich. In 1937 Mr. Seyler joined the Air Radio Research Institute, Oberpfaffenhofen, Germany, where until 1945 he was engaged in, and from 1942 directed, research on radio navigational aids, ground and airborne radar systems and radar countermeasures. For his contributions to the advancement of radar he received in 1943 an award of the Lilienthal Society for Aeronautical Research. From 1945 to 1948 he was employed by the U.S.A.A.F. in Germany as engineer for airborne radio and I.L.S. equipment.

Coming to Australia in 1948 under contract to the Department of Industrial Development, he joined the staff of the Research Laboratories of the Postmaster-General's Department and in 1956 he obtained the degree of Master of Electrical Engineering from Melbourne University. As Assistant Director-General, Advanced Techniques in Research Branch, Mr. Seyler is concerned with research in problems associated with the application of advanced techniques in television, transmission and processing of visual information, high speed pulse techniques, transmission lines and computations, radio propagation and microwave techniques. Mr. Seyler is a Senior Member of the Institution of Radio and Electronics Engineers Australia, a foundation member of the Television Society of Australia and a Member of the Fernsch Technische Gesellschaft (Germany).

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G. A. DOBBINS, author of the article "Ordering Material for the Crossbar Installation Programme", is a Divisional Engineer in the Exchange Equipment Section, Headquarters. His training in telecommunications started in 1939 at Automatic Telephone and Electric Company Ltd., Liverpool, England, where he spent 12 years. For seven years he had practical experience on the inspection and functional testing of automatic exchange equipment. From 1946 to 1951 he was on the engineering staff of the Contracts Department engaged on the design of automatic exchanges and exchange networks for the preparation of tenders to overseas administrations.

Mr. Dobbins joined the Department in April, 1951, as an Engineer, Grade 1, and was associated with the Trunk Mechanisation programme for three years. He was appointed Group Engineer in 1954 and attached to the section responsible for automatic equipment purchasing. In 1955 he was promoted to Divisional Engineer and is now engaged on the programming and purchasing of ARF, ARK and ARM crossbar equipment in the Works Programme Section.

Mr. Dobbins attends the meetings of the Crossbar Advisory Committee and Technical Development Committee (see pp. 176, 177, Vol. 14, No. 3) and is Chairman of the Automatic Equipment Supplies Conference. He is an Associate Member of the Institution of Electrical Engineers, London, and an Associate Member of the Institution of Engineers, Australia.

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M. O'CONNOR, author of the article, "Negative Impedance Repeaters", joined the P.M.G.'s Department as a Cadet Engineer in 1953 and graduated Bachelor of Electrical Engineering at the University of Melbourne in 1956. After experience in Regional Works and Services at Hamilton, Victoria, he spent four years as Group Engineer, Transmission Standards, with the Victorian Planning Branch. In 1963, he transferred to his present position as Senior Engineer with the Overseas Telecommunications Commission (Australia) in Sydney, where he has been engaged chiefly on the South East Asia Commonwealth Cable (SEACOM) project. His duties in this position include planning of terminal transmission equipment and overland cable works, and the procurement of plant associated with these aspects.

C. T. BREWER

C. T. BREWER, B.Sc., P.Eng., M.E.I.C., author of the article, "Telecommunications in Canada", was born in New Brunswick, Canada, and is a graduate in electrical engineering from the University of New Brunswick. Mr. Brewer served with the R.C.A.F. in Britain from 1942 to 1945 and joined the Bell Telephone Company of Canada in 1950. Since then he has had various engineering and operating assignments. He currently holds the position of General Engineer—Long Term Plans—in the Vice-President's Engineering organization at the Bell Company's headquarters in Montreal.

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R. A. CLARK, co-author of the article, "Self-Supporting Aerial Cable", joined the Postmaster-General's Department in Tasmania in 1950, after graduation from the University of Tasmania. Between 1950 and 1952 he was Group Engineer for the Devonport district and transferred to the Launceston Division in 1953 where he was responsible for the city district during the period when the first automatic exchanges were installed in Launceston and their cable networks were designed and installed. After a period as acting Divisional Engineer, Launceston, he transferred to Central Office, Lines Section, in 1958, where he has been engaged, as Divisional Engineer, Line Material Design. on improvements to many items of line material. Mr. Clark is particularly interested in aerial cable design and substitution of aluminium and plastics for more conventional materials in line plant.

R. A. CLARK

ANSWERS TO EXAMINATION QUESTIONS

Examination No. 5147—6th July, 1963, and subsequent dates. To gain part of the qualifications for Promotion or Transfer as Senior Technician (Telecommunications), Telephones. Postmaster-General's Department.

TELEPHONE AND LONG LINE EQUIPMENT

Answers by K. F. Cody.

QUESTION 1.

(a) List five alarms in one type of automatic exchange with which you are familiar. Along with each alarm state the delay period, if any, and the purpose of the alarm.

(b) List two methods that are used to obtain delay periods in the release alarm system.

(c) You are instructing a technician in the method of placing in the bank a 2,000 type or SE 50 type bimotional switch which is fitted with new wiper assemblies. What points would you stress to ensure that the wipers perform satisfactorily in service? Electrical tests on the switch are not required.

ANSWER 1.

(a) Five only of the following:—

ALARM	INDICATION	DELAY	CLASS
Fuse	An operated alarm-type fuse.	Nil	Prompt
Capacitor	Failure of uniselector spark quench.	Nil	Prompt
Release	Selector does not restore when release circuit is energised.	9 secs.	Prompt
Line finder	Line finder fails to find calling line.	6 secs.	Prompt
High or low voltage	Busbar voltage outside prescribed limits.	Nil (or 1 min.)	Prompt
Ring fail	Failure of exchange ringing supply.	Nil	Prompt
Machine fail	Duty ringing machine fails (second machine takes over).	Nil	Prompt
Charge fail	Overload or reverse current at circuit breaker.	Nil	Prompt
Meter battery fail	Failure of metering supply (+ 50V).	Nil	Prompt
P.G. supervisory	Incoming or 1st selector held without dialling.	Nil (or 6 mins.)	Deferred
C.S.H. supervisory	Called or calling subscriber holds after conversation.	3 mins.	Deferred
N.U. tone supervisory	Fault in equipment on ceased or unallotted lines.	9 secs.	Deferred
N.U. tone overload	Earth fault on line temporarily on N.U. Tone.	Nil	Deferred

(b) Several methods of obtaining delay periods in an alarm system are (two only required):—

(i) Time delay relay set, utilizing a stepped uniselector.
(ii) Dashpot relay (oil filled).
(iii) Valve-capacitor-resistor utilizing time constants.
(iv) Thermal relays.

(c) Before the switch is brought to the bank:—

(i) It should be restored to its home position and
(ii) It should be rendered "busy" by positioning the link in the appropriate test jacks or notifying the remote exchange in the case of incoming selectors.

After inserting the selector in the bank:—

(iii) Vertical pressure is applied to "seat" the selector firmly.

(iv) The "cut-in" of the wipers on the 1st, 5th and 10th levels should be checked.

(v) Alignment between wiper and bank on the 1st and 10th level for the 1st, 5th and 10th outlet is checked.

(vi) The selector should then be tested by impulsing to a number of levels.

QUESTION 2.

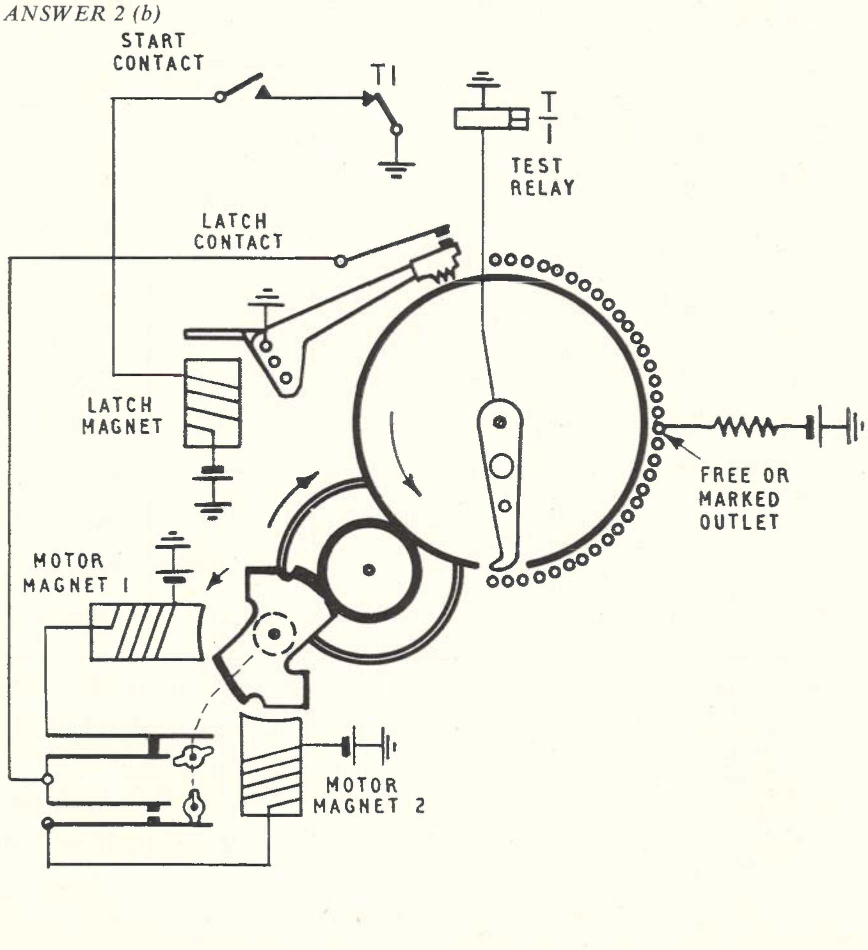
(a) Listed below are V.F. signals used in the Siemens 2VF signalling system. In the space provided state the frequency, duration and purpose of each signal.

(b) Describe with the aid of a simple schematic circuit the action of a Siemens motor uniselector in searching for and stopping on a free outlet.

ANSWER 2 (a)

Signal	Frequency	Duration	Purpose
Pick up	750 c/s	60-100 mS	To prepare equipment for call.
Release signal	600 c/s	450 mS-2 sec.	Busy outgoing until incoming is clear.
Answer—acknowledge	600 c/s	250-350 mS	To arrest the answer signal.
Ringing signal	750 c/s	manual	To attract distant operator's attention.

ANSWER 2 (b)



The basic action of a motor uniselector in searching for and stopping on an outlet is as follows:—

(i) The start contact is closed (external circuitry).

(ii) The latch magnet is energised and withdraws the latch detail from the wiper wheel teeth. The latch contacts close.

(iii) The motor now functions through the latch contacts.

(iv) When a free outlet is reached, the Test Relay (T) is operated from negative battery via the resistor and breaks the circuit to the latch magnet at T1 contact.

(v) The latch restores and arrests the wiper wheel; at the same time disconnecting the motor circuit at the latch contact.

QUESTION 3.

(a) What facility is available in a big exchange to give temporary service under certain conditions on a faulty subscriber's line?

(b) What line conditions are essential before such a service can be given?

(c) Show by means of a simple schematic circuit how line insulation is checked from a test desk.

(d) What procedure in an automatic exchange is designed to highlight those subscribers' services which have an excessive number of complaints?
What action would you take when such a service is brought to your notice?

(e) A subscriber calls 60 1813 and gets 018. What has happened to cause this?

(f) A subscriber calls 60 1813 and gets 7181. What has happened to cause this?

ANSWER 3.

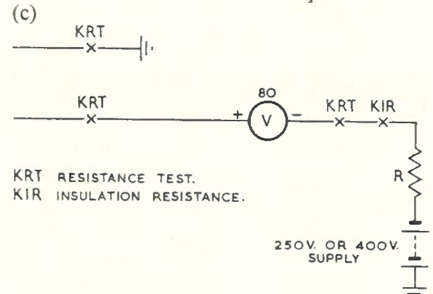
(a) A relay set to give "Special Service on Faulty Lines" can be connected into the subscriber's line by plugs at the M.D.F. This facility is often called a "Hospital" circuit.

(b) The line conditions under which the service can be given are restricted to those where one conductor is available free of earth or foreign battery. Since an earth return is utilized, this is possible if:—

(i) only one wire is earthed, contacting foreign battery or open, or

(ii) a short circuit exists between the wires of the pair, but without any other fault condition present.

(c)



(d) If, while attending to a repair request, one notes that more than two entries have been made on the subscriber's master card in two months, the card should be forwarded to the supervising technician for his attention. When the Supervising Technician receives the card, he should examine the entries to determine the history of the service, in relation to instrument, line and exchange equipment. If attention is considered necessary, a Special Inspection Docket E.M.52 is issued, noted on the Master card and in the Special Inspection Docket Register E.M.99. The service is completely overhauled by a different officer to the normal fault man and the subscriber contacted to confirm satisfactory service.

(e) Since 018 are the second, third and fourth digits in his call, it would seem that the first digit has been lost. The most likely cause of this would be a "drop-out" of the first selector after digit 6 had been dialled and the seizure of another first selector prior to subsequent digits. Another possible cause would be dialling before receiving dial tone.

(f) Since the 181 are common to both numbers the fault must have occurred before these digits.
Since 7 is a reasonable part of the 10 impulses for digit 0, it would appear that the second selector was seized during impulsing. This would occur if the original first selector "dropped out" after 6 was dialled, and another 1st selector was seized. The loss of 3 impulses from digit 0 would be caused by the time difference between the interdigital pause, the release lag of selector relays and the uniselector hunting and switching times. Contributing factors are poor wiper alignment and faulty vertical stepping due to poor adjustments.

QUESTION 4.

(a) List the equipment you would order for the installation of an intercommunication system, to provide for seven internal extensions, and one outdoor extension. A power lead from the exchange is not available.

(b) Outline two ways in which you can provide for service to be given on the installation referred to above during periods of failure of the A.C. power supply.

(c) What secrecy facilities are available on an A10 intercommunication system?

ANSWER 4.

Item	Quantity	Remarks
Extensions A10	7	
Transfer unit No. 3A	1	
Telephone	1	(Normal instrument)
Battery eliminator	1	Rating: 1.5 amps
Cable 20 pair	as required	42 wires
Cable 1, 2 or 5 pair	as required	Point of entry to main station wiring

Minor items include cable clips and staples.

(b) Service to the subscriber may be given during periods of A.C. failure by:—
(i) Provision of a standby battery of dry cells, connected when D.C. output from the eliminator fails.
(ii) Operation of keys on the transfer unit to extend one exchange line to the external extension.
Other methods involving the provision of standby normal telephone instruments via keys are possible.

(c) *Secrecy.*
(i) Normally calls from extensions to exchange lines are secret.
(ii) Calls by the external extension on an exchange line are secret.
(iii) Under night switched conditions, the external extensions may make secret calls but the calls of internal extensions on exchange line calls can be heard by the external extension.
(iv) Exchange line supervision may be granted to an extension by strapping in the instrument, permitting access to an exchange line which is already in use.

QUESTION 5.

(a) Draw a simple schematic diagram showing the call holding conditions on the p wire, on a call switched direct from one branch exchange to another. Assume the call is via a subscriber's uniselector, and show the connection of the subscriber's meter. Assume a 6 digit network. Designate switches, relays sets and wipers. Details of all relay contacts are not required.

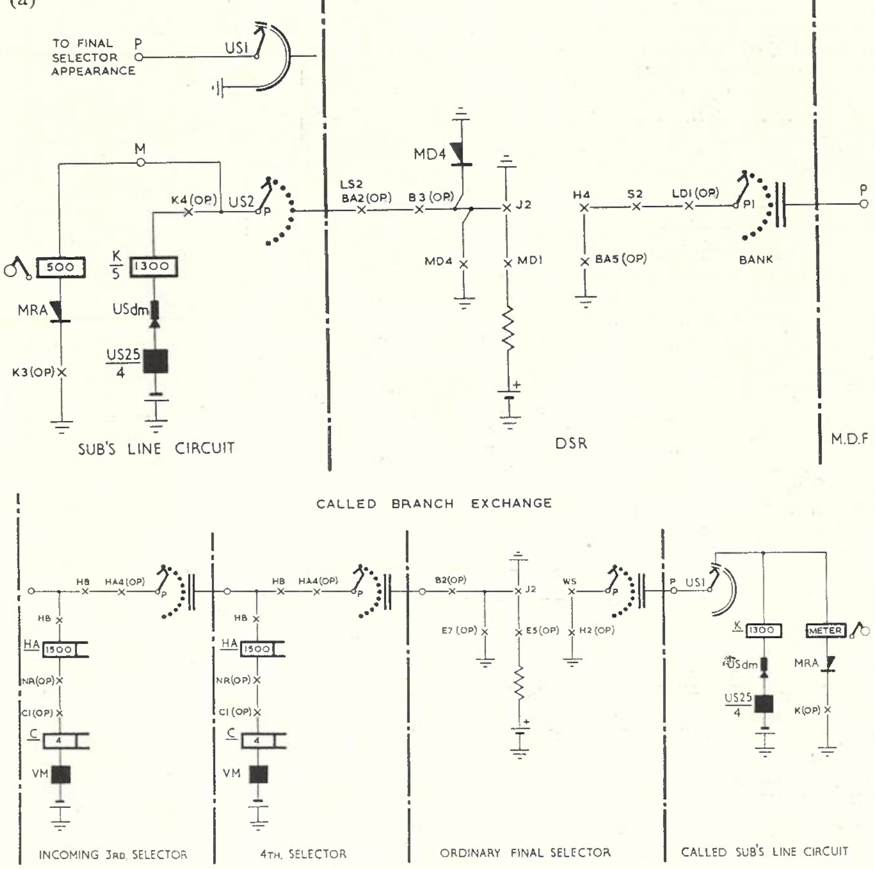
(b) Describe how metering takes place.

(c) What checks would you make on the exchange equipment when placing a new line in service?

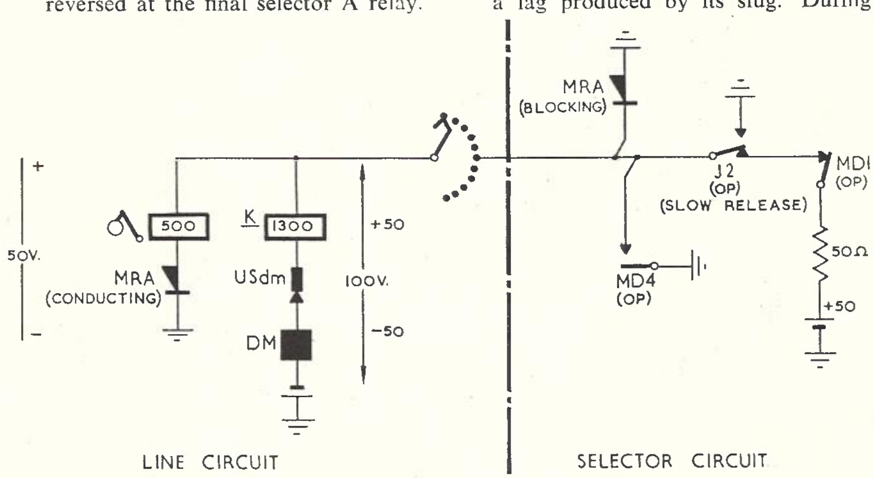
ANSWER 5.

(a)

ORIGINATING EXCHANGE



(b) The action of metering is as follows:—
When the called subscriber answers, the polarity of the speech wires is reversed at the final selector A relay. This reversal causes the operation of relay D in the DSR and in turn its slave MD. Contact MD2 opens the J relay circuit, which releases after a lag produced by its slug. During



that period, where MD and J are operated, a potential of +50 volts will be applied to the private. The rectifier MRA in the subscriber's meter circuit will conduct the metering pulse. Normally MRA is blocking to the negative potential behind the various relays on the private wire.

A condition equivalent to the meter pulse will occur in the called branch exchange. This pulse is originated by the final selector and will be applied to the privates of the 4th and 3rd selectors. However, since the private is not extended over the junction, this pulse will not produce metering at the originating exchange.

(c) The two checks carried out on the exchange equipment of a new line:—
   (i) Routine 177 is applied to the meter (i.e., 10 operate and 1 non operate pulses) and the number of registrations noted.
   (ii) Two service test calls are originated from the subscriber's line circuit, and the meter is re-read to check for correct operation.

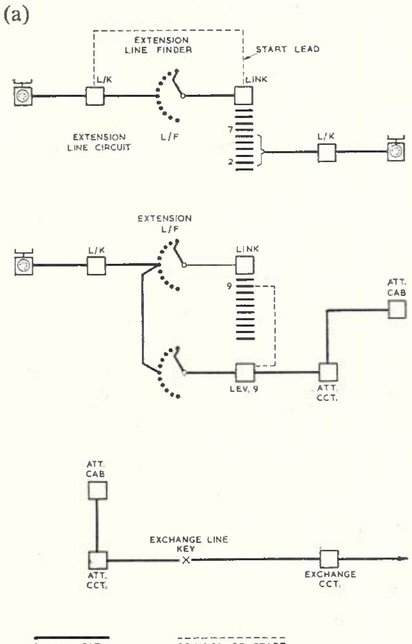
QUESTION 6.

(a) Show by means of single line block schematic diagrams the following call routings in a C type P.A.B.X. Designate relay sets and switches involved in each type of call.
(i) An extension to extension call.
(ii) An extension to switchboard call.
(iii) Switchboard to exchange call.

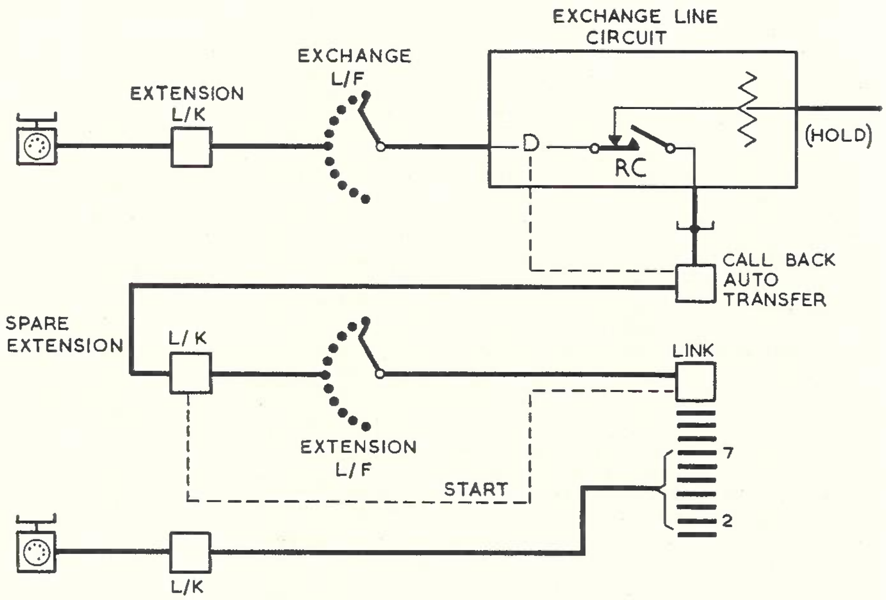
(b) With the aid of a simple block schematic diagram explain the operation of the "call back" facility on a C type P.A.B.X. (i.e., an extension disengages from an exchange call, makes a call to another extension and then comes back to the exchange call).

ANSWER 6.

(a)



(b)



When the original extension depresses an earthing button momentarily, a relay (D) in the exchange line circuit responds. The call back circuit then operates a relay (RC) in the exchange line circuit which holds the exchange line looped, and diverts the extension to the spare extension line circuit. The links are started, actuate their extension line finders and the first one to find returns dial tone. A second extension is dialled, with whom conversation takes place.

To return to the exchange line the button is again depressed. The call back circuit responds by restoring the exchange line back to its former through condition, and releasing the spare extension, link and called extension.

QUESTION 7.

(a) What is the acceptable range of impulse make ratio from a subscriber's line when tested from the exchange test desk?

(b) In what way does the spark quench on a telephone affect the make ratio as seen at the test desk?

(c) What are the approximate upper and lower limits of impulse make ratio to which a properly adjusted bimotional switch will respond without "missing" or "gaining" impulses? Assume the impulse speed is 10 i.p.s.—and state the type of switch to which you refer.

(d) What are the common sources of impulse distortion in a telephone network?

(e) What design features are incorporated in the telephone dial and the bimotional selector to ensure that the selector can be seized and ready for impulsing before the impulse train arrives?

(f) Under what operating conditions is a local selector most likely to receive an impulse train before it is seized and ready?

ANSWER 7.

(a) 34 to 39% make ratio.

(b) The presence of a quench in the dialling circuit tends to raise the impulse make ratio by about 3% as measured at the test desk.

(c) The upper and lower limits of impulse make ratio acceptable to a bimotional selector are:—

Pre 2,000	20-65% make ratio.
2,000	15-65% make ratio.
S.E.50	25-50% make ratio.

(d) The main sources of impulse distortion in a telephone network are:—
   (i) The variations in resistance (etc.) of junctions and subscribers' lines which are presented to the impulsing relays.
   (ii) The presence of the spark quench especially on short or long lines.
   (iii) Deterioration or maladjustment of the telephone dial.
   (iv) Maladjusted impulsing relays.
   (v) The limitations of capacitor type transmission bridges in repeaters, DSRs. and signalling relay sets.

(e) Features which ensure adequate preparation of selectors for impulsing include:—
   (i) The lost motion period in the telephone dial introduced before (or after) an impulse train.
   (ii) The impulse steering relay (CD) has a maximum release period not in excess of 200mS, to ensure that testing and switching of the previous selector begins as soon as possible after impulsing has stopped.
   (iii) Rapidity of search, by means of a self-interrupted forward acting drive. Maximum search time should not exceed 350mS.
   (iv) Selector pick-up time kept to a minimum by reducing the inductance of pick up loops.
   (v) Pre-operation of the impulsing steering relay (CD).

(f) A local selector could receive an impulse train before it is properly prepared under the following conditions:—

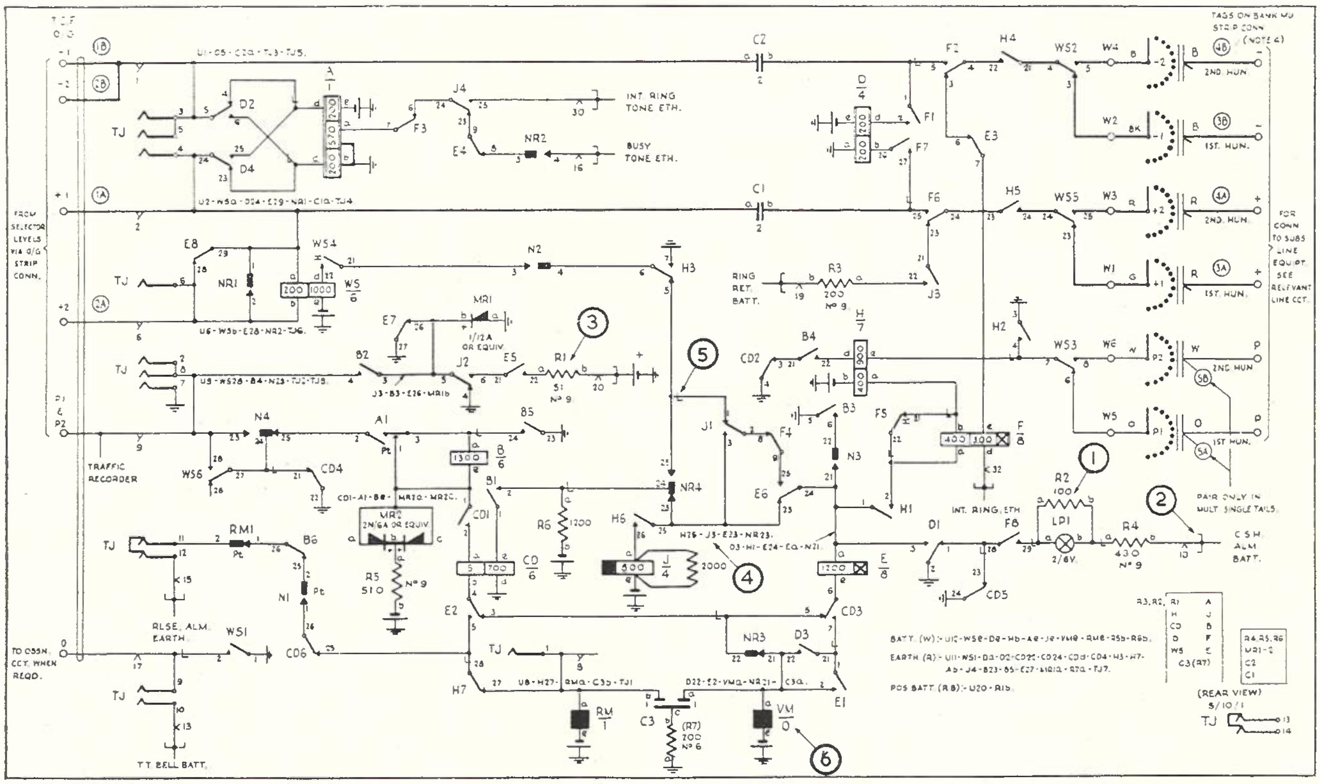
(i) Subscriber does not wait for dial tone. This can occur if a subscriber dials from the called subscriber holding condition on a final selector, or from the latter outlets of his uniselector.

(ii) Fumbling of the cradle switch (switch hook), or momentary breaks in the line circuit which have been accepted by the previous selector as impulsing.

(iii) Seizure of a selector during the release "blink" unguarded period.

(iv) Rapidity of dialling, especially in the case of one impulse, after which a search to a late outlet is involved.

(v) Seizure of another selector, after a "drop-out" has occurred from a previous digit.



QUESTION 8.

(a) Attached is the circuit of a final selector with arrows pointing to the features referred to in the following questions:—

What is the purpose of R2 marked by (1)?

What is the symbol marked by (2)?

What is the purpose of R1 marked by (3)?

What does H25-J3-E23-NR23 mean (4)?

What does the symbol L mean (5)?

What is meant by the 0 indicated by (6)?

(b) On a call to the even hundreds after the called subscriber has answered and metering has taken place, all relays except J are operated. Briefly explain why flashing of the switch hook by the called party while the calling party is still holding does not cause false metering.

ANSWER 8.

(a) (1) The resistor (R2) ensures the operation of the alarm even if the lamp (LP1) burns out or is removed. The resistor (R2) shunting the lamp also permits a larger current in the circuit for more positive operation of the CSH alarm supervisory relay (LA).

(2) This symbol indicates that CSH ALM BATT is multipled (commoned) to other switches. The direction of commoning shows that it is supplied *to* the selectors.

(3) The resistor (R1) serves as a limiting resistor to current from the metering battery:—

(i) in the event of an earth being on the private during metering,

(ii) in the event of a uniselector testing the private during the metering pulse,

(iii) to prevent "welding" of the circuit contacts during maintenance operations.

(4) The sequence H25-J3-E23-NR23 beside the line in the diagram indicates the route of the wire as from spring 25 on the H relay, to spring 3 on J relay, to spring 23 on E relay and ending on spring 23 on the Normal Rotary springs.

(5) The symbol L indicates that the wire on which it is placed is a loop, i.e., the wire runs from spring 3 of H relay, to spring 1 of J relay and then to spring 25 of the Normal Rotary springs.

(6) The 0 indicates that there are 0 (Zero) springsets actuated directly by the Vertical Magnet (for example Vertical Interrupters).

(b) For metering to recur it would be necessary to reoperate relay J to provide a path at J2 for metering on the private. (See (3) in part (a)). Considering the earths which might provide a path for reoperating J.

(i) The wipers are in the bank and for this reason NR4 springset is operated. This breaks any possible earth through the CD 700 ohm winding and contact B1.

(ii) J cannot reoperate through its own J1 springset since this is open.

(iii) The path via springset E6 has been broken by the operation of E relay. The E relay was operated by contact D3 and locked itself at E1. As long as the switch is kept off-normal and looped either by the calling and/or called subscribers, E will remain locked.

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2	October	1963	85-170	5	October	1964	341-432
3	February	1964	171-254				

REFERENCES:

(T.N.I.) refers to a short Technical News Item or a letter to the Editors.

Hitherto, a volume of the Journal was issued in six numbers over a period of two years, with a new volume commencing every alternate June. Publication dates were June, October and February.

As from February, 1965, a volume of the Journal will comprise three numbers (February, June and October). To change over to the new system, Volume 14 contained only five issues.

Answers to Examination Questions

Senior Technician (Telecommunications) Examination

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Telecommunication Principles				
Telephone	July 1963	5147)		
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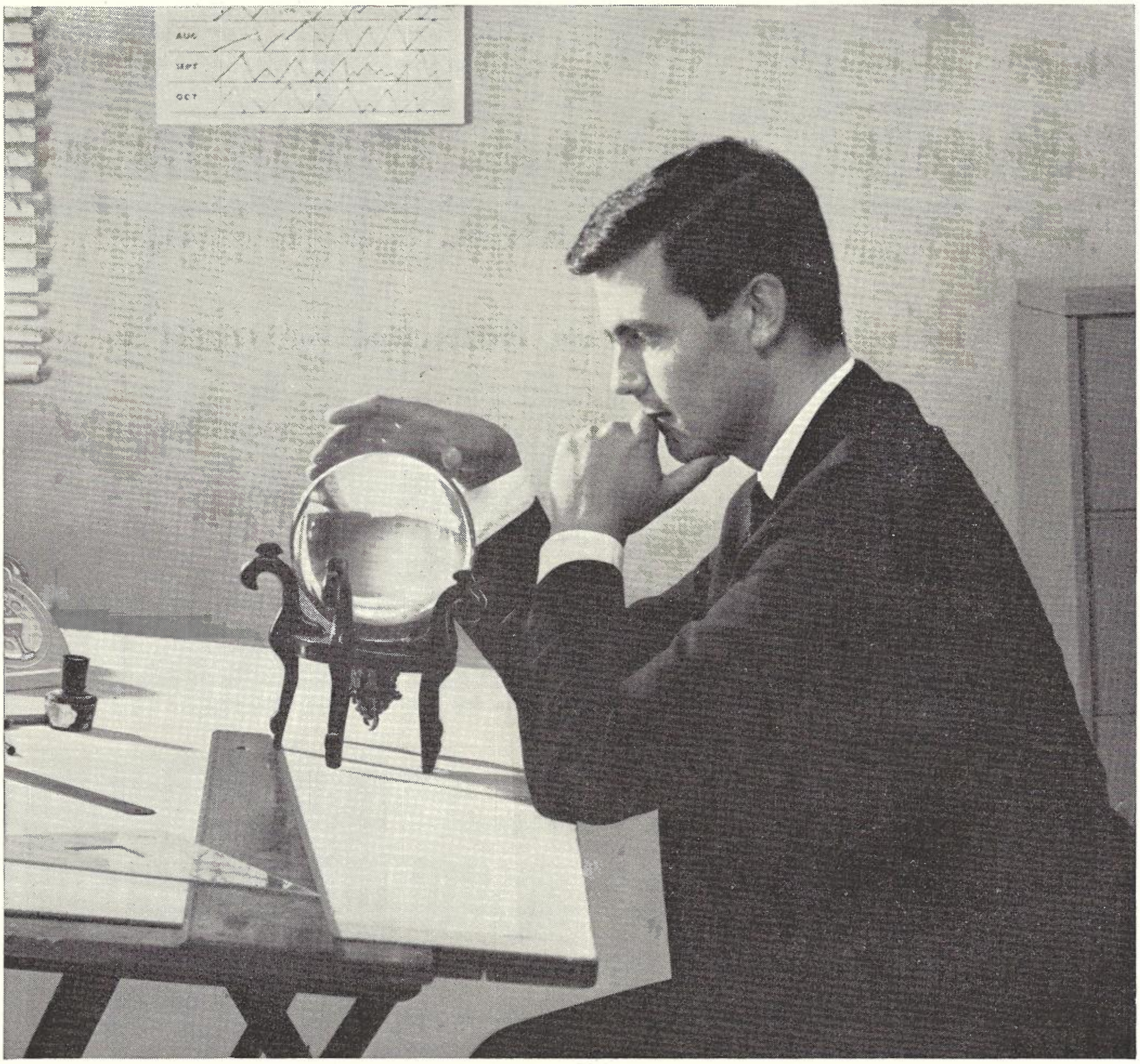

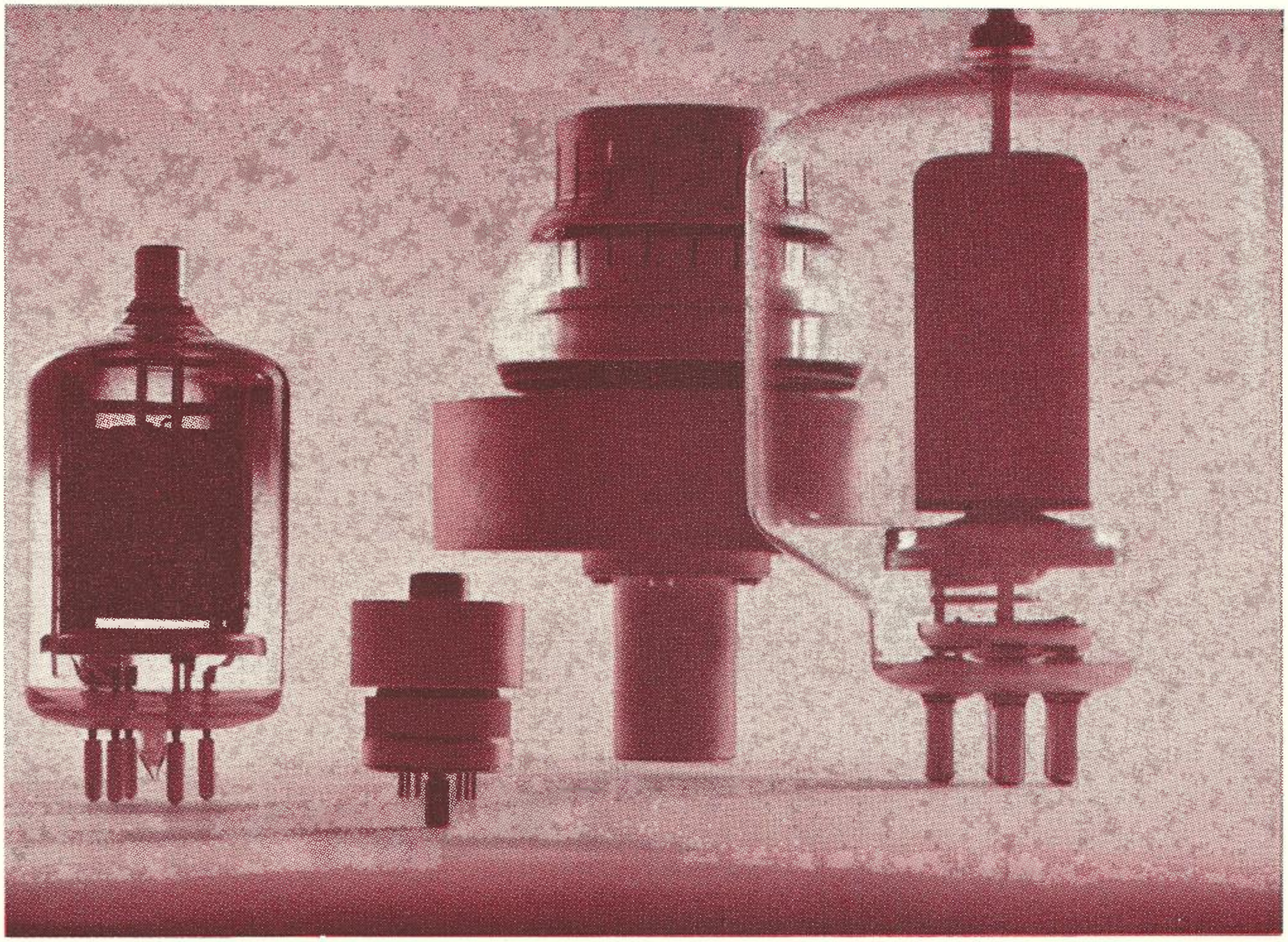

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3rd ORDER Intermodulation Distortion (db) (without feed-back)	34	35	30	35	35	30	31	31
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15	OC22 OC24 2A		OC23 2A			

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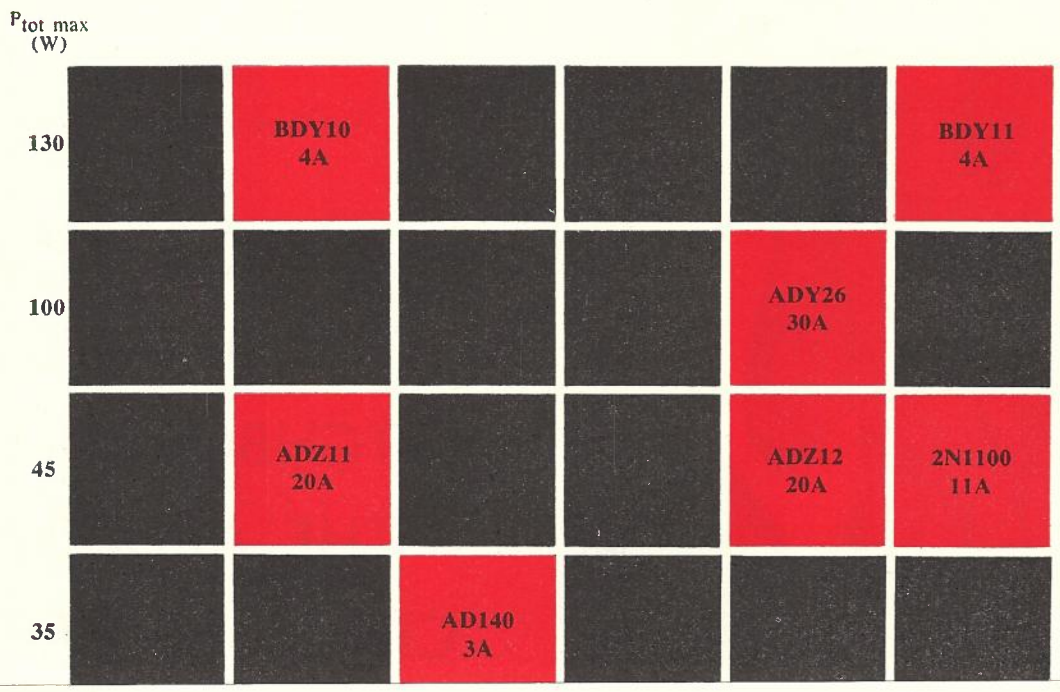
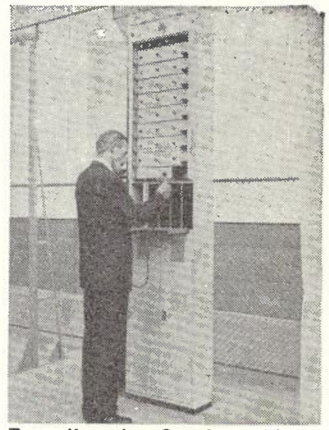


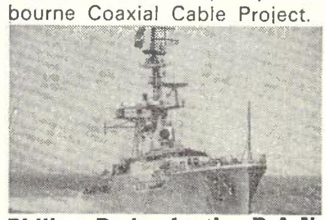
Ptot max (W)
130
100
45
35
BDY10 4A
BDY11 4A
ADY26 30A
ADZ11 20A
ADZ12 20A
2N1100 11A
AD140 3A

wide range of equipment manufactured by T.C.A.

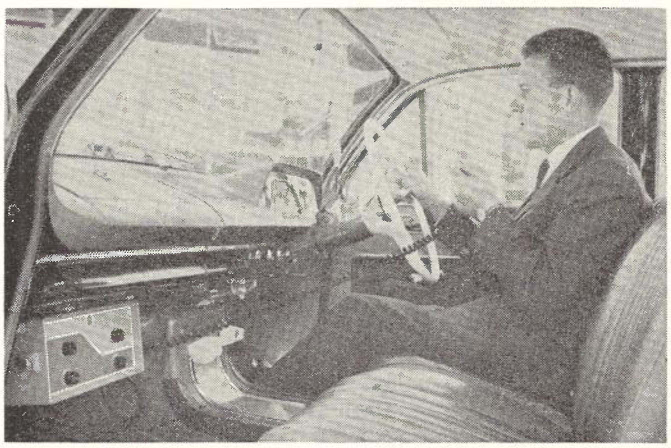
Radio Control of Traffic Lights. The Melbourne City Council ordered TCA Series 1857B equipment for nine King Street intersections. This equipment has been designed to enable the entire traffic light system of the city to be controlled, over a single VHF link, from a central point and includes the facility for voice communication to maintenance personnel. Eventually the system will embrace the whole of the central business district and finally to the extremities of the city.



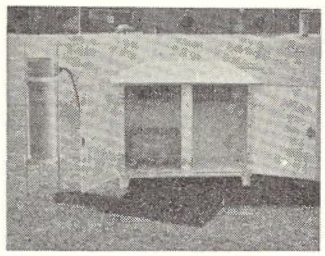
Broadband Carrier Telephone Equipment. This 48 channel modulation bay is being prepared for shipment to the Postmaster General's Department. The bay is identical to those previously supplied to the P.M.G. for the Sydney-Melbourne Coaxial Cable Project.



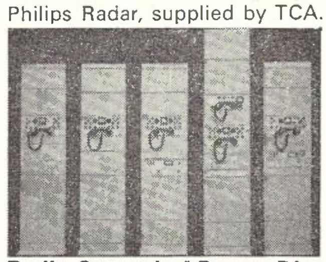
Philips Radar in the R.A.N. The anti - submarine frigates "Parramatta", and "Stuart" and the aircraft carrier "Melbourne" are all fitted with Philips Radar, supplied by TCA.



First to Transistorise Mobile Radiophones. In 1957 TCA led the world by replacing the vibrator power unit of its FM mobile radiophone unit with a transistorised DC/DC converter. The immediate acceptance and success of this venture inspired further development in transistorisation with the result that, in December, 1961, TCA commenced marketing a mobile unit with a fully transistorised receiver and DC/DC converter, and a transmitter that was transistorised to the extent that only three electron tubes remained. This unit is now the most field-proven unit available in Australia; already several thousand are in use throughout Australia and overseas countries by government and commercial organisations. For both recent Royal tours TCA mobile and base equipment was employed exclusively. The P.M.G. has approved the equipment for use throughout the Commonwealth.



Radio Reporting Rain Gauge System for the Commonwealth Bureau of Meteorology. To overcome the problem of obtaining regular details of rainfall in remote areas the Bureau has ordered from TCA a special Radio Reporting Rain Gauge System. The equipment operates at VHF and will automatically provide Bureau personnel, at the recording centre, with details of rainfall throughout their area. The facility for voice communication to maintenance personnel is also included. The Macleay River Valley will be the testing ground for the first system, where it is hoped it will aid the Bureau in providing a flood warning service to the many settlers in that area.



Radio Control of Power Distribution Networks. The Townsville and Mackay Regional Electricity Boards have taken delivery of a special electronic supervisory and control system designed and manufactured by TCA. The system provides a VHF duplex radio repeater link network connecting Townsville and Mackay with facilities for speech traffic, supervisory control of circuit breakers and tap changing regulators, and the telemetering of power flow indications.

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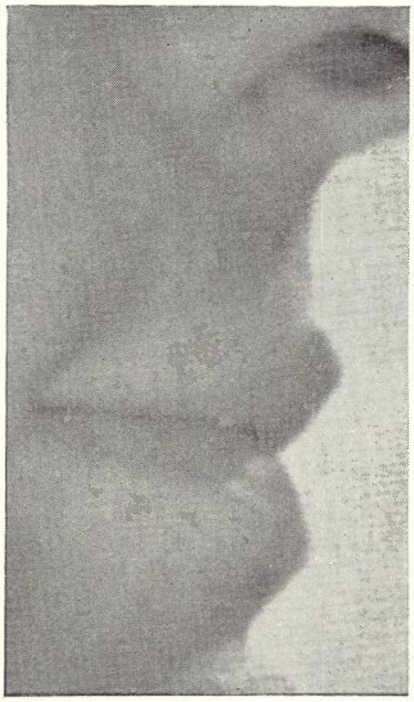
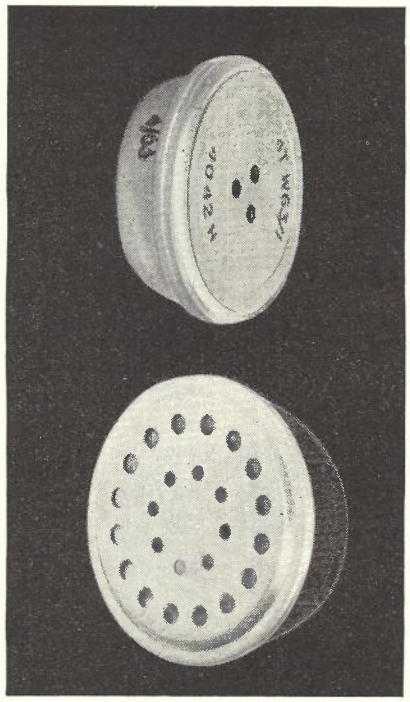
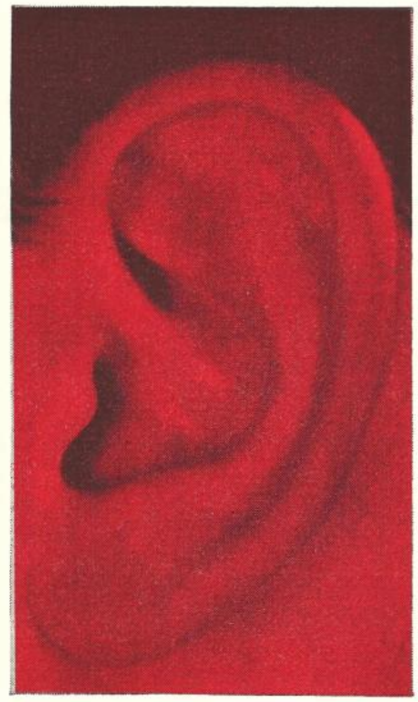

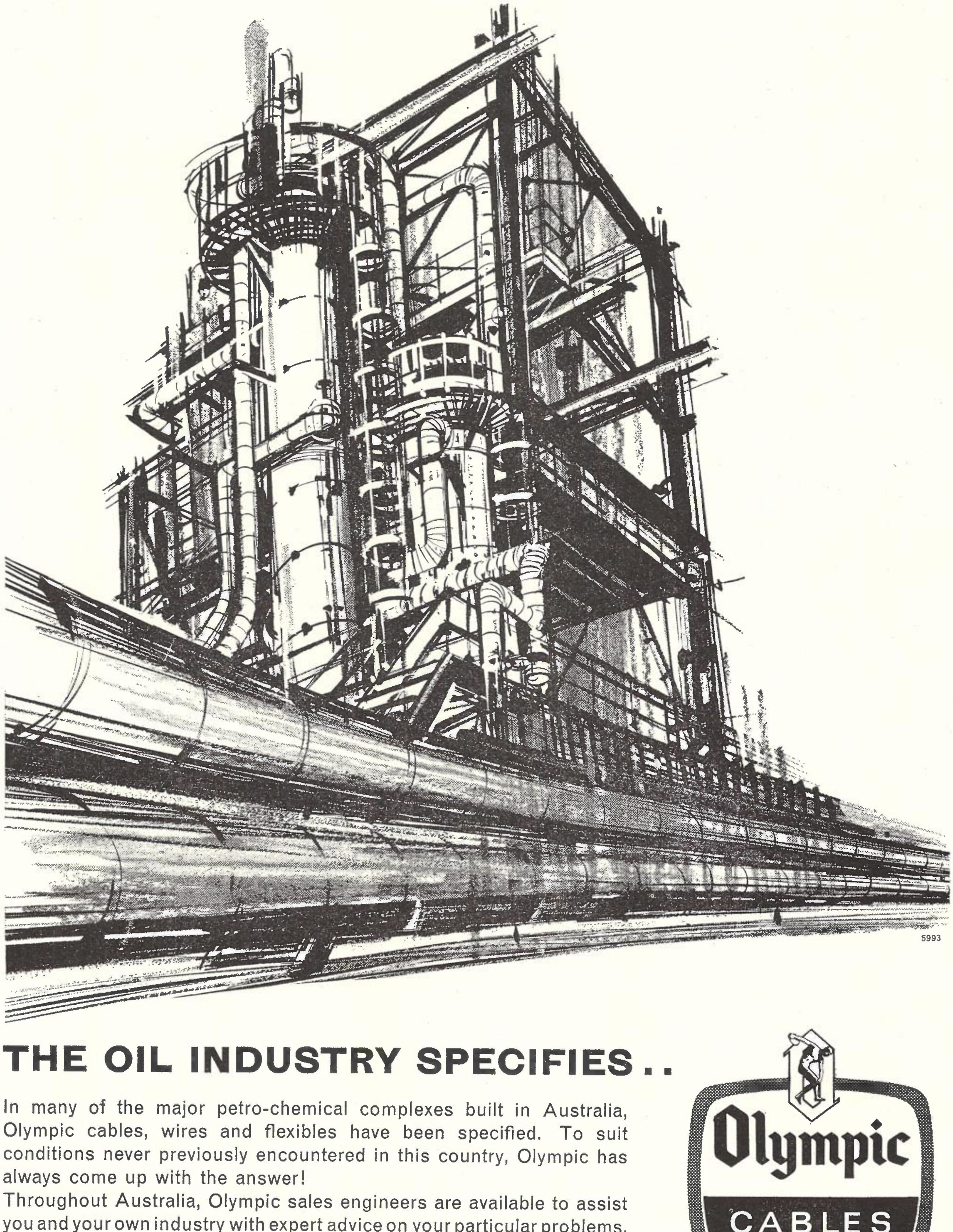

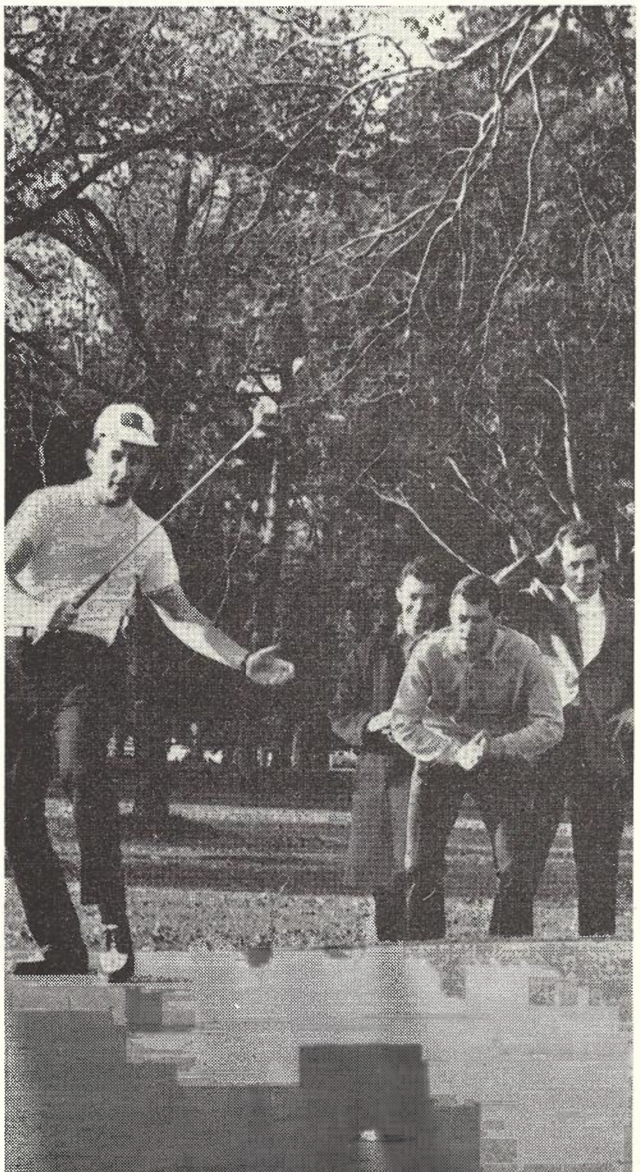

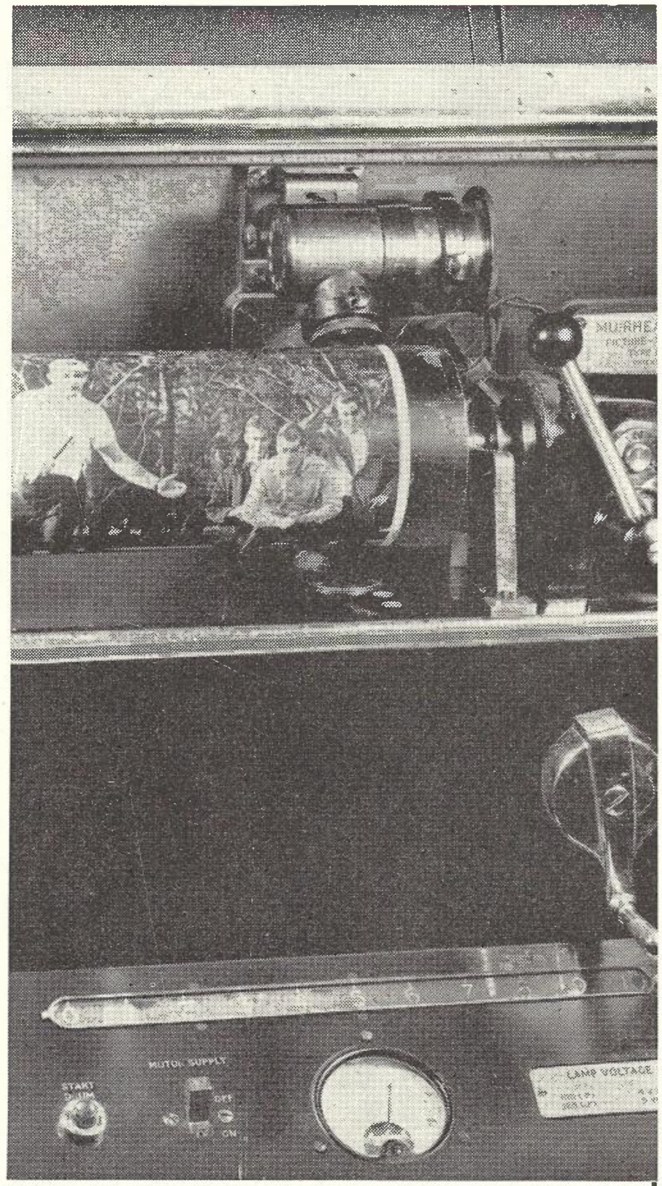
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In Australia Pye Proprietary Ltd. is proud to be accredited designers, manufacturers, and suppliers, to the Department of Civil Aviation, the P.M.G., the three Armed Forces and the Department of the Interior, and many state government utilities.

RADIO COMMUNICATION SYSTEMS for H.F., V.H.F. and U.H.F.
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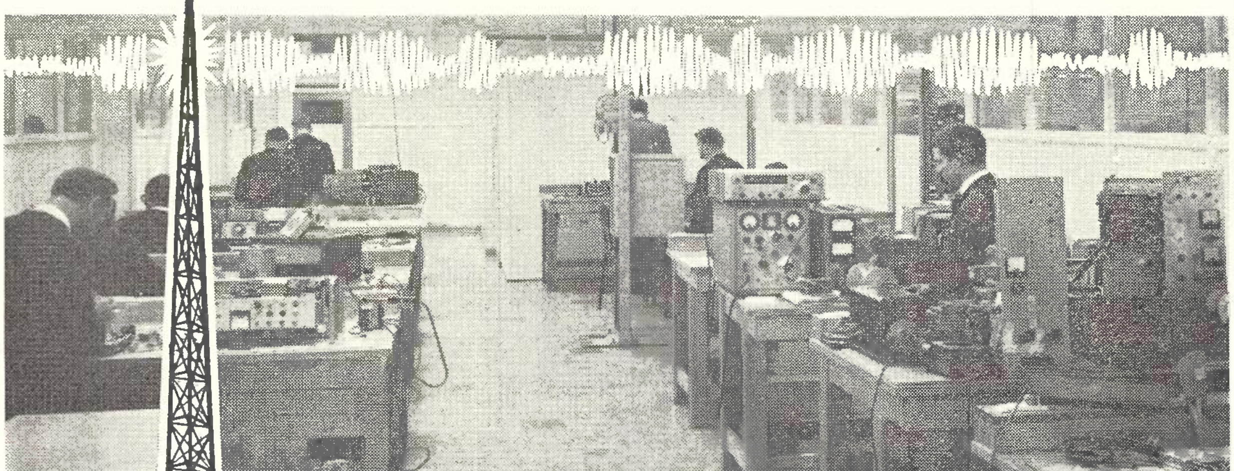

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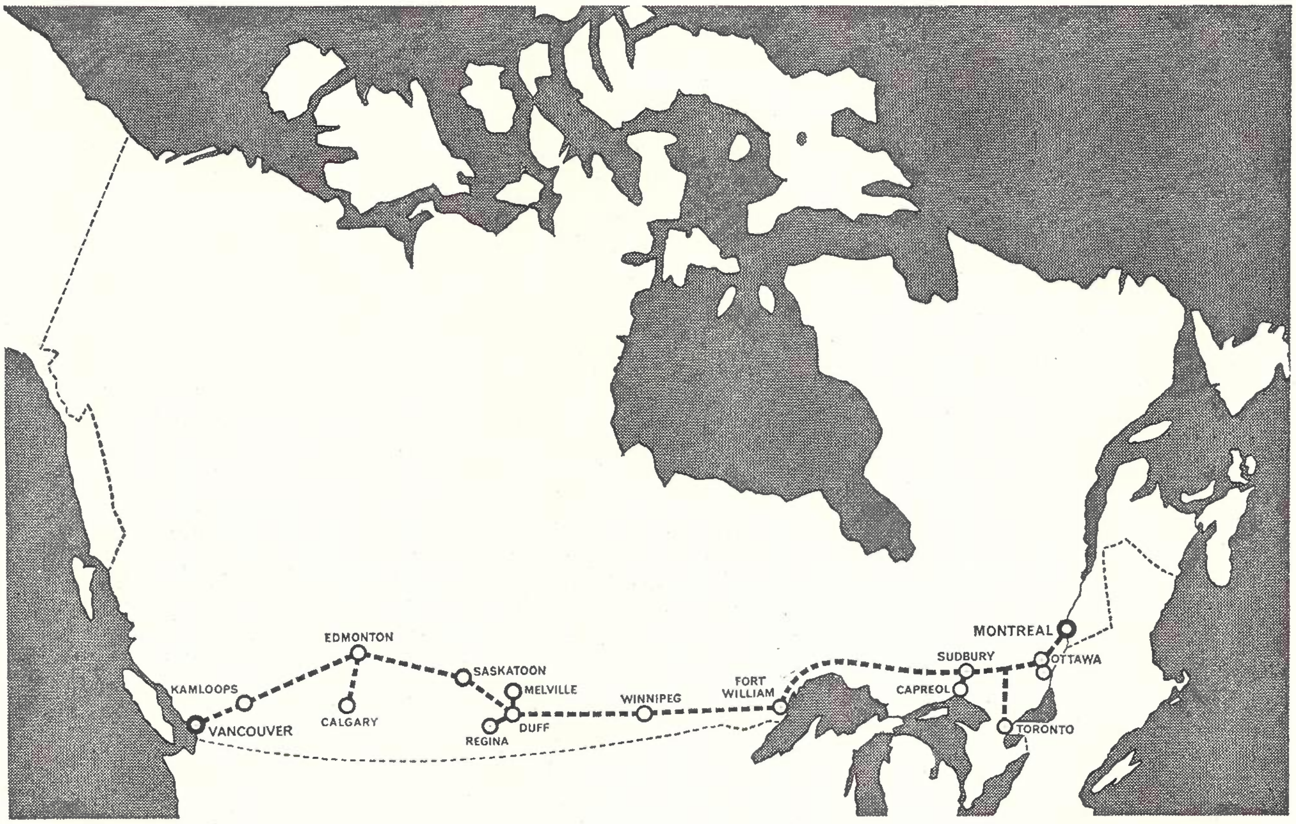
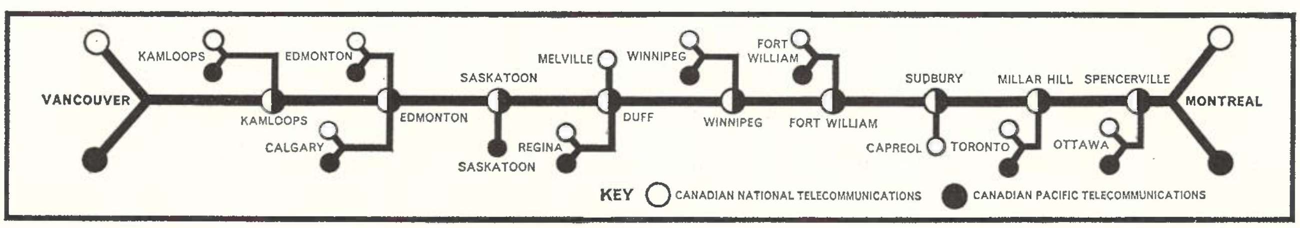


G.E.C. TRANSISTORED MULTIPLEX FOR THE MONTREAL-VANCOUVER ROUTE



G.E.C. has secured the order for all the multiplex equipment at the 32 terminal locations on the new Montreal-Vancouver microwave route which is being constructed jointly by Canadian National Telecommunications and Canadian Pacific Telecommunications.

All multiplex equipment of this system is completely transistored and extensive use is made of supergroup derivation filters at intermediate terminals to avoid demodulation of the supergroups directly connecting Montreal and Vancouver. These supergroups are equipped with automatic gain regulating equipment. Each group and supergroup in the system is provided with a reference pilot which is monitored by electronic scanning equipment and an alarm is given if the level of the pilot deviates by more than a fixed amount.

The multiplexing equipment used throughout this new system was designed and manufactured by The General Electric Company Limited of England, and supplied by Canadian General Electric-Toronto, Canada

G.E.C. everything for telecommunications

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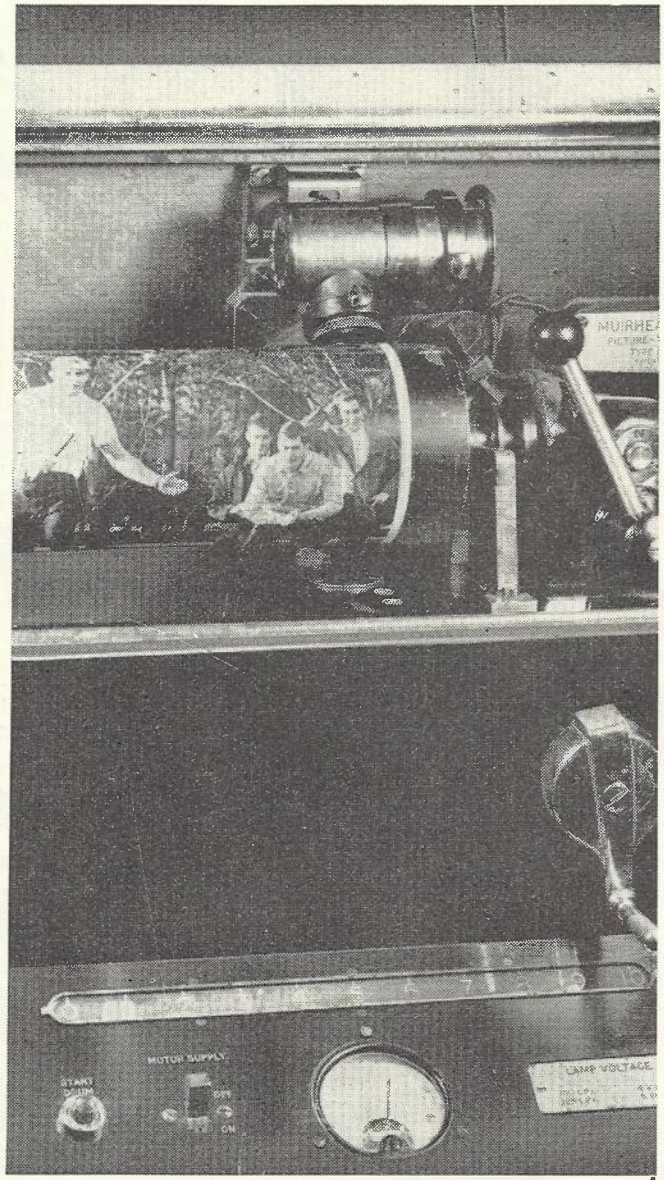
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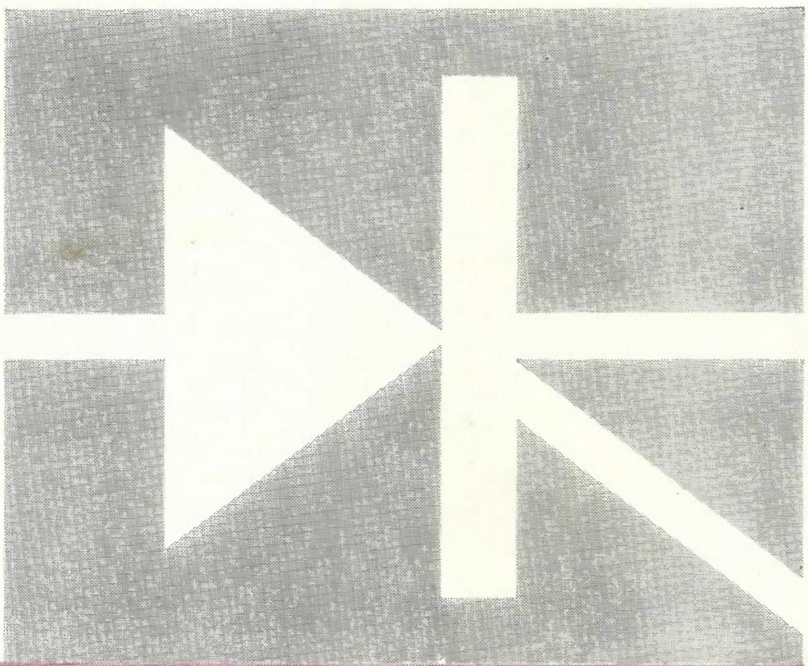
STC SILICON CONTROLLED RECTIFIERS

Now available in a wide range . . . and in PRODUCTION QUANTITIES



Solid state control at low cost.
No maintenance an important feature

STC's range of "2SF" codings are pnpn-type silicon controlled rectifiers for use in power control or switching applications. The reverse characteristic is similar to a pn silicon rectifier, and the forward characteristic is such that it will block below the peak forward voltage if no gate signal is applied. When a gate signal is applied, it switches to the conducting state and presents a very low forward voltage drop similar to a silicon rectifier.

The 2SF series silicon controlled rectifiers are available in extended voltage range and are identified by the following coding:

P.I.V.	300 mA	6.5A	11A	22A	55A	80A	200A
50	2SF101	2SF11	2SF21	2SF31A	2SF111	2SF121	2SF310
100	2SF102	2SF12	2SF22	2SF32A	2SF112	2SF122	2SF311
150	2SF103	2SF13	2SF23	2SF33A	2SF113	2SF123	2SF312
200	2SF104	2SF14	2SF24	2SF34A	2SF114	2SF124	—
250	2SF105	2SF15	2SF25	2SF35A	2SF115	2SF125	—
300	2SF106	2SF16	2SF26	2SF36A	2SF116	2SF126	2SF313
400	2SF108	2SF18	2SF28	2SF38A	2SF118	2SF128	2SF314
500	—	2SF200	2SF205	2SF210A	2SF120	2SF130	2SF315
600	—	2SF201	2SF206	2SF211A	—	—	—
700	—	2SF202	2SF207	2SF212A	—	—	—

FEATURES OF STC SILICON CONTROLLED RECTIFIERS

- ★ Low forward voltage drop during conducting state.
- ★ Low leakage current in both forward and reverse directions at high temperature.
- ★ Large power control with small gate power.
- ★ Wide range of allowable operating temperatures.
- ★ Quick response.
- ★ Stable operation and long life.
- ★ Compact, light weight.

The Industrial Products Division of STC can supply either the device or the complete equipment incorporating Silicon Controlled Rectifiers. In addition, engineering advice is available to assist in applying the wide range of S.C.R.'s offering. Its research facilities are at present engaged in the development of a complete range of equipment using Silicon Controlled Rectifiers for inverter/converter equipment up to 25 kVA, both 3 phase and single phase.

For further information on STC Silicon Controlled Rectifiers contact Industrial Products Division . . . **Standard Telephones and Cables Pty Limited** AN ITT ASSOCIATE

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Printed by The Ruskin Press Pty. Ltd., 39 Leveson Street, North Melbourne