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Mr. F. P. O'GRADY, M.I.E. Aust., S.M.I.R.E.

Mr., F. P. O'Grady, whose appointment as Deputy Engineer-in-Chief was announced recently, will leave South Australia after having occupied with distinction senior engineering positions in the P.M.G.'s Department and the Weapons Research Establishment in that State.

Mr. O'Grady's service began in January, 1917, when he was employed in a temporary capacity first as a Messenger and later as a Junior Mechanic in the old Central Telephone Exchange in Adelaide. Late in 1919, following the return of permanent staff from the First World War, all temporary employees were retrenched and Mr. O'Grady joined the electrical engineering firm of Unbehaun and Johnstone. Here he was employed on various electrical installations and inter-communication telephone services. One of the more amusing incidents during this period occurred during a visit to Adelaide of the Prince of Wales, now Duke of Windsor. Mr. O'Grady, with his flair for rising to the top of his profession, found himself engaged in fitting ornamental electrical lighting high up on the dome of the Exhibition Building. It is said that pedestrians walking along North Terrace were occasionally startled by exploding electric light bulbs surreptitiously dropped from a considerable height.

In June, 1924, having passed an open examination, he was permanently appointed as Mechanic in Adelaide, and in reading the Gazette in which his appointment was announced, he saw that an examination for appointment as Engineer was advertised for the following August. Needless to say, he sat for this examination and was successful in passing all five subjects. Following a period of acting as Class E Engineer in Adelaide, he was appointed Engineer in the Telephone Equipment Section, Central Office, in May 1926. For the following 18 months he was engaged in automatic telephone equipment design for Melbourne. He then returned to Adelaide to take charge of a small staff of Technicians, later to become known as the Transmission Section which was then being assembled to instal and maintain voice frequency repeaters and single channel carrier systems then being introduced into South Australia.

Mr. O'Grady's gift for teaching and his willingness at all times to explain technical matters to all who sought his assistance is gratefully remembered by many of the South Australian staff. During 1928 and 1929 he conducted a course of instruction for Mechanics, dealing particularly with the new problems and techniques connected with the introduction of carrier equipment and the associated electron tube to telephone services in the Commonwealth. Many of these lectures were later included in a Technical handbook well known as "The Red Book of Carrier" which was published by the A.P.E.U.

The take over of the private Broadcasting Companies into the National Broadcasting Service early in 1930 was competently undertaken by Mr. O'Grady who became one of the leading radio engineers in the Commonwealth. Reconstruction of radio transmitters to increase power output and the introductions of new regional stations in South

Australia was attended by much personal effort and it was a common practice in those days for him to work over-night with his staff, engaged in the reconstruction and rewiring of metropolitan broadcasting transmitters while the station was off the air.

By 1934, the Transmission Section in South Australia had reached Division Status and Mr. O'Grady was promoted as Divisional Engineer. The following years saw rapid expansion and he was responsible for much developmental work. Included in this was the replacing of the V.F. telegraph sending relay with the static modulator and the development of a single frequency V.F. dialling system which was widely used in South Australia from 1938 onwards. An article describing this system appeared in the February 1940 Edition of this Journal.

During World War II, radio navigational aids for the R.A.A.F. and Civil Aviation Department were installed under his direction in many parts of the Northern Territory and in South Australia and he was responsible for the provision of carrier telephone and telegraph services to Darwin involving the establishment of many new repeater stations in remote locations on the overland telegraph route. He also found time to undertake the duties of Major in the 4th L. of C. Signals Unit which was recruited from Postal Staff for security purposes after the entry of Japan into the War.

His appointment as Supervising Engineer, Transmission, Adelaide, was Gazetted in 1945 and then in February 1949 he severed his connection with the P.M.G.'s Department to take up an appointment with the Weapons Research Establishment at Salisbury. His first appointment was that of Principal Scientific Officer in charge of a scientific staff group, but later in the same year he was promoted as Principal Officer, General Services, in charge of the Engineering Division of the W.R.E. Again in 1951 he was promoted as Superintendent (Engineering) and later appointed Chief Engineer. Duties of the latter position involved the control of the planning of buildings, structures, workshops, engineering development, drawing office work, and general engineering for both Woomera and Salisbury.

During 1953 and onwards, his responsibilities also included duties associated with the Emu and Maralinga atomic trials. This involved a short visit to London in 1953 in connection with the atomic trials at Emu Field. In 1956 Mr. O'Grady again went overseas studying developments in tropospheric and ionospheric scatter radio systems. Three months were spent visiting England, Canada and the U.S.A. in connection with these investigations.

Mr. O'Grady is a Member of the Institution of Engineers, Australia and is at present Chairman of the newly formed electrical branch of the Institution in South Australia. He is also a Senior Member and Vice Chairman of the Institution of Radio Engineers, Adelaide Division.

His interest in Post Office Communications was exemplified when early in 1957 he applied for and was appointed to the position of Assistant Director (Engineering) Adelaide. This appointment was enthusiastically received, particularly by his South Australian colleagues who well remembered his genial personality and approachable manner. The good wishes of all his colleagues go with him to the high office to which he has now been elevated. The Postal Electrical Society also extends its best wishes having in mind also the fact that Mr. O'Grady has always shown a keen interest in the Journal activities, and has in the past contributed valuable articles.

THE S.E.50 GROUP SELECTOR CIRCUIT

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INTRODUCTION

Following the decision to adopt the S.E.50 selector mechanism as the standard for step-by-step exchanges, the Australian Post Office Administration commenced a programme of research into group selector circuit design; this resulted in the evolution of the circuit shown in Fig. 1. The S.E.50 selector mechanism wired to this circuit will be used for all new exchanges and extensions to 2000-type exchanges as soon as sufficient quantities can be produced by the Australian companies, Standard Telephones and Cables Pty. Ltd., and Telephone & Electrical Industries. As the group selector is a basic building block in step-by-step exchanges, and is used in quite large quantities, every effort has been made to avoid the known weaknesses in existing circuits and to take advantage of the latest circuit techniques and new features included in the S.E.50 mechanism.

FUNCTIONS OF A GROUP SELECTOR

To start with, it would be as well to recall the functions of a group selector and the conditions under which it must operate. Briefly these are:—

(1) When the selector is looped it must—
(a) return an earth on the P wire to hold and guard the connection. In the case of first selectors, the guarding earth should be returned as quickly as possible.
(b) provide dial tone when used as a first selector.
(c) provide for a P.G. alarm to be given on first and incoming selectors when dialling is not commenced within six minutes.

(2) On receipt of an impulse train it must—
(a) step vertically under the control of the dialled impulses;
(b) cut into the banks on the level dialled, drive to and seize the first free outlet;
(c) provide for the simultaneous testing of two outlets at each rotary step.

(3) On finding a free outlet it must—
(a) switch the calling line to the outlet selected;
(b) maintain a holding earth on the P wire for sufficient time for an earth to be returned from the selector or repeater seized;
(c) remove all bridging equipment from the speaking path and disconnect the guarding earth when selection is completed.

(4) If all outlets are busy it must—
(a) transmit busy tone to the calling party;
(b) operate the overflow meter.

(5) At the end of the call it must—
(a) release when the earth is removed from the P wire;
(b) provide a guard against intrusion during release;
(c) provide an alarm should a mechanical fault prevent normal release.

NEW FEATURES OF THE NEW GROUP SELECTOR CIRCUIT

The basic requirement of the new selector is that it must be completely interchangeable with existing 2000-type selectors.

In addition to providing all the above facilities the new group selector circuit incorporates the following distinctive features:—

(1) **Step-Over-Open Trunk.** This facility, which is unique, allows the searching selector to pass over an outlet having an open circuit in the negative, positive or private wires. Each conductor is tested for continuity before switching takes place and, although earth testing is used where the free condition on the private is normally an

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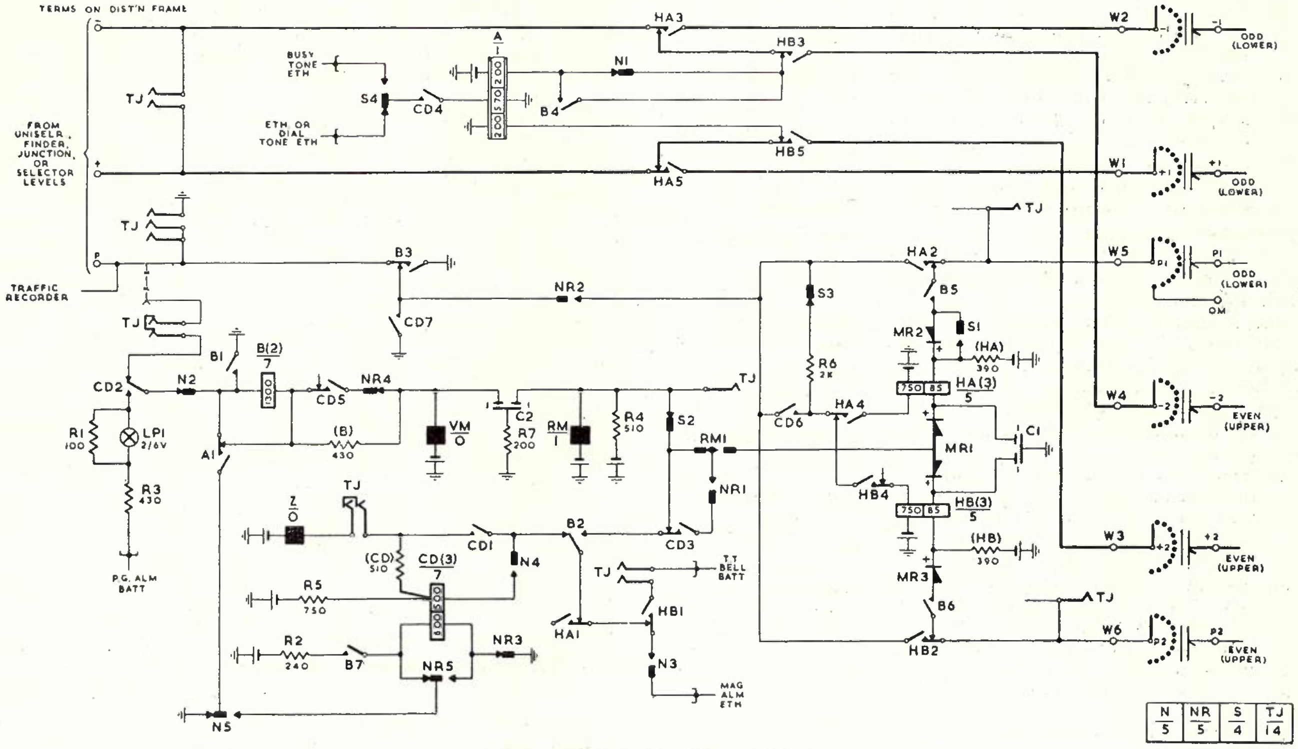

Fig. 1.—S.E.50 Group Selector Circuit.

open circuit, a similar condition due to a fault is recognised. Open circuit trunks have previously led to "drop outs" and "no progress" calls, but the step-over-open trunk feature virtually eliminates these troubles.

(2) **Fast Switching.** By using a single step cut through a fast connection to the next selector is obtained.

(3) **Magnet Alarms.** Both the rotary and release magnets are operated via the same magnet alarm circuit, which gives an alarm when a mechanical fault causes permanent energising of either of these magnets.

(4) **Low Holding Current.** As only one relay is held after cut through on a normal call, the current drain is very low compared with earlier circuits.

(5) **Reguard.** The reguard earth is applied by a relay springset instead of via N springs as in earlier circuits. Mechanically-operated springs tend to oscillate when the wiper carriage returns to normal and cause the reguard earth to flicker.

(6) **Pulse Operated Overflow Metering.** In earlier circuits, during periods of heavy traffic many overflow registrations were masked by continuous occupancy of the 11th step contacts. A pulse type overflow circuit has been incorporated giving a pulse of approximately 100 milliseconds' duration when the switch steps to the 11th contact.

(7) **Selector Pre-Busying.** With this facility the selector can be busied while the conversation is in progress and on completion of the conversion the selector is held busy and the test trunk bell is rung.

This feature eliminates the need for Test Set No. 26 and gives a quick and ready means of busying an engaged switch without affecting the release of the call or cutting into a conversation.

(8) **Alternative Testing.** By means of a simple wiring alteration, the selectors may be converted from earth testing to battery testing to suit special circumstances.

(9) **Back Busying.** A newly-designed auto-to-auto repeater incorporates the back-busying feature so that, if an incoming switch fails to release or is manually held off-normal, the repeater at the outgoing exchange will be automatically busied. This repeater requires special features in the incoming selector, and these have been incorporated in the new circuit.

(10) **Additional Features.** In addition to these main features, wiper-to-bank sparking has been reduced and sparking across the contacts of the switching relays is minimised by the use of low inductance circuits. The elimination of relays wound with fine wire and relays fitted with nickel iron and slugged cores will simplify manufacture.

DESIGN NOTES

Holding Systems

Switching systems can be classified by the holding arrangements employed. Generally, step-by-step systems can be classified as either forward or backward holding. Both methods possess certain advantages and disadvantages, and the following is a summary of the more important features:

(a) **Forward Holding:**

In this case transmission bridges and meter control circuits are fitted to first and incoming selectors. Other group selectors and final selectors are not equipped with transmission bridges. An example of this technique is the Siemens No. 16 system.

The advantages are:—

(i) A forwarding holding system is free from drop-out troubles. Faulty trunks or switches cause no-progress conditions, which are preferable from a traffic aspect. No-progress calls are easier to trace and faulty equipment can be localised more readily than with drop-out faults.

(ii) A metering battery is not required. Either 4th wire negative battery metering or increased current metering between first selectors and uniselectors can be used economically.

(iii) Outgoing junction repeaters are not required, but guarding relays on the P wire of outgoing junctions are necessary.

The disadvantages are:—

(i) A loss in standardisation results due to special circuits being required for first and incoming selectors to provide transmission bridges and metering facilities. Other group selector circuits can be of simpler design.

(ii) Loop dialling cannot be used between first and final selectors.

(iii) Impulses are repeated to subsequent switches by first and incoming selectors.
(iv) Testing cannot be carried out from the test desk on incoming "09" lines.
(v) Ring-back circuits (level 07) cannot be provided.
(vi) Tracing of malicious calls is made more difficult as switches cannot be held back from the final selectors.

(b) **Backward Holding:**
In this case final selectors and outgoing junction repeaters are equipped with transmission bridges and metering control circuits. The conventional pre-2000 and 2000 type equipment are examples using this principle.

The advantages are:—
(i) A uniform circuit can be used for all local and incoming group selectors.
(ii) The subscriber's loop is switched through to each successive switch in turn on a local call, thus avoiding impulse repetition and allowing loop dialling to be used at all stages.
(iii) Testing can be carried out from the test desk over normal traffic channels on incoming lines on the "09" level without the necessity for using the Test Distributor.
(iv) Use can be made of a "ring back" circuit (07).
(v) Tracing of malicious calls is facilitated as a call can be held from the final selectors back to the uniselector or incoming selector.

The disadvantages are:—
(i) Drop-outs and mis-routed calls may occur if open circuit negative, positive or private trunks are encountered.
(ii) A positive battery is necessary for metering unless a 4th wire is extended from the final selector or auto-auto repeater back to the uniselector.

The advantages offered by the backward holding step-by-step system outweigh those offered by a forward holding system. Furthermore, it is necessary to adhere to backward holding to meet the condition that the S.E.50 selector must be completely interchangeable with earlier pattern 2000-type switches.

Release Control

The release of a connection may be controlled in four different ways, each having its own particular advantages:—

(a) **Calling Party Release.** This has the advantage of vesting control of the connection with the originating subscriber who is paying for the call.

(b) **Called Party Release.** This system simplifies the tracing of annoyance calls.

(c) **First Party Release.** This system ensures that the equipment will be cleared as soon as possible after the end of a conversation.

(d) **Last Party Release.** This system guards against the connection being released prematurely by either subscriber placing or touching the switchhook inadvertently.

It was decided to adhere to standard A.P.O. practice in the design of the new selector. This employs calling party release used in conjunction with last party release final selectors.

Group Selector	2000 Type CE-65 Earlier Circuit	2000 Type CE-65 Present Circuit	2000 Type A.T.E. S210782 Mk. II	G.E.C. S9155 Similar to CE-65	Repeater Auto-Auto CE-59
"C" Release	220	220	120	180	
Search (10 steps)	310	235	245	270	
Switching Lower	50	50	60	50	
I Total	580	505	425	500	
Repeater					
"A" Operate					8.5
"B" Operate					13.5
"HA" Operate					40.0
II Total					62
I/C Grp. Selector					
"A" Operate	8				
"B" Operate	20				
"C" Operate	24				
Safety Margin	20				
III Total	72				
Total Switching Times (Full Search)	714	639	559	634	
% Susceptible to Overtaking					
Sub Dialling	15%	6.5%	2.5%	6.5%	
Operator Dialling	46%	24%	10%	24%	

Table I—Typical Switching Times (milliseconds)

Inter-Digital Pause

The interdigital pause, which is the time allowed between successive trains of digits transmitted from a telephone dial or key sender, is governed by the lost motion incorporated in the standard dial and the speed with which the operator can pull the dial off-normal between digits. Tests have shown that the minimum inter-digital pause which can be obtained from a dial when a series of "1's" are dialled as quickly as possible is 450 milliseconds.

The length of the inter-digital pause is important in the design of switching equipment, as group selectors must search, select a free outlet and seize the next switching unit in this time. The worst case is that of a call which is routed via an inter-exchange junction. Here the following times are required before the incoming selector is ready to select the next digit. (See Table 1.)

From the figures in Table 1 it is apparent that speed of search is an important factor as searching time occupies nearly half of the inter-digital period when full search to the 10th contacts is necessary.

Pre-2000 type selectors have a searching speed of 25 to 30 steps per second, which is the maximum which can be obtained with the particular type of interacted drive used. Early 2000-type selectors had a searching speed of 35 to 40 steps per second, this was reduced to 30 to 35 when the design of the rotary magnet was changed. More recently this speed has been increased to the original figure by the introduction of a modified rotary circuit. In an ideal circuit the speed of search would be the unrestricted speed of the mechanism which, by design, should be as high as possible consistent with the maintenance of adequate wiper to bank contact for testing purposes. In practice, the optimum speed is determined by—

(a) the most suitable adjustment range for the switch;
(b) the type of testing method employed;
(c) the type and effectiveness of the spark quench or shunt placed across the rotary magnet;
(d) the characteristics of the testing relays;
(e) the factor of safety required in testing.

It has been found that a speed of 35 to 40 steps per second offers the best compromise with the S.E.50 switch.

Testing Methods

Two testing systems are available which are commonly known as battery and earth testing. The term "battery testing" is applied to the testing method in which the searching selector tests for the presence of a negative battery potential on the free outlet. An earth potential or open circuit is indicative of the engaged condition. An "earth testing system" is one in which an earth potential, which indicates the engaged condition, prevents the testing relay from switching. The presence of battery potential, or an open circuit, on the P wire indicates a free outlet.

(a) **Battery Testing:** The advantage of the battery testing circuit is that the selector can only test in and switch to an outlet marked "free" by the presence of a negative potential applied through a resistance of appropriate value. Private contacts which are open circuit or connected to a negative battery through high resistance, for example selector-holding relays, are marked "busy". This arrangement is applicable to three-digit networks where the resistance of one holding relay would be on the P wire. In a six-digit 2000-type exchange, the joint resistance of the holding relays on the P wire is equivalent to 290 ohms at the instant the guarding earth is removed.

Dual switching can be eliminated with the battery testing system by designing the testing relays so that either two relays will not operate in parallel or two relays will not hold in parallel. Where multi-switching stages are involved using a continuous P wire, the difficulty arises of distinguishing between the normal free condition and the condition brought about by the paralleling of holding relays. The value of the battery limiting resistance which applies the free condition must be selected so that it is readily distinguishable from any other condition on the P wire. The pick-up resistance would need to be of the order of approximately 50 ohms to satisfy this condition and, to ensure immunity from parallel operation of the two testing relays, the ratio of relay resistance to pick-up resistance should not be less than one to five, and preferably should be one to ten in order to achieve sufficient margin. The marginal hold method, which is preferable to the marginal operation, is not suitable where a high resistance holding circuit on a common multi-stage private wire is used.

With battery testing no release unguard period followed by a reguard earth to cover the release time of the selector is necessary. The removal of the holding earth from the P wire initiates the release of the switch train, but each selector does not reconnect the "test in" battery to its P wire until it is restored to normal.

As momentary opens in the P wire, due to wiper bounce or overshoot, do not affect a battery-testing selector, a fast rotary search can be used in conjunction with high-speed relays.

To realise the foregoing advantages, a circuit similar to Fig. 2 would be required, which demands the use of a test relay and a relief switching relay. In this circuit the test relay is of the high-speed type and is arranged to work on the marginal hold principle. Compared with earth testing, battery testing involves higher capital expenditure and, because of the close adjustment required to the test relay, the maintenance cost could be higher. Because of these

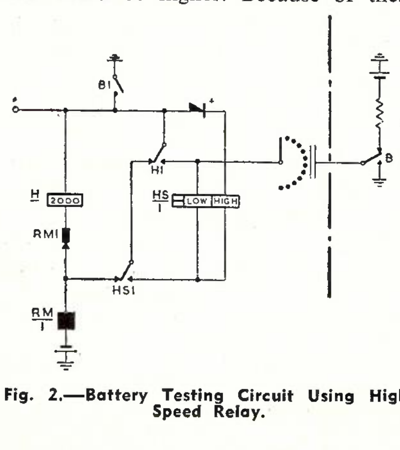

Fig. 2.—Battery Testing Circuit Using High-Speed Relay.

considerations, battery testing is generally used only if equipment is called upon to perform a large number of operations within the busy hour, where holding times are short, where lost calls due to unguard on relay testing would be excessive and where the P wire is used only between one switching stage and the next.

Battery testing circuits have the following disadvantages:—

(i) A battery testing selector when "testing in" will hold some or all of a releasing selector train due to the existence of the earth potential behind the testing relay.

(ii) Due to the presence of this earth potential, it is impossible to prevent the selector from switching into a releasing selector train because of the relatively low parallel resistances of all switching relays in systems using a common multi-stage P wire.

(iii) To ensure an adequate margin of safety against dual switching, it is usual to provide a very low test in battery resistance. This introduced fire risk and difficulties due to the inadvertent busying by applying a parallel connection on a working outlet.

(iv) The testing relay must be very lightly loaded to ensure quick operation. This means that either a lightly loaded 3000-type relay or a high speed relay must be used with a parallel relay.

(v) Any high resistance on the P wire during testing can make the switch pass idle trunks. However, this defect is probably preferable to the corresponding defect in an earth testing selector where a similar condition causes the selector to test in on a busy outlet.

(b) **Earth Testing:** Earth testing offers a convenient and economical testing method for use with switches having speeds of up to 40 steps per second. Using the release action of a heavily-loaded nickel iron cored relay, response times of 3 to 4 milliseconds can be obtained to give high search speeds. This does not offer any particular advantage as switches fitted with non-bridging wipers have momentary opens in the P wire when the wipers pass between the bank contacts approaching the response time of the testing relay.

Earth testing has the advantage that searching selectors will not hold releasing switch trains when the test relay is connected to a P wire from which other switches are releasing. Also, the fire risk associated with battery testing is eliminated.

The main disadvantages of earth testing are:—

(i) With early earth testing circuits, private wires which are open circuit due to a fault condition are marked "free", and "drop-out" will result if the switch "tests-in". This difficulty has been overcome by the inclusion of the "step-over-open-circuit" feature.

(ii) Earth testing selectors are inherently more susceptible to dual switching than battery testing selectors but, in service, the possibility can be made very low as the response time of the testing relays is only 6 to 8 milliseconds.

(iii) The P wire is unguarded during the release "blink" necessary to restore the holding relays at the conclusion of a call.

(iv) High resistance, due to poor wiper-to-bank contact on the P wire during testing or wiper overshoot, could cause the switches to "test in" to a busy outlet.

(v) A delay equivalent to the release or operate time of the test relay occurs between the seizing of an outlet and the application of the busying earth. This results in a period of unguard. The unguard periods produced by this condition, and also by condition (iii), can cause other switches to test in.

With the step-over-open-trunk facility, earth testing offers a very practical test circuit for bimotional switches and produces very little complication when working with earlier type equipment.

Earth Testing Methods

(a) **Time-on-Contact Testing:** As the name implies, time-on-contact testing exposes the testing relay to the bank contact under test for the full period that the P wiper is resting on the contact. With the switch stepping at 34 steps per second, the time on each contact may amount to 27 of the 30 milliseconds taken for each step. The other three milliseconds are taken up in moving the wiper from one contact to the next.

This would seem to be the most logical testing method to adopt as it gives the maximum testing time on each contact, and a comparatively simple relay design could be used. However, tests have shown that circuits of this type are prone to stop-on-busy troubles if the rotary magnet receives an additional pulse after the test relay has commenced to operate. This can be caused by:—

(i) If a high-resistance wiper-to-bank contact is encountered the test relay may receive barely enough current to operate. This causes the relay to operate slowly. If the relay is insufficiently fluxed when the magnet re-operates for the next rotary step, it will not release in the 2 to 3 millisecond interruption as the wiper passes from one bank contact to the next, but will lock. If the next outlet happens to be engaged, stop-on-busy will result.

(ii) It is possible for the test relay to operate after the rotary magnet has been partially energised if the outlet becomes free for at least the pulse operate time of the relay. Sequential adjustment of the testing relay springs controlling the rotary magnet and locking circuits will not overcome this difficulty.

(b) **Toggle-Open-Time Testing:** Toggle-open-time testing presents the testing relays to each outlet for the time during which the rotary magnet circuit is opened by the interrupter springs. This method of testing obviates the stop-on-busy troubles due to the causes mentioned above.

When stepping at 38 steps per second, the magnet interrupter springs on an S.E.50 selector are open for 11 milliseconds and closed for 16.3 milliseconds, therefore the testing relay, which has a response time of 5 to 6 milliseconds, must function within the 11 millisecond period. When the toggle recloses, the rotary magnet requires a pulse from 6 to 8 milliseconds to just move the rotary armature. This introduces a safety period between the breaking of the testing circuit and the operation of the rotary armature to ensure that, once the armature commences to move, there is no possibility of the testing relay responding until the toggle re-opens.

(c) **Relay Release Testing:** The relay release method is used in the 2000 type group selector circuits. In this system the test relay is held operated on one winding while the wipers are stepping between outlets; when the next contact is reached the holding circuit is broken and the test winding is connected to the outlet during the testing time. If the trunk is busy the relay will remain operated and the switch continues to step, but if the trunk is free the relay releases, stops the drive and operates a controlling relay (C or CD) which, in turn, operates the test relay.

One advantage of this method is that, by suitable circuitry, a 3000 type test relay can be made to respond within three milliseconds. It has the disadvantage, however, that a two-stage cut-through is required, which increases the switching time and introduces extra series contacts into the speech path. Another disadvantage is that two relays per switch are held operated during each call.

(d) **Relay Operate Testing:** The relay operate method is used extensively in battery testing systems, and also in some uniselector circuits such as the subscriber's line circuit and junction hunters. This method has been used in the new circuit as it gives a single stage cut-through and reduces the holding current for each switch. Shunting the rotary magnet by a rectifier spark quench and a 500-ohm non-inductive resistance ensures that the time the toggle remains open is sufficient to allow a margin of safety on the response times of the testing relays.

Stop-on-Busy and Passing-Idle-Trunks

Stop-on-busy faults can occur in 2000 type exchanges because of—

(a) Incorrect adjustment of the HA and HB relays.
(b) Faulty setting of wipers on the bank contacts.
(c) Faulty wiper-to-bank alignment.
(d) Faulty interrupter spring adjustment.
(e) Excessive rotary play.
(f) High resistance between wiper and bank contacts.
(g) Testing-in during metering.
(h) Testing-in during release unguard.
(j) Faulty adjustment of NR and S springs.

With the exception of (g) and (h), all the above faults introduce momentary opens in the testing circuit of sufficient duration to allow the testing relay to release. A sharp increase in stop-on-busy faults was first noticed when a redesigned rotary magnet with a greater number of turns was fitted to the 2000 type switch. The higher back E.M.F. resulting from the increased inductance accelerated the release of the testing relays to a point where they were forced out in approximately three milliseconds. This short release time gave very little margin for the circuit to discriminate between free outlets and momentary open circuits caused by incorrect adjustments.

In order to allow for the momentary open circuits on the P wire as the switch loses its adjustment, the testing relay should not respond in less than five milliseconds. The pulse-operate-time of the relay should be approximately 50-60% of the testing time available on each contact which, with toggle-open-time testing, would amount to 50-60% of the total toggle open time. Relays having a longer response time than this would give improved stop-on-busy immunity but would be more likely to pass idle trunks.

In a circuit using "toggle-open-time" and "relay operate" testing, the closer the pulse-operate time of the testing relay approaches the toggle-open-time the greater is the immunity from stop-on-busy. On the other hand, as the pulse-operate-time approaches the toggle-open-time the selector becomes more likely to pass idle trunks. A compromise slightly favouring immunity from stop-on-busy is the only solution.

Drop-out Faults

In a backward holding system a considerable number of no-progress and misrouted calls are caused by drop-outs. A drop-out occurs when the holding earth is not extended back from a switch when it is seized. After the slow release period of the B relay the local holding earth is removed and the switch restores; any other switches held in the train will also release. If the subscriber continues to dial the remainder of his incomplete number; he will either connect to a wrong number if the remaining digits are a directory number or be switched to another route and make no further progress. The conditions responsible for drop-outs are:—

(a) Incorrect restoration of a bimotional switch. If the carriage does not restore properly to normal, a switch wired to the CE.65 circuit will cause the N4 spring to break from the N3 but not make on the N5 to close the B relay operate circuit.
(b) Badly adjusted wipers or worn wiper springs.
(c) Disconnected wiper cords.
(d) Faulty contact between MR8 and 9.
(e) Open circuit A relay in the selector or repeater.
(f) A riding A relay armature in a selector or repeater.
(g) Testing-in during release.
(h) Open circuit trunking.
(j) Dirty banks or faulty wiper-to-bank contact.
(k) U jacks 9 and 11 not contacting when a switch or repeater is withdrawn from the shelf.
(l) Open circuit 1500 ohm winding on HA or HB relay.
(m) Loose battery fuse in shelf supply.

The new circuit is substantially free from drop-out trouble because of the feature which steps the switch over open circuits.

Unguard Periods

Switch unguard periods must be kept to a minimum to reduce the risk of other switches testing-in. Unguards which occur during the initial test-in and also on release, can cause stop-on-busy, wrong numbers, no progress, drop-outs and holding of unguarded incoming junctions.

The release of all group selectors in a chain of switches commences simultaneously and is dependent on the momentary open (blink) before the reguard function of a final selector, a junction repeater, a group selector on the 11th step or a group selector looped under the no-progress condition.

The potential existing on the private during the blink period varies with the type and number of group selectors in the train. The K relay in the line circuit stores a greater amount of electrical energy than the HA and HB relays in the selectors, so that on release the K relay will be delayed while the HA or HB relays are accelerated. As each HA or HB relay releases, the private will be broken into individual switch privates.

With relay release testing used in 2000 type selectors, each switch will remain unguarded for the duration of the release time of relay C, which is approximately 25 milliseconds. Selectors wired to CE.65, Sheets 1 and 3, and SW.9155 connect battery via the HA relay to the incoming P wire during this unguard period.

When relay C releases it removes the battery potential and earths from the private, thus battery is connected to the incoming P wire for the full duration of the blink, that is, for the release times of the HA or HB relays plus the C relay, which is approximately 40 milliseconds.

In the new circuit earth is extended to seize the P wire of the selected trunk within 8 milliseconds, which is the maximum operate time for the HA and HB relays. On release the P wire is reguarded when CD reoperates, which is approximately 25 milliseconds after the commencement of release open circuit. This represents the minimum release unguard that a CE.65 selector will respond to, and thus the shortest possible unguard has been achieved.

DESCRIPTION OF THE OPERATION OF THE NEW SELECTOR CIRCUIT

Relay Functions:

Relay A—Impulsing, battery and tone feeds.

Relay B—Guarding and holding.

Relay CD—Completion of impulse train, rotary drive control, step-off-open-trunk control, and release reguard.

Relay HA and HB — Testing, drive tripping and switching.

Circuit Operation:

The following is a detailed description of the circuit operation.

(i) **Seizure of Selector:** When the selector is seized, relay A operates and, in turn, operates relay B (A1, N2) which, in turn, operates relay CD (B7, NR3). The fast guard earth is applied to the incoming private circuit when the selector is preceded by a uniselector (U9-8 strapped, TJ14-13, CD2, N2, A1, N5). On first and incoming selectors, the operation of CD lights the supervisory lamp (CD2, N2, B1), which operates via the PG alarm relay, and provides for the PG alarm.

(ii) **Dialling:** When dialling commences, the vertical magnet is operated under the control of relay A (NR4, CD5, A1, B1). On the first vertical step the N springs operate, extinguishing the supervisory lamp and preparing the release circuit of relay CD. Relay B holds during dialling by virtue of the short-circuit applied by A1 to relay B during the break period of each impulse, and relay CD holds because the 500 ohm winding is shunted by 510 ohms, and during the make period of each impulse the 600 ohm winding is short-circuited (NR3 to earth, and NR5, N5 A1, B1 to earth).

(iii) **Cut-in and Search:** At the conclusion of impulsing, relay A remains operated, and relay CD releases in 90-135 milliseconds. The rotary magnet operates (S2, CD3, B2, HA1, HB1, N3, magnet alarm earth) moving the wipers to the first row of bank contacts. The earth previously short-circuiting relay CD is transferred by NR5 to re-operate CD, which transfers the rotary magnet operating earth to the test relays (via NR1 and RM1). RM1 being operated during the period in which the toggle is operated, the 85 ohm windings of the HA and HB relays are thus presented to the private to be tested. An earthed private will prevent the corresponding relay from operating by shunting the operating battery, but if the private is free the relay will operate, HA taking preference over HB in the subsequent locking if both relays operate. The negative, positive and private wires are extended and relay A releases, followed by relays CD and B. Relay HA (or HB) holds via 2000 ohms during the conversation period. All other relays are released so that the current drain, and the surge voltage which occurs on the private wire on release, are both reduced. After cut-through to the next selector, relay B, on releasing, connects the forward private through to the incoming side (via B3).

(iv) **Step-Off Open Trunk:** If the seized selector fails to return an earth on the P wire (i.e. if the positive, negative or private is o/c) the switching relay is released at CD7 when relay CD releases (approximately 40-80 milliseconds after cut through). The rotary maget is then re-energised by HA1 (or HB1) and the wipers are moved to the next pair of outlets. Relay A will be reoperated followed by relay CD, which at CD3 transfers the magnet operate circuit to the test relays during the toggle operated time, i.e., the rotary search conditions are re-established, and the search continues until a free outlet is found. It is essential for relay CD to release in 40-80 milliseconds to ensure satisfactory operation of the "step-off-open-trunk" feature.

(v) **All Outlets Busy:** If no outlet is available, the selector steps to the 11th row and busy tone is fed to the calling subscriber and an earth pulse of approximately 100 milliseconds operates the overflow meter. Pulse registration of the overflow meter is achieved by the re-application of the switching relay test circuit to the private wire.
In the general case relay HA operates and holds via CD6 and CD7, and releases relay A (HA3 and HA5). Relay CD releases in 40-80 milliseconds, followed by relay HA Relay A re-operates, followed by CD, so that under the all-outlets-busy condition, relays A, B. and CD are held under the control of the calling subscriber. In the case of an earth being present on the 11th row contact (as may occur if 2000 type group selectors are in use in the same rank) relay HA cannot operate, but relay HB operates and a similar sequence of relay operations occurs leaving relays A, B and CD operated under the control of the calling subscriber. No overflow meter pulse is given, but it would in any case be ineffective in these circumstances as the overflow meter is already held operated. To prevent damage to rectifier MR2, which would otherwise have approximately 100 milliamps through it under this condition, it is short-circuited by S1.

(vi) **Normal Release:** Release is initiated by the removal of the holding earth from the P wire on the seized outlet. Relay HA (or HB) releases and the speech path is disconnected. Relay CD is operated via its 500 ohm winding (N4, B2, HA1, HB1, N3 magnet alarm earth) and CD7 provides the reguard earth on the incoming private wire until the switch returns to normal, when N3 and N4 release relay CD. CD1 operates the release magnet, and the negative line is kept open-circuited by N1 until the selector restores. This prevents premature operation of relay A, and provides junction guard at the originating exchange if repeaters to drawing CE.850 are used.

(vii) **Release from all Outlets Busy:** Release is initiated by the calling subscriber clearing and releasing relay A. Relays CD and B release and, on the release of B2, relay CD reoperates providing the release reguard on the incoming P wire.

(viii) **Prebusying:** When the selector is required for maintenance reasons, but a call is in progress, the release link may be removed from test jacks 11 and 12 and replaced in test jacks 10 and 11. When the release condition is applied, relay CD is operated but the magnet alarm earth is extended via CD1 and test jacks 10 and 11 to the TT bell (which immediately operates) and not to the release magnet. The release reguard applied by CD7 is maintained until the selector is taken out of service or the release link restored to normal, but all other selectors in use on the call will have released during the release unguard period, i.e., from removal of earth on P wire until HA (or HB) has released and CD has re-operated. After 9 seconds the release alarm also operates, ensuring prompt attention—this is important when the selector concerned is connected to an incoming junction circuit.

Design Features

(i) **Relay A:** The 570 ohm winding is at all times connected either to a low impedance tone source, or directly to earth. This minimises cross talk, and reduces to safe limits the surge voltage which can otherwise be of the order of 1400 volts under short-line unquenched dialling conditions.

(ii) **Relay B:** This relay is designed to hold over dialling at 12 impulses per second on a 1200 ohm line with the dial make ratio as low as 20%, all of which, of course, are well beyond normal limits. The release time must be at least 130 milliseconds (relay short-circuited).

(iii) **Relay CD:** This relay operates normally on the 600 ohm winding, which is designed to have a short-time constant to ensure that the relay operates quickly when the selector is seized, and also to ensure that there is a maximum growth of magnetic flux in the short time available between the first rotary step and cut through on one of the first outlets, so that the relay release time will not be too short. When cutting through, an earth is fed forward during the release of relay A and the subsequent release of relay CD, and under this worst condition (i.e., cut-through on one of the first two outlets) this period may be as low as 50 milliseconds. An adequate safety margin exists, however, as the maximum time for the operation of relays A and B in the selector ahead is 35 milliseconds.
At the end of the impulse train, the slow release period is obtained by short-circuiting the 600 ohm winding and shunting the 500 ohm winding with 510 ohms. After the first operation of the rotary magnet, the shorter release time (40 to 80 milliseconds) necessary for the step-off-open trunk feature is given by shunting the 500 ohm winding only.
When releasing from the 11th step, relay CD releases and then

immediately reoperates. To ensure an adequate release unguard period, the 500 ohm winding is reverse-connected compared with the 600 ohm winding, so that the magnetic flux must collapse to zero and then build up in the opposite direction.

The 510 ohm shunt across the 500 ohm winding is only connected after its operation so that the speed of operation, both initially and during the release of the selector, is not lengthened by a permanently connected shunt.

On the return to normal at the end of the release of the selector, the shunt is disconnected by N springs, and the relay releases quickly although its release period is sufficient to cover the time of wiper carriage bounce and N spring vibration. It is important that the relay should release quickly in order to prevent an operation of the vertical magnet, while the relay A contacts are bunched if the selector has been seized during the release unguard.

The 750 ohm resistor in series with the 500 ohm winding of the relay is required so that a faulty (non-releasing) switch may be located by removing the test link from T11-T12, thus reducing the current drain via the shelf alarm relay (RA) sufficiently for it to release; on the other hand, it must be low enough for relay CD to operate reliably under the prebusying condition.

(iv) **Relays HA and HB:** These relays are designed to operate in 8 to 9 milliseconds under static circuit conditions. Under dynamic test conditions the HA and HB relays should not operate with 200 ohms on either or both of the first two outlets, but the particular relay concerned should operate on any subsequent outlet on which 700 ohms is present. In practice a busy resistance in excess of 100 ohms is not encountered, and, in fact, a subscriber's uniselector (which has a similar test circuit) will stop on a busy outlet quite readily if the busying resistance is of the order of 100 ohms.

The springset loading of each of these relays consists of five "K" units. A "K" springset gives a lighter loading than either a "B" or a "C" unit, although it has a slightly heavier loading than an "M" unit. This spring build-up, together with the short time constant of the operating winding, ensures a high speed of operation.

After cut-through, an additional resistance of 2000 ohms is inserted in series with the 765 ohms winding to reduce the holding current to 19 milliamperes. This has the following effects:—

(a) Overall exchange current drain is correspondingly reduced.
(b) At the end of the call a fast release is obtained—an open circuit of 5 to 6 milliseconds is sufficient to release the holding relay.
(c) The surge of voltage on the private wire is reduced
(d) The coupling between the holding relays of various selectors is reduced —the presence of a single slow release or shunted relay on the P wire affects the release time of all other holding relays.

The operation of relays HA and HB as a means of arresting the rotary search is used in preference to the release of these relays (as used in the 2000 type circuit) because a single stage cut-through is possible, and only one relay is held for the duration of the call. Better immunity from stop-on-busy is achieved also because these relays have a slightly longer response time than the release time in the conventional 2000 type or equivalent circuit.

(v) **Capacitor C1:** The adjustment of the drive tripping and the holding contacts is not critical because of the provision of the capacitor C1. This capacitor is discharged when the rotary interrupter contacts are operated, and the HA and HB relays are testing their respective outlets. When a free outlet is encountered the effective testing time is extended slightly while the capacitor charges via the relay operate windings after the toggle has restored or HA1 (HB1) has opened.

(vi) **Rectifiers:** The 1/6A rectifiers MR2 and MR3 prevent the earth potential behind the test winding of HA (HB) from holding a releasing switch train if the selector should be testing in at the beginning of the release unguard period.

The 2P/24A rectifier assembly, MR1, prevents operation of the test relay to positive battery if testing occurs whilst a meter pulse is being applied on the P of the tested outlet. In addition, it acts as a non-linear resistance which considerably increases the difference between private resistances giving operation and non-operation of the test relay. Rectifier elements 1/12A have insufficient non linearity in the required range to affect the range of non-operate to operate P resistance.

(vii) **Rotary Magnet Shunt:** The provision of the 510 ohm shunt in parallel with the rotary magnet decreases the speed of rotary search slightly to ensure that the rotary detent functions correctly; at higher rotary speed it does not always latch into the rotary ratchet satisfactorily.

(viii) **Relay Coils:** Relays A, HA and HB must be fitted with S.R.B.P. front cheeks, but relays B and CD may be fitted with copper front cheeks.

(ix) **Rotary Off-Normal Contact in the Private Circuit:** With the selector busied, the NR make contact in the private circuit prevents the HA (or HB) locking to the private wire when the maintenance technician is adjusting this relay.

QUALITATIVE MAINTENANCE

*H. T. WRIGHT, A.M.I.E.Aust.**

Introduction: Ever since the invention of mechanical switching equipment, Preventive Maintenance has been generally practised throughout the telephone world, the aim being to prevent the occurrence of faults by overhauling the equipment at regular intervals. This Preventive Maintenance philosophy or procedure developed into a system of routine tests and examinations at predetermined intervals. Another system, known as Corrective Maintenance, was practised to a limited extent in some countries, the procedure being to attend only to equipment as faults developed. In the last seven or eight years the new philosophy of Qualitative Maintenance has been developed, particularly in the United States of America. Qualitative Maintenance procedure, as introduced in America, does away with all regular routine maintenance and testing, except lubrication, wiper adjustment and bank cleaning, and relies on complaints, indicators and statistics to indicate where attention is necessary.

The exponents of Qualitative Maintenance realise that perfect service cannot be given and are prepared to accept a lower grade than perfect service, although this outlook does not imply that Qualitative Maintenance will result in a lower grade of service than has been given in the past under Preventive Maintenance. Indeed, evidence suggests that an improved standard of service may be expected under Qualitative Maintenance. However, it is necessary to take into consideration that the exchange equipment faults are only a percentage of the total faults which are comprised of exchange, line and substation faults. Subscribers are not concerned with where the faults on their services occur but they are concerned with the overall grade of service. This should also be the Engineer's concern. It is obviously uneconomic to spend large sums of money in attempting to obtain 100% performance from automatic switching equipment if we cannot obtain 100% performance from line plant and substation equipment.

It is probable that the Preventive Maintenance procedure was originally developed by automatic equipment specialists who did not take a broad enough service view and were, no doubt, extremely interested in the performance and development of the equipment in their charge. As will be shown later, Preventive Maintenance is not only uneconomic but can actually cause harm to the switches and, consequently, more faults and a lower quality of service.

Qualitative Maintenance: Qualitative Maintenance procedure involves a much more positive and dynamic approach than either Preventive or Corrective Maintenance. In Preventive Maintenance, endeavours are made to prevent faults by the carrying out of regular routine overhauls, while in Corrective Maintenance equipment is only attended to as it becomes faulty. In Qualitative Maintenance, equipment performance is carefully watched by means of certain indicators, such as complaint reports, traffic observations and statistics, and action is taken to overhaul equipment where and when necessary to enable a satisfactory grade of service to be maintained. More specifically, these indicators are:—

Subscribers' complaints;
Fault analysis;
Service observations;
Artificial traffic machine records;
Visual and aural observations of equipment performance by the exchange staff.

Any or all of these indicators may show up weaknesses, and the remedy may be examinations of certain sections of equipment, tests of equipment or alterations to circuits. Certain regular routines, such as lubrication, wiper adjustments, bank cleaning and alarm testing are retained in the Qualitative Maintenance procedure. In Amercia, routine testing has been abandoned but here in Australia we are not yet prepared to abandon regular testing, though it is proposed to reduce the frequency of tests and it is possible that the frequency of tests will be reduced still further in the future.

In considering the introduction of Qualitative Maintenance in Australia, it is necessary to consider the differences that exist between American and Australian conditions, and from the following table comparisons can readily be made of the two cases:—

America	Australia
Pre-2000 type equipment (still being manufactured)	Pre-2000 type equipment
Crossbar equipment	2000 type equipment
200-point Line Finders	Uniselectors
Generally no meters	Meters
Limit of one repeater in six-figure systems	Five repeaters in six-figure systems
Large exchanges up to 80,000 lines	Exchanges usually limited to 10,000 lines
No automatic routiners	Automatic routiners
Straight trunking	Discriminating selector repeaters
Single-contact relay springs in a large quantity of pre-2000 type equipment	Mostly double contact relay springs
Circuits generally simpler than Australian	Circuits more complex than American

Consideration of these conditions led to the decision to retain regular testing in Australia; there was also the fact that Qualitative Maintenance procedures had not yet been applied to 2000-type equipment. While there was no reason to suppose that 2000-type equipment could not be maintained by Qualitative Maintenance methods, there did exist a certain element of doubt. When Qualitative Maintenance was first being introduced by the Australian Post Office, an amended fault-recording procedure was under consideration and it was adapted in several ways to meet the requirements of Qualitative Maintenance. In addition, a system of individual switch records was introduced; these records have proved to be most useful and have shown that more than 50% of the total switch faults occur on less than 15% of the switches. By concentrating on this 15% of switches, it has been possible to effect considerable improvement in the plant performance at comparatively small cost.

Qualitative Maintenance has been on trial in 10 exchanges in Sydney and 12 exchanges in Melbourne for the past two years and in a number of exchanges in the other capital cities for approximately 12 months (as at July 1957). The results to date have been very satisfactory. In nearly every exchange the fault incidence has been reduced and an improved grade of service achieved; in the few cases where the fault incidence increased; investigation disclosed a satisfactory explanation in each case. It has now been decided to introduce the Qualitative Maintenance procedure in all Australian automatic exchanges. The results obtained will be continually analysed, and no doubt, as a result, testing frequencies will be further reduced.

It is of interest to consider the three main factors in the maintenance of an automatic exchange and to offer comments thereon. The factors are:—

1. The electrical and mechanical design of the system.
2. The qualifications of the staff.
3. The housing of the equipment.

1. **The Electrical and Mechanical Design of the System:** The circuits and mechanical features of our existing pre-2000 and 2000 type switches are matters which we can do comparatively little about, the problem is to get the best performance out of the switches. There is no doubt that the switches we have will give sterling service if they are properly adjusted, lubricated, given good working conditions, left alone whilst they are working satisfactorily, and there is

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no evidence of defects likely to bring about faults. Tests made by a leading overseas telephone company are of very great interest. They took the form of life tests on ten 2000-type switches. The tests showed that the fault incidence was higher if the switches were routine examined at regular intervals than it was when they were left alone, except for lubrication. Further tests showed that skilled adjusters spent considerable time readjusting switches they had previously adjusted if the switches were given to them a second time without them knowing they were the same switches. In all these tests highly-skilled adjusters were used.

The conclusions reached by the company engineers as a result of these tests and careful examination of the switches and switch parts were that best service will be obtained if:—

(i) A switch is checked for adjustment before it is brought into service.

(ii) It is lubricated annually.

(iii) The banks are cleaned as infrequently as possible in order to reduce disturbance to the switch.

(iv) The switch is subjected to frequent functional tests to ensure that it is giving good service to the subscribers.

The explanation put forward to account for the results obtained is as follows:—

"A selector is a collection of moving parts all operating in association and sliding and impacting upon each other. During the first year the parts are establishing and consolidating their relations with each other. Slight burrs are being worn away, sharp edges rounded and normal positions are being taken up. If the switches are adjusted every year the relations which the parts have been establishing with each other are altered. The alterations may be within the allowable tolerances of adjustment but the selector has to set about readjusting itself all over again, since the angles of thrust have been changed, together with points of impact and lengths of movement. No sooner has the switch settled down again than the process is repeated. This happens each year, and it is thought that it is this constant alteration of the stresses, strains and movements in the selector which promotes faults and causes parts to break."

It is well known that accelerated life tests can be misleading because they never quite simulate actual working conditions. In the case of these tests, operating signals were perfect and not distorted although passed through as many as five repeaters. Ageing of materials did not occur, probably because the action of dust and moisture could not be reproduced exactly. However, the tests do indicate that 2000-type mechanisms will operate well in good conditions if left substantially alone, except for lubrication.

2. **Staff:** There is an insufficiently high percentage of adequately trained exchange maintenance staff in Australia, and there is only one complete cure for this—more training. The Supervising Technicians in charge of our exchanges are well trained and highly skilled technicians, but there is a need for management training if the full benefits of Qualitative Maintenance are to be achieved. The selection of Supervising Technicians will become increasingly important because, with Qualitative Maintenance, leadership, initiative and judgement are all necessary.

3. **Accommodation:** Although good accommodation is important in any form of maintenance of automatic switching equipment, it becomes increasingly important with Qualitative Maintenance. It will be remembered that one of the aims in Qualitative Maintenance is to interfere as little as possible with equipment which is functioning correctly. Switches are removed from shelves only when necessary attention cannot be given with the switch in situ. It therefore becomes increasingly important to house switching equipment in dust-free accommodation so that contact troubles and mechanical wear will be minimised.

Telephone exchange buildings now being put into use in Australia are generally of good standard and quality but do not always meet the requirements of our new conception of maintenance in several ways, namely:—

(i) Mechanical switching equipment is not isolated from the parts of the exchange, such as Test Desk, Main Distributing Frame, Adjustment Benches and Supervising Technician's Office, in which the greatest staff movement is occurring. The equipment aisles are quite often used as passageways between the above points, the main entrance and such other rooms as battery and power, and air-conditioning rooms.

(ii) Doors in the switch rooms do not always fit well, and gaps of ¾" between the floor and bottom of doors are not uncommon.

(iii) Large windows in some air-conditioned switch rooms can be opened and are not provided with locks.

(iv) "Stairway" cable entrances often lead to street manholes via tunnels, thus raising the possibility of dust entering the switchroom more readily via the underground duct system.

(v) Air-cleaning plant now being installed is generally provided with self-cleaning viscous oil filters which are not highly efficient, and consideration may be given to the use of other types, such as fabric filters. These are more expensive to install and maintain than oil type filters, but their greater efficiency could justify the higher expenditure.

(vi) Air intakes are not always placed in the best position to ensure that the cleanest possible air is taken into air-cleaning equipment.

The most important of these matters is the fundamental one of the layout of the exchange building floor plan. It is certain that a plan can be prepared to meet all the requirements of good maintenance at very little extra cost, and attention is being given to this question. The other items mentioned are comparatively simple matters of design and workmanship, and should be easily solved in the future.

A more realistic approach in the provision of air-conditioning plant seems necessary. In each case a "dust count" and "dust analysis" could be made at each new exchange site and the results of these tests used to determine the installation or otherwise of air-cleaning plant of a particular type, while meteorological records could be used to determine the need and the types of equipment for air heating and refrigeration. This reference to air-conditioning plant does not take into account the staff comfort requirements but only refers to the equipment maintenance requirements. It appears that if the switching equipment were isolated it would be possible to reduce the amount of space that is necessary to fully air-condition in an exchange, thus achieving operating economies in the air-conditioning plant.

When we provide air-cleaning plant at considerable cost, it follows that we must ensure that dust and dirt are not brought into the equipment room on the clothes and shoes of technicians (exchange and substation), linemen and visitors to the exchange. It is therefore most important that our future exchange buildings are designed so that the equipment room is not used as a passageway any more than is absolutely necessary. In some overseas countries, great care is taken in this respect, and in some cases staff who have to enter the equipment room are provided with dust coats made of lint-free material, and rubber shoes. Clean, lint-free rags for cleaning switches are also provided.

Conclusion: Given good staff co-operation, Qualitative Maintenance will be successful because it is based on common-sense principles and eliminates unnecessary work. The type of work eliminated is the regular routine overhaul of equipment; this repetitive work can be very monotonous and soul-destroying, particularly to the skilled technician. The success of the scheme depends, to a great extent, on the local decisions which will need to be taken from time to time by the responsible men on the spot, namely, the Supervising Technicians. This will, in turn, no doubt tend to enhance their status and may lead to their being regarded as exchange area managers, more directly conscious of the grade of service given to subscribers in their area.

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APPLICATION OF TYPE N1 CARRIER SYSTEMS IN AUSTRALIA

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INTRODUCTION

After the second World War the demand for additional trunk circuits grew rapidly in Australia. This growth occurred particularly on a number of existing short cable routes up to approximately 40 miles in length, which had been provided originally for voice frequency operation. To meet these requirements some use was made of standard type K twelve-channel carrier equipment arranged for working in single cables with signalling facilities provided by either 2 V.F. equipment or by separate path signalling systems. The latter systems provided 12 signalling channels on a single voice frequency channel.

This provision was expensive and bulky and was regarded as an expedient pending the availability of suitable carrier systems with cheap signalling facilities, which would be economical for long term use on existing subscribers and minor trunk cables. The Department consequently was very interested in the development of the Type N1 system by the Bell System during 1950. At that time this system was relatively cheap compared with other types of systems available. Orders were placed during 1952 for 20 systems for use in the minor trunk network centred on Sydney, New South Wales, and the first 5 of these systems were placed in service between Sydney and Avalon during October, 1953.

PRESENT INSTALLATIONS

The general geographical locations for which Type N1 equipment was ordered are shown in Fig. 1. The Avalon route passes through the popular beaches north of Sydney and carries heavy residential and holiday traffic. An indication of the growth in the area is given by the fact that one of the first multi-metering schemes in Australia has been installed at Avalon. The Windsor, Penrith and Liverpool routes are west of the city and cater for developing industries. Details of the equipment installed on these routes are given in Fig. 2. A description of the Type N1 equipment and of the engineering planning of the systems has been given in an article in the last issue of this Journal (Ref. 1).

INSTALLATION DETAILS

Cables: As indicated in Fig. 2 the systems are installed on paper insulated 10 lb. and 20 lb. local type cables, and 40 lb. multiple twin. All cables are underground with the pairs required for N1 system working deloaded. The cable bearers were selected by measurements similar to those carried out for the junction carrier installations described in the October 1948 issue of this Journal (Ref. 2). The testing frequency used was 250 Kc/s and pair combinations giving a far end crosstalk reading better than 35 db were regarded as satisfactory. Selection of bearers with these characteristics was relatively easy and is one of the advantages of using a compandored system. Data on the attenuation characteristics of the cables is given in Fig. 3.

A sealing current of 20 mA. has proved necessary to maintain bearer circuits with constant characteristics. Some difficulties have been encountered with span pad failures caused by too high currents resulting from shorts and earths being placed on working pairs during cable rearrangements. Sealing current fed at 48V is preferred to 130V.

At each exchange the pairs allocated as bearers are picked up in lead covered paper cable at the joint outside the building, bypass the M.D.F. and terminate in a sealed cable head above the system racks. This avoids the use of the enamelled silk and cotton insulated cables which are used to terminate the external cables on the M.D.F., and has the advantage of removing the carrier circuits from inadvertent interference on the M.D.F. Carrier frequency cabling of the systems is carried out with Western Electric cable type 720. Switchboard cable is used for voice frequency circuits, balancing networks and signalling leads. A jackfield giving access to each channel for monitoring and testing purposes is provided.

Terminals: Standard 10 ft. 6 in. racks 20¼ inches wide are used for mounting the equipment, and a single rack takes 2 system terminals with associated jack panels, terminal block, and power transformer (240/115V) for the blower motor. Fig. 4 shows an installation of 5 terminals at City North. The righthand side rack carries the 28 pair sealed cable head (20 pairs only terminated) and the order wire and alarm equipment.

Pad switching is incorporated in all circuits with the exception of those terminating at Richmond. Normal line up conditions give a 6 db loss from trunk switchboard to trunk switchboard with the 3 db switching pads in circuit. The circuits terminating at Sydney are unusual in that the associated trunk switchboards are not in the same building as the carrier equipment. The trunk exchange is at Dalley Street which is .2 mile from the City North building and .9 mile from the City South building. To ensure stable circuits, separate four wire terminating sets are provided in the

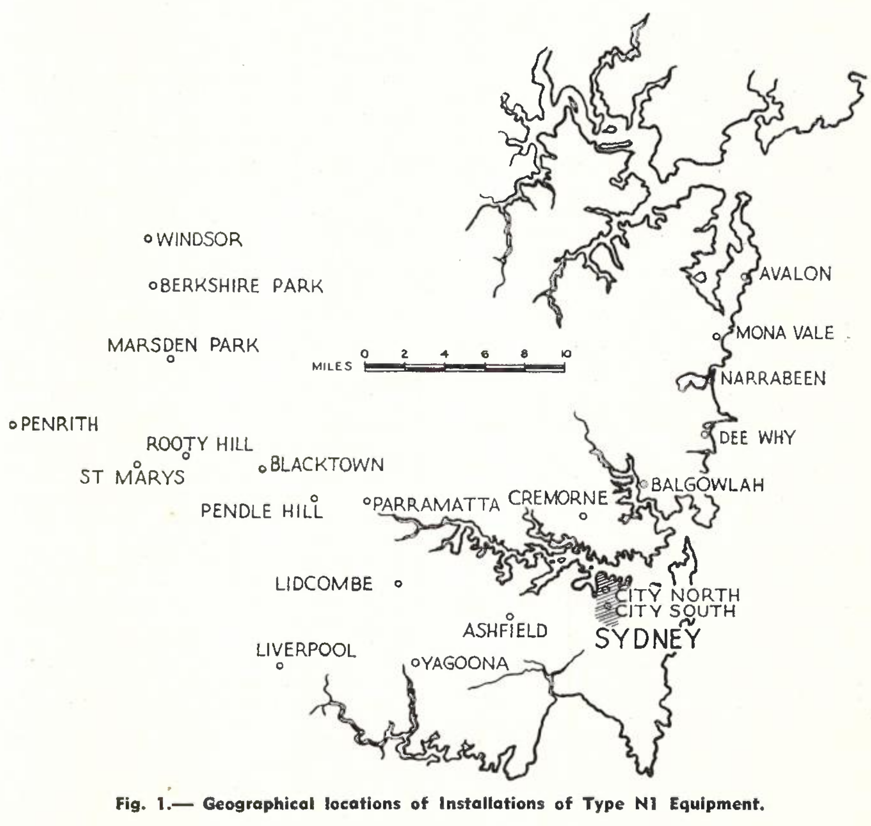


Fig. 1.— Geographical locations of Installations of Type N1 Equipment.

*Mr. Gunn is a Divisional Engineer in the Long Line Equipment Section, Central Administration.

trunk exchange with four wire extensions from the system terminals at City North and City South.

Repeaters: Repeaters are installed mostly in established telephone exchanges, although some use has been made of pole mounted repeaters in the outer parts of the network. In existing exchanges, the carrier equipment is either placed in line with the automatic exchange equipment or, if sufficient floor space is available, in a separate row reserved for carrier equipment. Where no accommodation is available pole mounted repeaters are used and the pole mounted repeater at Marsden Park is illustrated in Fig. 5. The twin pole construction used gives excellent working conditions at the repeater, and discourages vandalism. A pole mounted cabinet accommodates 12 repeaters. Exchange installations use 10 ft. 6 in. racks which carry 20 repeaters per rack where local power is used and 32 repeaters if power fed.

Signalling: Most circuits use the option of 3700 c/s signalling tone off during conversation although in the case of private lines or two wire extensions, tone on during conversations is used to avoid the condition of permanent ring on a channel failure. Suitable relay sets to integrate the trunk exchange equipment with the system signalling facilities were designed and installed at the stations concerned.

Order Wires and Alarms: The alarm equipment provided with the systems has been installed and use is made of the fault tones to transmit power supply and system failure alarms to the terminal stations. The complete order wire facilities of N1 carrier have not been provided as most of the stations concerned are automatic exchanges with existing facilities for interconnection.

The alarm facilities will be rearranged to enable all alarms to be transmitted to City South for the western route and City North for the northern route, as these stations are continuously staffed. As a final arrangement it is intended that all alarms from all routes will be taken to City South to make that station the maintenance control centre for the whole network.

The final order wire facilities to be provided will consist of a 4-wire physical circuit on each route equipped with 4-wire amplifiers and magneto ringing. This will give the complete flexibility required and will enable any station to speak with any other station or all stations.

Power: Terminal power supplies and the supplies for most repeaters are derived from rectifier and battery installations backed by standby diesel alternators. The automatic exchange battery provides the –48V required. For anode supplies 130V auto-controlled rectifiers with 63 cell open type plante or radio type enclosed batteries are used. Two rectifiers are provided per station. The current drain of a terminal is 4 amps at –48V and 1.1A at 130V.

Repeaters require + 130V only if local A.C. power is available or ± 130V if power fed. Current drain of one repeater is 170 mA. In the case of power fed repeaters the power required is transmitted over the quad carrying the system and it has proved possible to use + 130V –48V for this power feeding, thus saving the provision of –130V batteries. Power feeding has been used for the repeaters indicated in Fig. 2, and enables savings to be made in the provision of the power facilities required for these stations. However the power feeding voltages in the cable are regarded as a hazard and where possible the pairs concerned are labelled in each cable joint in these repeater sections to enable normal cable work and maintenance to be carried out in safety.

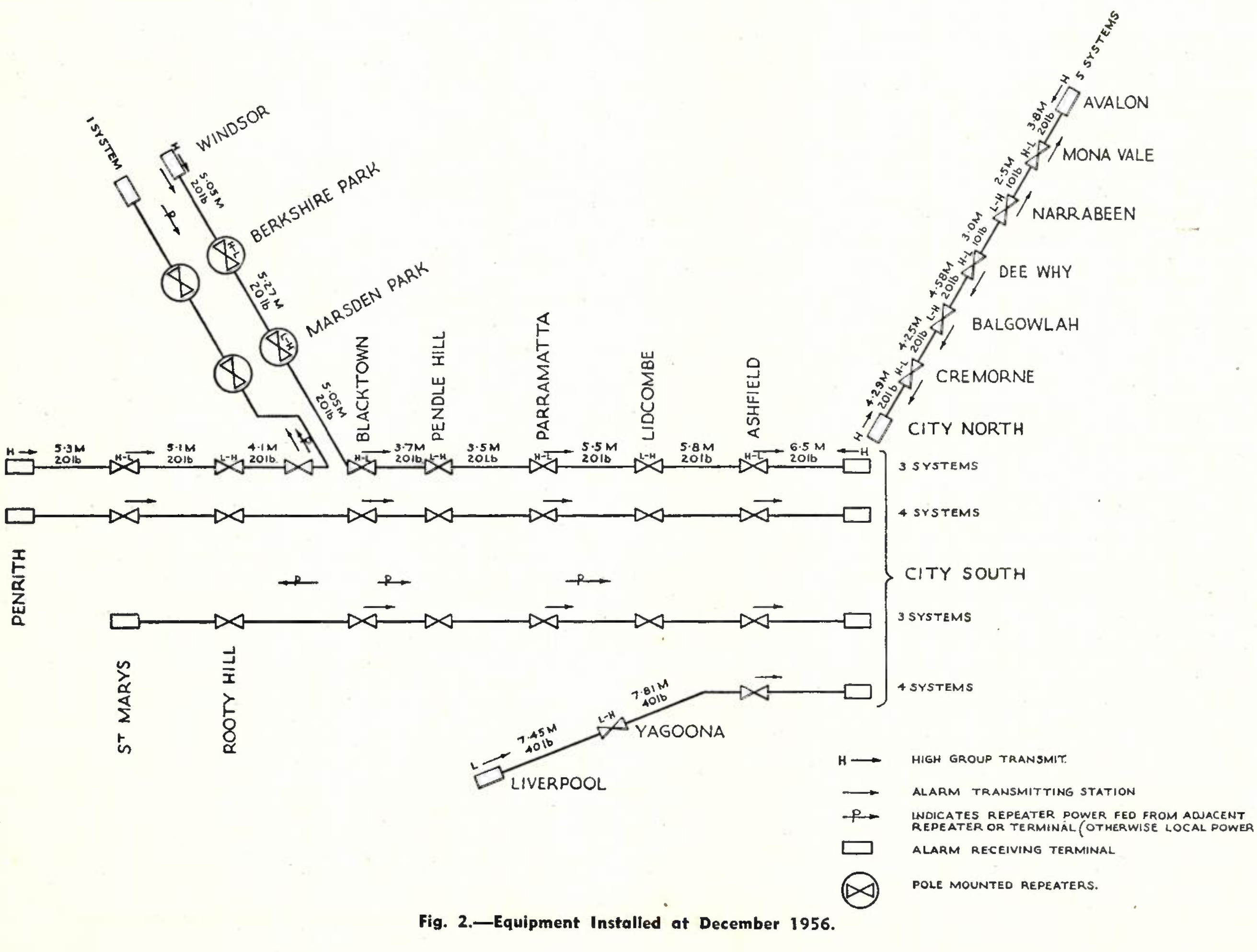


Fig. 2.—Equipment Installed at December 1956.

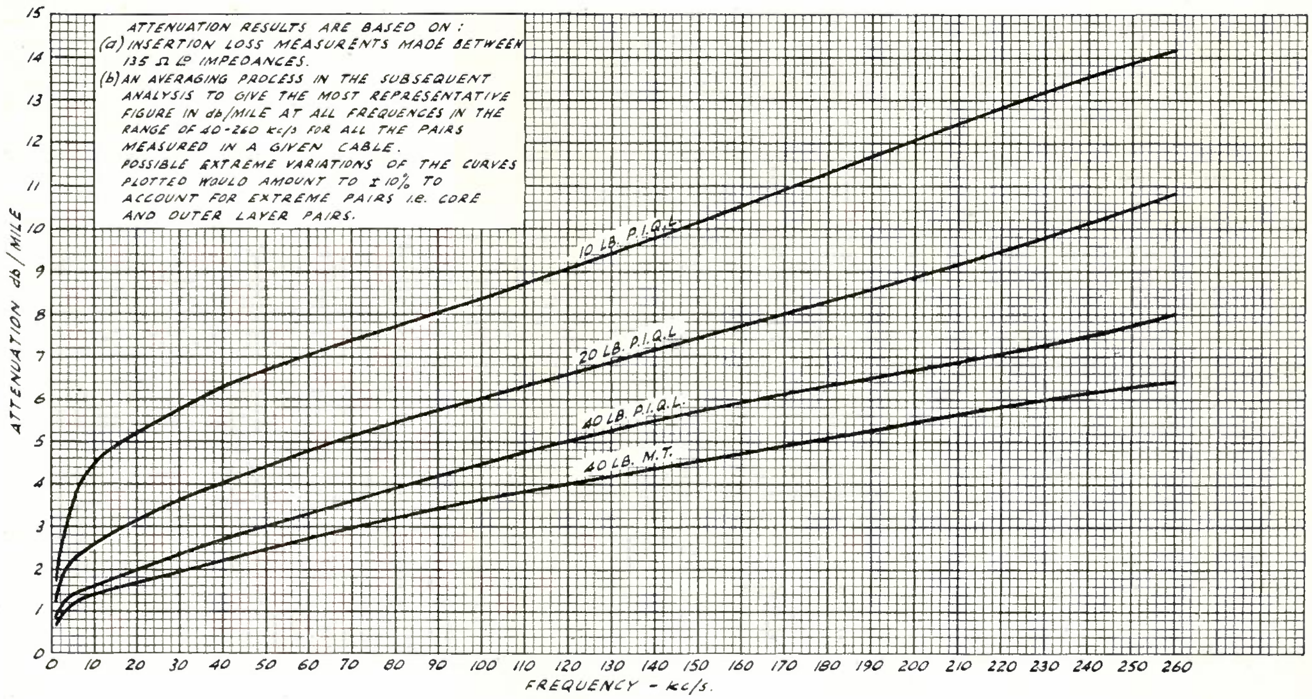


Fig. 3.—Cable Attenuation Characteristics.

PERFORMANCE

Five systems were put into operation between Sydney and Avalon during October, 1953. These systems have performed satisfactorily since that date without undue fault incidence. The channel frequency responses obtained are not as good as were expected and a typical channel falls within the envelopes sketched in Fig. 6. The channel responses on this type of system depend to some extent on the selection of the individual terminal channel units, and responses similar to those illustrated in Fig. 7 have been recorded in laboratory tests on two systems.

In field use regular maintenance checks on the signalling performance are necessary and for convenience in the adjustment required, the channel units have been modified to enable access to the controlling potentiometer to be obtained from the front panel. A modified channel unit is illustrated in Fig. 8. Dialling distortion of these systems is affected by power supply voltage changes and by signalling tube changes in the channel units.

The first systems cut over on the western minor trunk cables were the City South-Windsor systems and these systems unfortunately gave a poor noise performance at that time. Location of the noisy repeater sections was difficult because of the presence of transmitted carriers which also provide regulation and a technique was developed to enable noise measurements to be taken from each terminal in turn, with each repeater section added in sequence. This showed the City South-Ashfield, Ashfield-Lidcombe and Lidcombe-Parramatta to be the worst sections. These are the longest sections in the cable and are in busy areas of high telephone density.

The system design allows for a maximum repeater spacing giving a loss of 65 db at 256 Kc/s. The City South-Ashfield 6.5 mile 20 lb. P.I.Q.L. section gives a loss of 69.5 db at this frequency and the Ashfield-Lidcombe and Lidcombe-Parramatta sections 62 db and 59 db respectively. The City South-Ashfield section was 1 mile longer than was originally intended because of the necessity to reroute through Newtown.

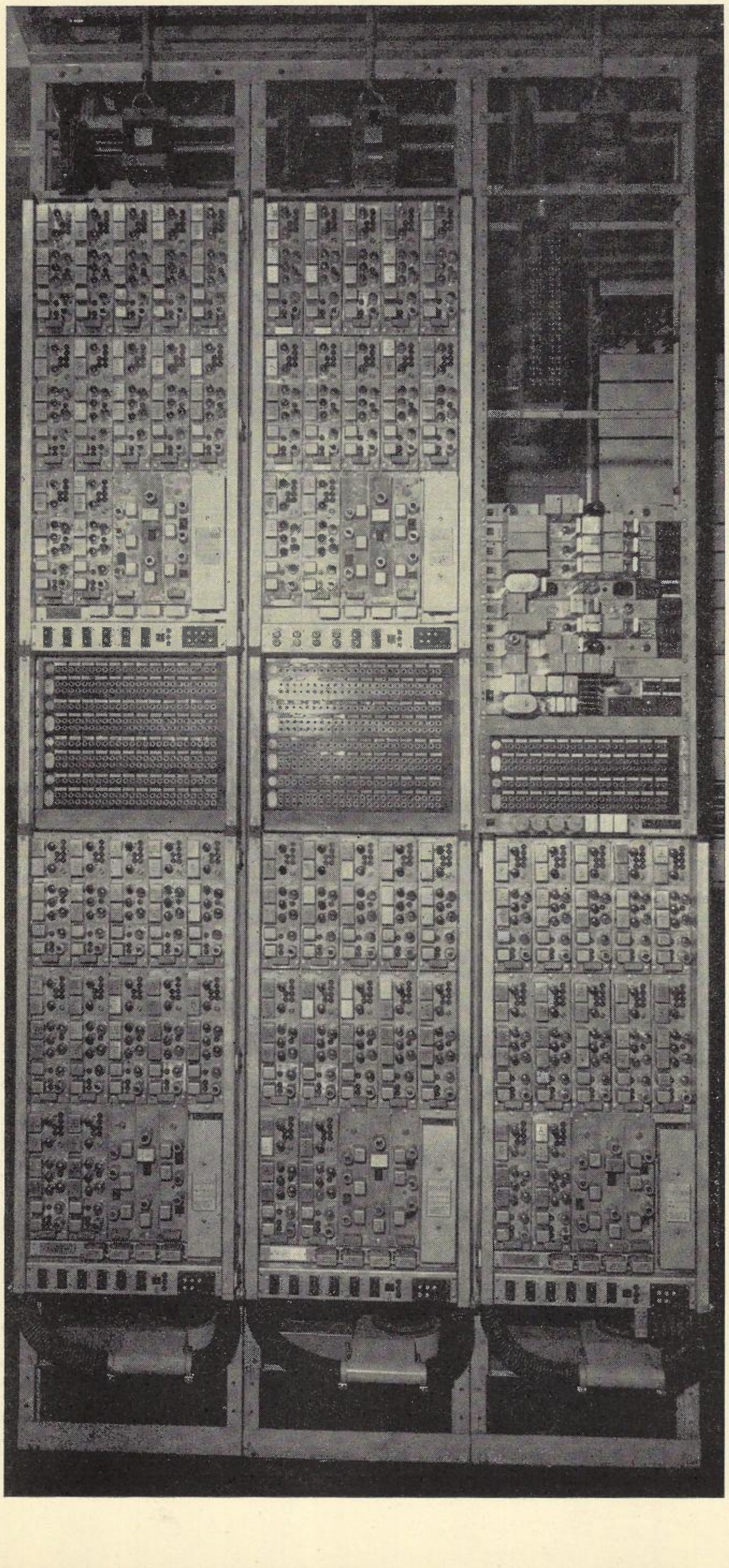
Noise in these cables is affected by a number of factors and usually approximates –70 to –90 dbm unweighted in a 4 Kc/s band up to 250 Kc/s which corresponds to a weighted figure of –80 dbm to –100 dbm. In the case of the City South-Ashfield section the attenuation is sufficient to reduce a send test level of + 4 dbm for the highest frequency channel to the order of –66 dbm which is only 15-30 db from the cable noise. The compandor advantage of 20-25 db was insufficient to obtain satisfactory overall performance and some cable re-arrangements have been required. The performance of the City South-Ashfield section has been made satisfactory by routing the high frequency band through a separate 40 lb. trunk cable, and a new repeater station has been provided at Silverwater to replace that at Lidcombe, and enable 40 lb. cables to be used over those sections also. At present the City South-Liverpool circuits give a typical weighted channel noise at a zero level point relative to the trunk switchboard of –60 dbm average with 10 db peaks. These measurements were made with a Western Electric Type 2B noise set with 144 line weighting, and for convenience the levels are quoted in dbm which is derived by subtracting the noise in dba from 90.

The crosstalk and intermodulation characteristics of the system terminals alone have been laboratory tested in accordance with the techniques previously set out in this Journal (Ref. 2), and proved quite good with no figures worse than –63 dbm. The field performance of all systems is now satisfactory.

MAINTENANCE

The unit construction of Type N1 equipment facilitates maintenance at a central depot and advantage has been taken of this feature. A central maintenance depot has been established at the City North terminal and is equipped with the necessary test equipment to overhaul all types of units making up the systems. At present, this test centre holds all spare Type N1 equipment and carries out routine testing and repair of all the equipment installed in the network. Individual card records on each particular unit are kept to cope with the continual shifting of the units. In the event of a fault on a working unit at any station, the required replacement unit is obtained from the maintenance centre within a few hours.

Details of the final maintenance set up to be adopted are still under discussion. The most likely development will be to have the maintenance centre do repairs on all the short haul unitised equipment in the Sydney network and hold spare channelling equipment only. Each station will then hold spare group equip-



ment for immediate restoration of complete system failures and will forward the faulty unit replaced to the maintenance centre for repair.

POLICY FOR FUTURE USE

Since the original purchase of Type N1 equipment, other more economical types of short haul systems have been developed and it is intended to concentrate the 20 type N1 systems purchased on to the Sydney-Windsor and Sydney-Penrith cables over the next few years. Finally, all the systems will be installed on the Sydney-Windsor cable to meet the 20 year development on that route.

The systems presently installed between Sydney-Avalon and Sydney-Liverpool will be replaced by Philips STR.113 short-haul equipment which provides 8 channels on one cable pair using the frequency bands 6-54 and 60-108Kc/s. This type of equipment is less complex than the type N1 equipment and will enable significant savings to be made in the provision of these circuits. The installation of the Philips systems will require the installation of crosstalk balancing frames to enable the required far end pair to pair crosstalk of 65 db at 108 Kc/s to be obtained. Also, the repeater sections for these systems have been kept short (20-30 db) to control the performance with respect to cable noise, and limits −52 to −72 dbm are anticipated at a point of zero level relative to the trunk switchboard. The most difficult section will be City South-Ashfield which, over the present route of 6.5 miles of 20 lb. cable could give figures of 10db worse than those quoted. However, it is intended to use another 20 lb. cable on a shorter route 5 miles in length, which should enable channels with a satisfactory noise performance to be derived.

Fig. 4.—Five Terminals City North.

Fig. 5.—Pole Mounted Repeater Marsden Park.

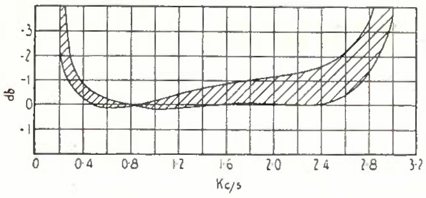


Fig. 6.—Channel Responses Sydney-Avalon.

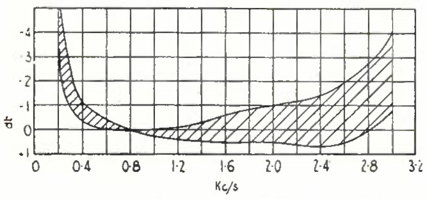


Fig. 7.—Channel Responses Laboratory Tests.

The Type N system is a versatile system and has been developed to meet the wide range of installation conditions which exist in the U.S.A. This includes installation on aerial or underground cables of widely varying characteristics, with a minimum of engineering effort. These design features have been met, but at the cost of some complexity and at the present stage of development of the Australian network, systems using simpler channelling equipment but retaining inbuilt signalling and frogging facilities similar to Type N systems, have some advantages.

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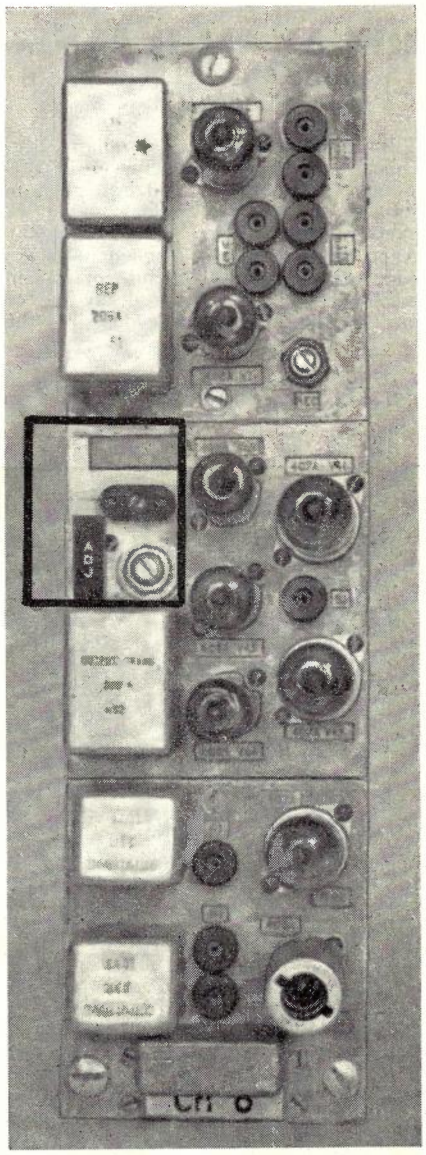

Fig. 8.—N1 Channel Unit Modified for Ease of Signalling Adjustment.

DECAY AND INSECT ATTACKS IN POLE TIMBERS

*F. A. SAMUELSON**

Introduction: The Australian Post Office has approximately 2,400,000 wooden poles and 900,000 iron poles in service, the average annual usage of wooden poles being about 100,000. Approximately 65,000 wooden poles are condemned annually, because of loss in mechanical strength due to decay and/or insect attack. This article describes the causes of decay and gives information on the insects which attack wooden poles and crossarms.

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Fungoid Decay in Poles. Decay in pole timbers is caused by fungi, a large group of plant organisms, none of which possess chlorophyll which is found in most higher plants and algae. Consequently they are unable to utilise the carbon dioxide of the air for the production of carbohydrates by photosynthesis and require organic compounds as a source of food. Some fungi break down complex plant and animal matter in the soil to provide food for green plants and some obtain their food from textiles and timber in service, including poles, etc. Wood destroying fungi live principally on cellulose and lignin and the presence of starch does not increase the susceptibility of wood to fungal attack. On the other hand there are sap staining fungi which live principally on starch and these lower the value of timber used for decorative work and in making of plywoods and veneers.

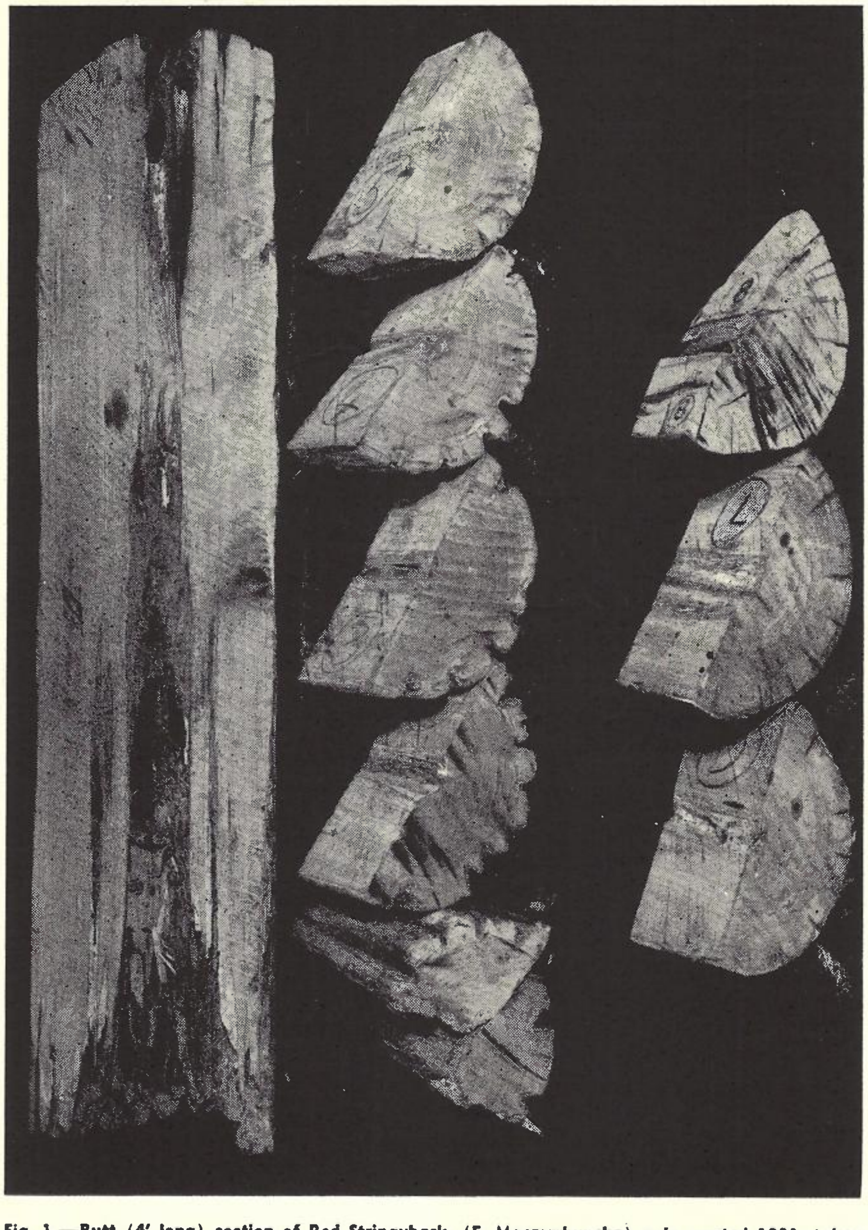

Fig. 1.—Butt (4' long) section of Red Stringybark, (E. Macrorrhyncha) pole erected 1931, taken from Willow Tree—Tamworth Section. Extensive internal rot of fungal origin tapering into the central region towards upper end. Extension of the rot above ground, by way of the central pipe, would be quite probable, especially in damp situations. No insect damage visible.

Wood rotting fungi are generally aerobic; that is to say that the required oxygen is obtained from the atmosphere. It is probable, however, that some growth can take place under anaerobic conditions, the oxygen being obtained by intramolecular change in the timber. The end products in this case are organic, that is alcohol, oxalic acid, etc., instead of carbon dioxide. Initial infestation of the timber will not occur unless the moisture content is above 20%, but once attack has started, providing evaporation is not too rapid, the water produced as an end product of decay, increases rapidly and is usually sufficient to maintain the process. Reduction of water content below 20% is not sufficient to destroy fungal hyphae which may be dormant for several months. It can be expected that decay will be more severe in damp than in dry localities.

The destructive part of a fungus is its vegetative system called mycelium, made up of exceedingly fine tubes, called hyphae, which grow by elongating their tips, passing from cell to cell in the wood. Enzymes are secreted into the surrounding medium and bring food materials into solution. Thus cellulose is oxidised into carbon dioxide and water.

$$C_6H_{10}O_5 + 6O_2 = 5H_2O + 6CO_2$$

The life cycle of fungi is (1) Spore, (2) Hyphae, (3) Mycelium, (4) Fruiting Body or Fructification, (5) Spore. The fruiting bodies are of diverse shapes, familiar ones being bracket shaped growths attached to poles, fences, etc. Some of these fruits are estimated to produce between 800 and 900 million spores per hour, the spore being extremely small, not often exceeding 0.01 mm in length with a weight of the order of 1×10^{-11} grams. They can remain suspended in air for a fairly long period and drift a long way. Conditions essential to fungal growth are food supplies, adequate moisture, suitable temperatures and oxygen supplies. In most circumstances growth is dependent on adequate moisture supplies, the wood itself being the food supply. Oxygen can always be obtained except in a vacuum or under completely waterlogged conditions. Fungal growth ceases at, or below, freezing point and is very slow below 40°F, optimum temperatures varying with different fungi but being in the region 65°F—85°F.

Timber loses its strength as a result of decay. In poles decay is most pronounced from about a foot above to eighteen inches below the ground line, just in the part where the maximum stress occurs. A little consideration will show that here, there is always plenty of air, usually sufficient moisture and relatively small variations in temperature. Figs. 1 and 2 illustrate typical fungal attack in poles. There are many species of wood decaying fungi which attack poles at the wind and water line and to give an idea of the diversity of types met, the following species are quoted:—

Trametes lilacino — gilva (grey or purplish brackets);
Trametes cinnabarina (orange coloured brackets);
Lenzies species (fan shaped brackets);
Poria species (white spreading patches).

Above ground, poles dry out quicker and temperatures vary greatly and rapidly; fungal growth is therefore retarded. In areas of high temperature and humidity considerable decay does occur above ground particularly at pole tops and around arm slots. In some parts of the Lismore Division, N.S.W., up to 50% of poles are condemned because of decay in the tops of poles. The lives of poles in service depend very largely on the concentration and distribution of fungal flora which are directly influenced by climatic conditions, soil types, vegetation, etc. With low rainfall and little forest, decay is met with much less than in forest areas of similar rainfall. In areas of 25″ average annual rainfall, particularly in southern areas, rate of decay varies directly with the rainfall.

Poles in very wet or very dry soils resist decay longer than poles set in soils which are alternately wet and dry, decay varying directly with the organic content of the soil. It is often stated that poles erected in the area from which they are obtained last longer than if set elsewhere. The only records obtainable, bearing on this matter, were from the Wagga Wagga Division for Stringybark poles renewed between 1938 and 1951. 4,863 poles renewed east of the Sydney-Melbourne railway line had an average life of 24.6 years whilst 1,523 erected west of the railway had an average life of 18.6 years. For the years 1946 to 1951 the average lives were 24.5 and 22.8 years respectively. The area, east of the railway where all poles were obtained is hilly to undulating and the west predominantly flat. There is insufficient data to arrive at any conclusion in the matter.

Insect Attack on Poles. Borers, beetles and termites also attack poles, termites attacking and seriously affecting both sapwood and true wood. They cause by far the most serious insect damage to poles in service and also attack living trees. Living trees, if injured or unhealthy, can be attacked by pin hole borers, which may continue the attack after the timber is felled. These borers cannot, however, live in dry timbers because their larvae live on a fungus introduced into the holes by the parent. The damage caused is usually not significant. A larger group of borers, **Cerambycidae,** which includes the common long horn beetles, may damage standing trees or freshly felled poles. Their holes may be ¼″ to 1″ in diameter and may be oval or circular in shape, being popularly known as grub holes. If infestation occurs in the tree or log, the young larvae may take some years to develop and appear on the surface of standing poles. The holes do not appear to affect pole strengths but may become focal points of fungal decay.

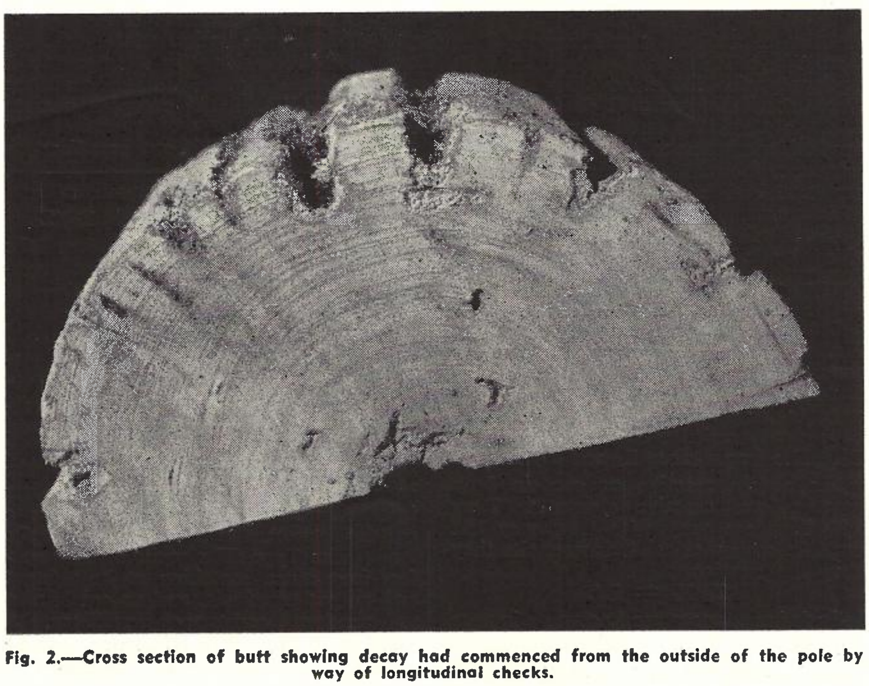

Fig. 2.—Cross section of butt showing decay had commenced from the outside of the pole by way of longitudinal checks.

Insects of two groups, **Bostrychidae** (Auger Beetles) and **Lyctidae** (Powder Post Beetles), may infect freshly felled logs, seasoned poles in storage or standing poles even after some years in service, but confine their attack to the sapwood. These insects reduce the sapwood of some species of timber to powder which must be removed if the poles are to remain at all sightly.

A large number of termites commonly called white ants, are found in Australia, over 50 of the more important species being listed in a recent C.S.I.R.O. publication "Australian Termites" by Ratcliff, Gay and Greaves. They are more prevalent in tropical and sub-tropical areas than in temperate areas, only 2 or 3 species being found in Tasmania. The most characteristic habit of termites is the shunning of light within a completely enclosed system of galleries and covered ways. For this reason if termites are attacking timber above ground from within, the outside layer of wood is not eaten. The purpose of this sheltered existence is to give protection and also to provide some measure of control over the humidity, for termites prefer high humidities.

Termites may be divided into two main groups, the wood dwelling and soil dwelling groups. In Australia by far the greatest damage to pole timbers is caused by the latter group. These soil dwelling species live in the soil generally within a system of underground galleries. If they construct a nest, it may be raised above the ground in the familiar mound or very occasionally may be attached to a trunk of a tree or pole top, but always maintaining connection with the soil by galleries running down the surface of the tree or pole. The soil dwelling species can severely attack timber in contact with the ground and may extend their attack to timber a considerable distance above the ground, but at all times retaining their soil connection by their internal workings in the wood or by the covered runways which may extend over brickwork or durable timbers to make contact with more suitable material. The appearance of these galleries on the surface of a pole is frequently the first indication of their presence. The wood dwelling termites do not construct nests but live in the galleries excavated in the wood on which they feed. Some species can live in seasoned timber, but most dwell in timber which has a moisture content above 20%. Decaying timber which has a high moisture content is one source of food for this type of termite.

Infestation of poles may occur in one or two ways. A nearby colony may extend its galleries to a pole or a reproductive or winged pair may find a suitable place in a check at, or near, the ground line in which to establish a new colony. The strength of poles infested with termites is seriously impaired and such poles should be treated with a suitable preservative as soon as the presence of termites is detected.

Some of the more durable timbers contain extractives of an oily or solid nature which may make the wood unsuitable as a food for fungi or insects. One Australian timber studied by the C.S.I.R.O. in 1931 was cypress pine. Examination showed that an acid 1-citronellic acid, was the most toxic extractive to fungi and that a volatile and ether-soluble resin was the most distasteful to termites. It does not appear possible to synthesise these materials for commercial application but it is hoped to evolve some relatively simple compound for this purpose. No work has been published in this field recently. Other things being equal it is often found that dense woods tend to be more durable than lighter woods. This is not always the case, however with a few exceptions it may be applied as a general rule to eucalypt timbers. As a rule density is secondary to the effects of extractives.

It is hoped that this article will provide an introduction to the general subject of preservation of wooden poles and crossarms which will be discussed in later articles.

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NOMOGRAMS FOR EQUALISER DESIGN

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Introduction

An attenuation equaliser is any network inserted between a generating circuit and a load for the purpose of introducing a loss varying with frequency. As the name implies, this is usually done to compensate for varying losses in other parts of the system, thus producing a total loss approximately independent of frequency. The most familiar application of equalisers is in telephonic line transmission, where the attenuation of a line generally rises with frequency, though not always in a regular manner. Equalisers are also an important part of sound recording systems, and circuits of the equaliser type can be used as weighting networks in noise measurement. The design methods described in this article apply to fairly simple types of equaliser, such as those used in broadcast programme line equalisation, though the basic principles also apply to the more elaborate circuits used in carrier systems for equalising over a wider frequency band.

Requirements for Programme Lines

Standards for the equalisation of programme channels are laid down by the Australian Broadcasting Control Board (Refs. 3, 4). In all cases the tolerances are with reference to the response at 1,000 c/s. For medium frequency stations the overall response from microphone to aerial output must be within the following limits:—

± 2 db from 100 to 5,000 c/s.
± 4 db from 50 to 10,000 c/s.

Where the programme line length exceeds 10 miles, the Board may approve variations from these standards for frequencies between 5,000 and 10,000 c/s. For outside broadcast lines, the response limits are ± 2 db from 100 to 5,000 c/s, unless otherwise approved by the Board.

For television sound channels, the overall microphone-transmitter output response is to be in accordance with a specified (50 microsecond) pre-emphasis curve with certain tolerances. The studio-transmitter link is to have response limits of ± 2 db from 30 to 15,000 c/s. The same limits apply to radio links for television outside broadcasts.

The limits at present normally used by the Post Office in Victoria for local programme channels are (referred to 1,000 c/s) ± 1 db from 50 to 10,000 c/s and for channels on trunk lines ± 2 db from 50 to 10,000 c/s, except on lines equipped with 5.6 kc/s filter groups, where the limits are ± 2 db from 50 to 5,000 c/s. Lines used for high-class musical programmes to the Melbourne frequency modulation station at Jolimont are equalised to ± 1 db from 35 to 15,000 c/s. The sound channels to the National television station are being provided by cable pairs equalised to the A.B.C.B. requirements.

Equaliser Circuit Theory

Basic Types: The networks shown in Fig. 1 may be regarded as the standard equaliser types. In all cases it is assumed that the circuit is to be inserted between a generator and a load, both of which have purely resistive impedance equal to R_0. The impedances Z_1 and Z_2 may be either purely reactive or contain both resistive and reactive elements. They will therefore vary with frequency but must be such that at all frequencies they obey the relation

$$Z_1 Z_2 = R_0^2.$$

Such impedances are known as inverse impedances. Their reactive components at any frequency are of opposite sign. Typical pairs of inverse impedances are shown in Figs. 2 and 3. It will be seen that

(a) the inverse of an inductance is a capacitance,

(b) the inverse of a series circuit is a parallel circuit,

(c) the inverse of a series resistance is a shunt resistance,

(d) a resonant frequency of any circuit is an anti-resonant frequency of its inverse.

Inverse impedances are not restricted to the simple types here shown. The networks can be of any complexity so long as the requirements are fulfilled.

From the assumption that generator and load both have impedance R_0, it may be readily proved that for all the circuits of Fig. 1 the complex current ratio

$$\frac{\text{Current in load without equaliser}}{\text{Current in load with equaliser}} = (R_0 + Z_1)/R_0 = (R_0 + Z_2)/Z_2.$$

The insertion loss is therefore the decibel equivalent of the modulus (numerical value) of this ratio or

$$20 \log_{10} |(R_0 + Z_1)/R_0| = 20 \log_{10} |(R_0 + Z_2)/Z_2|.$$

It can also be seen that the simple series and shunt equalisers, Type I in Fig. 1, do not match impedances correctly at either input or output terminals. The L circuits, Type II, have an input impedance equal to R_0 and so match the generator impedance to the equaliser input terminals, but do not provide a match between the equaliser and the load. The Type III circuits all give perfect impedance matching at both input and output terminals, and so are known as constant resistance equalisers. A number of Type II or III sections can be connected in tandem, each working into

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the impedance R_0 presented by the input terminals of the next section. All the circuits of Fig. 1 except Types I(b) and III(d) are shown as unbalanced to earth, but the corresponding balanced types can be readily derived by placing half of the series impedance in each arm.

The simplest and most commonly used Type III circuit is the bridged-T, Type III(c), or in balanced form bridged-H. When this circuit is terminated in R_0, it may be regarded as a balanced bridge, since $R_0/Z_2 = Z_1/R_0$. No current then flows in the right-hand R_0 arm. This arm therefore only serves to make the circuit symmetrical and match impedances in both directions. It may be open-circuited, which converts the circuit to Type II(b), or short-circuited, giving Type II(a).

Inverse Arms Purely Reactive: When Z_1 and Z_2 are purely reactive, their numerical values vary between zero and infinity as the frequency changes. Z_1 may now be written jX_1 and the insertion loss in db becomes

$$20 \log_{10} \sqrt{\frac{R_0^2 + X_1^2}{R_0^2}}$$

$$= 10 \log_{10} \frac{R_0^2 + X_1^2}{R_0^2}$$

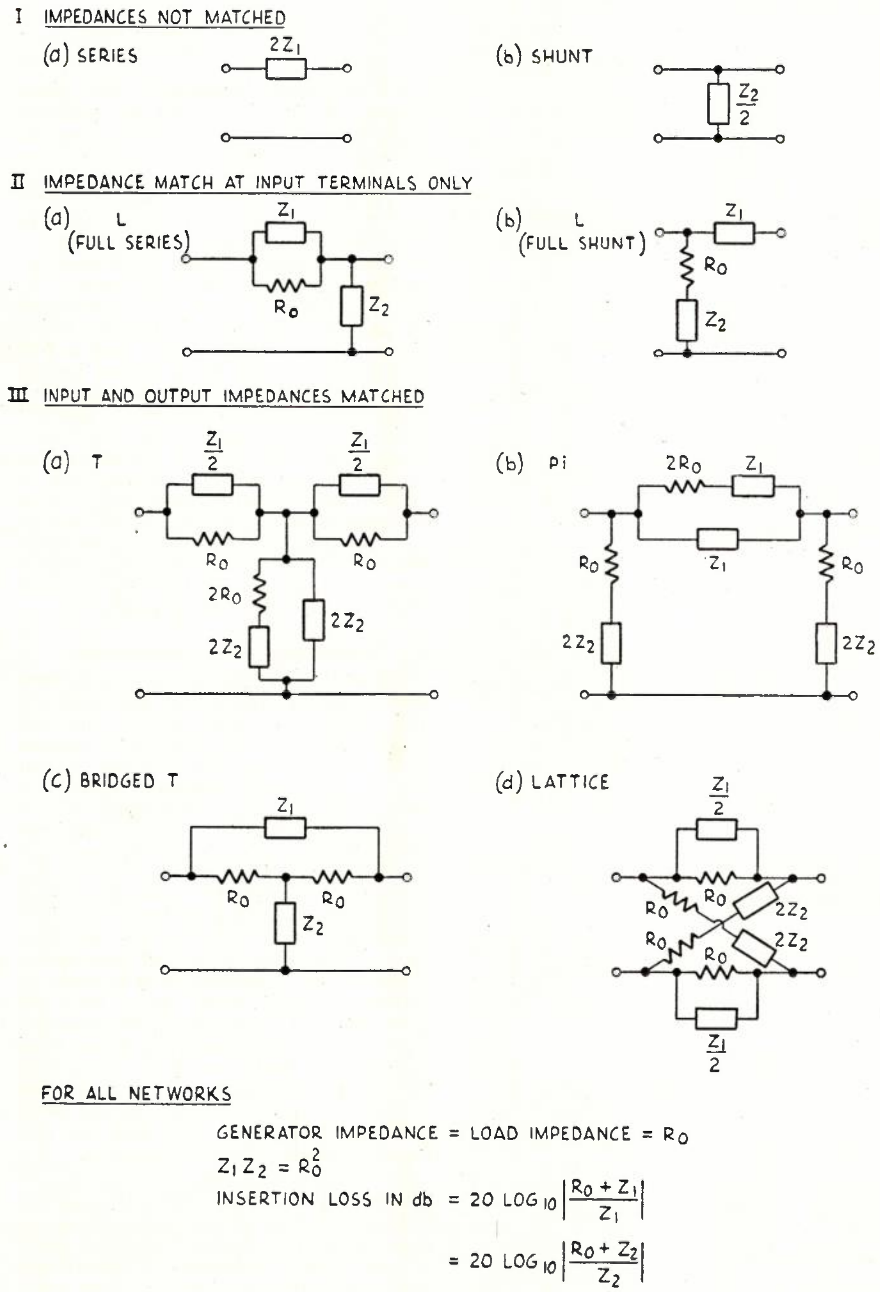


Fig. 1.—Basic Equaliser Types.

This loss will vary between zero and infinity as X_1 varies with frequency. Fig. 2 shows the simplest configurations for reactive inverse arms, together with the forms of the loss curves for the equalisers built up by using them in any of the circuits of Fig. 1.

At a frequency f_A such that X_1 and X_2 are each numerically equal to R_0 the insertion loss becomes $10 \log_{10} 2 = 3$ db.

From the above relations and the forms of the inverse impedances, it is possible to deduce the design formulae for the component values shown in the lower part of Fig. 2. The shape of the desired loss curve determines the form of impedance elements, the 3 db frequency f_A, and in the case of the resonant circuits (iii) and (iv) the resonant frequency f_R. The ratio f_R/f_A is denoted by a, assuming f_A to be less than f_R. The values of inductance and capacitance can then be found from the design formulae.

It should be noted that the loss curves of (iii) and (iv), if drawn with a logarithmic frequency scale, are symmetrical about f_R.

Inverse Arms Containing Resistance and Reactance: From the properties of inverse impedances, it can be seen that if one arm contains a series resistance the other must contain a shunt resistance. If Z_1 includes a series resistance R_1, then the numerical value of Z_1 can never be less than R_1. The insertion loss will then have a minimum value of $20 \log_{10} [(R_0 + R_1)/R_0]$ which is greater than 0 db. This is obviously undesirable, since an equaliser should not introduce unnecessary loss. In practical equalisers, therefore, Z_1 consists of a resistance in shunt with one or more reactive elements. Its inverse Z_2 must then contain a series resistance. The simplest impedances of this type are shown in Fig. 3.

Let Z_1 consist of a resistance R_1 shunted by a reactive impedance jX_1. The numerical value of X_1 will vary between zero and infinity. At a frequency where $X_1 = 0$, then $Z_1 = 0$ and the insertion loss is 0 db. When X_1 is infinite, $Z_1 = R_1$ and the equaliser acts as a pure resistance network with loss $20 \log_{10} [(R_0 + R_1)/R_0]$ db. This is the maximum loss which the equaliser can introduce. In the case of a constant resistance equaliser the circuit then behaves as a resistance pad, and this loss is known as the pad loss. The loss then varies between zero and the pad loss value.

If the maximum loss is expressed in the form of a current ratio K, then the maximum loss in db is $20 \log_{10} K$ and $K = (R_0 + R_1)/R_0 = (R_0 + R_2)/R_2$

Then $R_1 = R_0 \cdot (K-1)$

$R_2 = R_0/(K-1)$

Since Z_1 consists of R_1 and jX_1 in parallel, its value is given by

$$Z_1 = \frac{jR_1 X_1}{R_1 + jX_1} = \frac{jR_0X_1(K-1)}{R_0(K-1) + jX_1}$$

The complex current ratio is then

$$\frac{R_0 + Z_1}{R_0} = \frac{R_0 (K-1) + jKX_1}{R_0 (K-1) + jX_1}$$

From this the insertion loss in db can be found to be

$$10 \log_{10} \cdot \left[1 + \frac{K^2 - 1}{1 + (K-1)^2 \left(\frac{R_0}{X_1}\right)^2} \right]$$

At the frequency at which X_1 has the numerical value $R_0 (K-1)/\sqrt{K}$, the insertion loss becomes $10 \log_{10} K$ or half the maximum loss in db. This frequency is denoted by f_B.

For the four different pairs of inverse arms of Fig. 3, the design formulae for the component values can now be obtained, and are shown in the lower part of Fig. 3. For resonant circuits the ratio f_R/f_B, where f_B is less than the resonant frequency f_R, is denoted by b. The loss curves for resonant circuits, if drawn with logarithmic frequency scale, are again symmetrical about f_R.

Loss curves for equalisers using the various inverse impedance configurations and for various pad loss values have been published (1), showing losses plotted against f/f_A, f/f_R or f/f_B according to the type of circuit.

Simplified Bridge-T Circuit: The bridged-T circuit in which Z_1 is any of the networks of Fig. 3 can be transformed to a circuit using only three resistors instead of four. In Fig. 4 are shown the basic circuit (a) and the useful form (b) where Z_1 consists of resistance R_1 in parallel with reactive component jX_1. It will be seen that the four resistances constitute a three-terminal network enclosed by the dashed line. It is well known that any such network is equivalent to a simple T section, and since all the components are resistances this will be the same at all frequencies. Replacing the resistive network by the equivalent T section gives the circuit of Fig. 4(c). The reactive components are unchanged but new resistance values are required, given by

$$R_1 = R_0 \cdot \frac{K-1}{K+1}$$

$$R_2 = R_0 \cdot \frac{2K}{K^2-1}$$

Simple Shunt Equaliser: For short programme lines consisting of unloaded cable a simple shunt equaliser using the circuit of Type I(b), Fig. 1, is sometimes suitable. A type which has been adopted in Victoria is shown in Fig. 5. This uses a shunt impedance $\frac{1}{2}Z_2$ where Z_2 is of the configuration (iv) of Fig. 3, with a resonant frequency of approximately 9 kc/s, at which frequency the theoretical loss is zero. The maximum loss can be varied by adjusting the resistance. The equaliser works into a 600 ohm load; but since the generator impedance (that is the impedance looking back from the equaliser to the line) is not 600 ohms the loss cannot be calculated exactly from the standard formula. This equaliser is suitable for use on lines of up to 7 miles of 10 lb. cable, with which it can be adjusted to give a response of ± 1 db referred to 1,000 c/s from 30 to 8,000 c/s. For a 7 mile line a typical value for total loss at 1,000 c/s is 32.5 db with a resistance of 23 ohms.

Programme Line Equalisation

Circuits Used: The circuits most commonly used in programme line work are the bridged-T sections of Fig. 4(b) and (c) or their balanced bridged-H equivalents. These have loss curves as in Fig. 3. It is often necessary to use two or even three sections in tandem. Equalisers are installed at the receiving end of the line or of each amplifier section. Present practice in Victoria is to use unbalanced bridged-T sections with transformer matching on both sides, but balanced sections are in use on some lines. Equalisers with pad loss made adjustable by providing plug-in pads of different values have been used in Queensland (11) on long trunk line circuits. In Victoria, however, it has been preferred to design complete equalisers for each case, on account of the varying nature of the lines concerned, the large number of cable circuits and the different response standards required.

The British Post Office uses L circuits based on Type III(a) of Fig. 1, and has developed a line of equalisers made up from a limited number of fixed component values, by means of which any likely loss curve can be fitted with sufficient accuracy (7, 9).

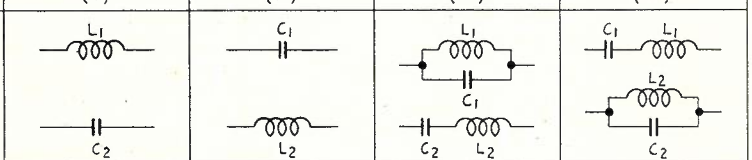
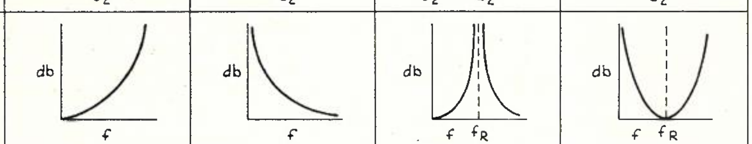
INVERSE ARMS PURELY REACTIVE				
TYPE	(i)	(ii)	(iii)	(iv)
Z_1, Z_2				
INSERTION LOSS CURVE				
POWER RATIO AT FREQUENCY f	$1+\left(\frac{f}{f_A}\right)^2$	$1+\left(\frac{f_A}{f}\right)^2$	$1+\left(\frac{a-\frac{1}{a}}{\frac{f}{f_R}-\frac{f_R}{f}}\right)^2$	$1+\left(\frac{\frac{f}{f_R}-\frac{f_R}{f}}{a-\frac{1}{a}}\right)^2$
DESIGN FORMULAE	$L_1=L_A$ $C_2=C_A$	$L_2=L_A$ $C_1=C_A$	$L_1=L_R\left(a-\frac{1}{a}\right)$ $L_2=\frac{L_R}{a-\frac{1}{a}}$ $C_1=\frac{C_R}{a-\frac{1}{a}}$ $C_2=C_R\left(a-\frac{1}{a}\right)$	$L_1=\frac{L_R}{a-\frac{1}{a}}$ $L_2=L_R\left(a-\frac{1}{a}\right)$ $C_1=C_R\left(a-\frac{1}{a}\right)$ $C_2=\frac{C_R}{a-\frac{1}{a}}$
	$L_A=\frac{R_0}{2\pi f_A}$	$C_A=\frac{1}{2\pi f_A R_0}$	$L_R=\frac{R_0}{2\pi f_R}$	$C_R=\frac{1}{2\pi f_R R_0}$
	WHEN R_0 = 600 OHMS AND F_A AND F_R ARE IN kc/s $L_A=\frac{95 \cdot 49}{f_A}$ mH	$C_A=\frac{0 \cdot 2653}{f_A}$ μF	$L_R=\frac{95 \cdot 49}{f_R}$ mH	$C_R=\frac{0 \cdot 2653}{f_R}$ μF
	$R_0^2=\frac{L_A}{C_A}=\frac{L_R}{C_R}=\frac{L_1}{C_2}=\frac{L_2}{C_1}$			
DEFINITIONS	$R_0 = Z_0$ = EQUALISER RESISTANCE f_A = FREQUENCY FOR 3db LOSS f_R = RESONANT FREQUENCY $a = \frac{f_R}{f_A}$ DEFINED AS GREATER THAN 1 POWER RATIO = $\frac{\text{POWER TO LOAD WITHOUT EQUALISER}}{\text{POWER TO LOAD WITH EQUALISER}}$ = $(\text{CURRENT RATIO})^2$ INSERTION LOSS IN db = $10 \log_{10}$ (POWER RATIO)			

Fig. 2.—Formulae for Reactive Inverse Impedances.

Procedure: When a line is to be equalised, its insertion loss is measured and plotted against frequency between the required limits. From this curve the desired equaliser loss curve is obtained by subtracting the loss at each frequency from the maximum value. The types of inverse arms required are found from the shapes of the corresponding loss curves of Fig. 3. For each section to be used, the following information is obtained from the desired loss curve:—

All sections—Pad Loss = maximum loss in db

f_B = half-pad-loss frequency

(for resonant sections use value less than f_R).

Resonant sections — f_R = resonant frequency of reactive arms

L_1—C_1 and L_2—C_2

$b = f_R/f_B \ (b > 1)$

The component values can then be calculated from the formulae of Figs. 3 and 4. Tables of resistances and values of $(K-1)/\sqrt{K}$ and $b-1/b$ are useful for this purpose.

Equaliser Construction: When resonant equaliser sections are being made up, inductors are wound to give as nearly as possible the theoretical values of L_1 and L_2, and capacitors selected to resonate with them at the desired frequency.

In the bridged-T circuits, Fig. 4(b) and (c), the theoretical value of R_2 must be taken to be the total resistance in the shunt arm. Where the inverse impedances are Types (ii), (iii) and (iv) of Fig. 3 the shunt arm includes an inductor L_2. The measured resistance of this inductor must be subtracted from the theoretical value of R_2 to find the resistor value required.

Nomograms

Use in Finding Component Values: Most of the computation can be avoided by using the nomograms of Figs. 6 and 7, which are based on the design formulae. These have been prepared to give component values for circuits of the simplified bridged-T type of Fig. 4(c), but it can be seen from the preceding theory that the inductance and capacitance values so obtained can be used for deriving circuits of any of the other types. The resistance values apply only to the circuit of Fig. 4(c). For other circuits resistance values are found from the formulae of Fig. 3 or from tables. All values given by the monograms are for 600 ohms impedance.

The chart Fig. 6 gives the inductances and capacitances required for the non-resonant sections corresponding to inverse impedances (i) and (ii) of Fig. 3. Section (i) is not normally used in line equalisation, but has been included for the sake of completeness.

The pad loss scale at the right is double-sided, the side to be used depending on the type of circuit. The point corresponding to the desired pad loss is located on this scale. In the usual case of the type (ii) section, the right-hand side will be used.

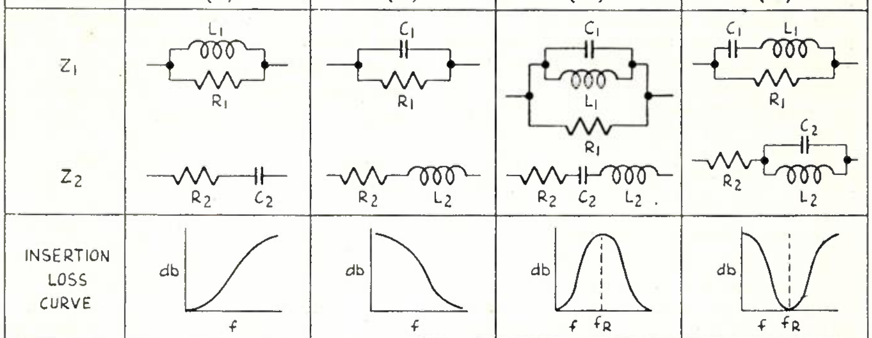
The half-pad-loss frequency f_B is then located on the scale at the left. A straight line drawn through the f_B and pad loss points will intersect the centre scale at a point giving C_1 in microfarads on the right-hand side of the scale and L_2 in millihenries on the left-hand side.

Fig. 6 does not give resistance values. As these are the same for both resonant and non-resonant types, they may be found from Fig. 7 or from tables.

The second chart, Fig. 7, applies to the resonant sections (iii) and (iv). The scale for b is double-sided, the left-hand

INVERSE ARMS CONTAINING RESISTANCE AND REACTANCE

TYPE	(i)	(ii)	(iii)	(iv)



	(i)	(ii)	(iii)	(iv)
POWER RATIO AT FREQUENCY f	$1+\frac{K^2-1}{1+K\left(\frac{f_B}{f}\right)^2}$	$1+\frac{K^2-1}{1+K\left(\frac{f}{f_B}\right)^2}$	$1+\frac{K^2-1}{1+K\left(\frac{\frac{f}{f_R}-\frac{f_R}{f}}{b-\frac{1}{b}}\right)^2}$	$1+\frac{K^2-1}{1+K\left(\frac{b-\frac{1}{b}}{\frac{f}{f_R}-\frac{f_R}{f}}\right)^2}$
DESIGN FORMULAE	$L_1 = L_B\frac{K-1}{\sqrt{K}}$	$L_2 = L_B\frac{\sqrt{K}}{K-1}$	$L_1 = L_R\frac{K-1}{\sqrt{K}}\left(b-\frac{1}{b}\right)$	$L_1 = L_R\frac{\frac{K-1}{\sqrt{K}}}{b-\frac{1}{b}}$
	$C_2 = C_B\frac{K-1}{\sqrt{K}}$	$C_1 = C_B\frac{\sqrt{K}}{K-1}$	$L_2 = \frac{L_R}{\frac{K-1}{\sqrt{K}}\left(b-\frac{1}{b}\right)}$	$L_2 = L_R\frac{b-\frac{1}{b}}{\frac{K-1}{\sqrt{K}}}$
			$C_1 = \frac{C_R}{\frac{K-1}{\sqrt{K}}\left(b-\frac{1}{b}\right)}$	$C_1 = C_R\frac{b-\frac{1}{b}}{\frac{K-1}{\sqrt{K}}}$
			$C_2 = C_R\frac{K-1}{\sqrt{K}}\left(b-\frac{1}{b}\right)$	$C_2 = C_R\frac{\frac{K-1}{\sqrt{K}}}{b-\frac{1}{b}}$
	$L_B = \frac{R_0}{2\pi f_B}$	$C_B = \frac{1}{2\pi f_B R_0}$	$L_R = \frac{R_0}{2\pi f_R}$	$C_R = \frac{1}{2\pi f_R R_0}$
	WHEN R_0 = 600 OHMS AND f_B AND f_R ARE IN Kc/s			
	$L_B = \frac{95 \cdot 49}{f_B}$ mH	$C_B = \frac{0 \cdot 2653}{f_B}$ μF	$L_R = \frac{95 \cdot 49}{f_R}$ mH	$C_R = \frac{0 \cdot 2653}{f_R}$ μF
	$R_1 = R_0(K-1)$		$R_2 = \frac{R_0}{K-1}$	
	$R_0^2 = R_1R_2 = \frac{L_B}{C_B} = \frac{L_R}{C_R} = \frac{L_1}{C_2} = \frac{L_2}{C_1}$			
DEFINITIONS	$R_0 = Z_0$ = EQUALISER RESISTANCE PAD LOSS = MAXIMUM LOSS IN db = $20 \log_{10} K$ K = CURRENT RATIO AT MAXIMUM LOSS f_B = FREQUENCY FOR HALF MAXIMUM LOSS f_R = RESONANT FREQUENCY $b = \frac{f_R}{f_B}$ DEFINED AS GREATER THAN 1 POWER RATIO = $\frac{\text{POWER TO LOAD WITHOUT EQUALISER}}{\text{POWER TO LOAD WITH EQUALISER}}$ = (CURRENT RATIO)^2 INSERTION LOSS IN db = $10 \log_{10}$ (POWER RATIO)			

Fig. 3.—Formulae for Complex Inverse Impedance.

side applying to (iii) and the right-hand side to (iv).

Scales for R_1 and R_2 are included, one on each side of the pad loss scale. These apply to all the four circuits considered. Since R_1 and R_2 depend only on pad loss, the markings on the pad loss scale have been extended horizontally to meet these scales. To find R_1 and R_2 it is only necessary to note the values at which the desired pad loss marking meets these scales. The R_1 and R_2 scales are not an essential part of the nomogram, and should be disregarded when other component values are being found.

To find inductance and capacitance values, two operations are necessary:

i. Draw a straight line joining the required values of pad loss and b, using the appropriate side of the b scale. Mark the point where this line cuts the central reference line.

ii. Locate the value of f_R on the scale at the extreme right. Draw a straight line joining this to the intersection point found as above on the reference line, and extend it right across the diagram. The component values are read off from the intersections of this line with the L_1–C_2 scale (at extreme left) and the L_2–C_1 scale (to the right of the centre line).

Resonant frequency of any L–C circuit: Fig. 7 may also be used to obtain the resonant frequency of any L–C combination within the scale ranges, or to find one component when the resonant frequency and the other component are known. A straight line drawn across the chart through the inductance value on the L_1 (or L_2) scale and the capacitance value on the C_1 (or C_2) scale will cut the f_R scale at the resonant frequency of the circuit.

Change of Impedance Value: The component values obtained as above are for the usual impedance of 600 ohms. If components are required for any other impedance Z_0 ohms, value may be found from the charts and the following procedure adopted:—

Resistance and inductance—multiply by $Z_0/600$.

Capacitance—divide by $Z_0/600$.

Change of Frequency: The charts cover the range of values likely to be encountered in programme line equalisation. By using multiplying factors they may be used for frequencies and component values outside this range.

The inductance and capacitance values are inversely proportional to f_B or f_R. If these values are found from the chart for any value f_1 of f_B or f_R, the value for any other frequency f_2 may be obtained by multiplying by f_1/f_2. The frequency f_2 may have any value,

e.g. (a) Required values for $f_B = 50$ c/s (Fig. 6).
Find values for $f_B = 0.1$ kc/s and multiply by 2.

(b) Required values for $f_R = 40$ kc/s (Fig. 7).
Find values for $f_R = 4$ kc/s and multiply by 0.1.

The same method may be used in the unlikely case where the desired frequency is within the scale range but any of the inductance and capacitance values are found to lie beyond the scale limits.

Circuits with Inverse Arms Purely Reactive: The nomograms may also be used to find components for circuits using the reactive arms of Fig. 2, for which the maximum loss is infinite. It will be noted that the algebraic expressions for these components are similar to those of Fig. 3, with the term in K omitted, and a and f_A substituted for b and f_B. This leads to the following rule for finding components of the circuits with the inverse reactances of Fig. 2:

Use the nomogram for the corresponding circuit based on Fig. 3, and proceed normally, but use f_A instead of

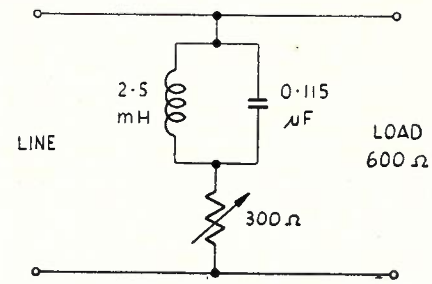


Fig. 5.—Simple Shunt Equaliser.

of f_B, for resonant circuits a instead of b, and work from the mark "X" on the pad loss scale. This mark is at 8.4 db, for which $(K-1)/\sqrt{K} = 1$.

Examples of Use of Nomograms

(a) Design a non-resonant 600 ohm bridged-T equaliser using circuit (ii) of Fig. 6, having maximum loss of 5 db at zero frequency, and loss of 2.5 db at 3.5 kc/s.

Use right-hand pad loss scale of Fig. 6. Join 5 db on this scale to 3.5 kc/s on f_B scale. Intersection on centre scale gives

$C_1 = 0.13$ μF
$L_2 = 46$ mH.

From pad loss scale of Fig. 7, for 5 db, $R_1 = 168$ ohms and $R_2 = 980$ ohms.

(b) Design a resonant 600 ohm bridged-T equaliser using circuit (iv) of Fig. 7, with maximum loss of 20 db, 0 db loss at resonant frequency of 7 kc/s, and 10 db loss at 5 kc/s.

We have $b = f_R/f_B = 7/5 = 1.4$.

In Fig. 7, use right-hand for b. Join 1.4 on this scale to 20 db on pad loss scale. Mark intersection on reference line. Draw line across diagram through this point and 7 kc/s on f_R scale. Intersection of this line with scales of component values gives

$L_1 = 57$ mH $L_2 = 3.3$ mH
$C_1 = 0.0092$ μF $C_2 = 0.16$ μF

From pad loss scale, for 20 db, $R_1 = 490$ ohms and $R_2 = 122$ ohms.

(c) Design a simple resonant shunt equaliser to work between 600 ohms impedances, with loss curve as in Fig. 3 (iv), maximum loss of 10 db, 0 db loss at resonant frequency of 5 kc/s, and 5 db loss at 2.5 kc/s.

From Fig. 1 the circuit is Type I(b) and the shunt impedance $\frac{1}{2}Z_2$ where Z_2 is as in Fig. 3(iv). The required circuit consists of a resistance $\frac{1}{2}R_2$ in series with a combination of $\frac{1}{2}L_2$ and $2C_2$ in parallel. The values of L_2 and C_2 may be found from Fig. 7 but not the value of R_2 which is given by $R_0/(K-1)$. Substituting $R_0 = 600$ ohms and $K = \text{antilog}(10/20) = 3.16$, R_2 is found to be $600/2.16 = 278$ ohms.

The value of b is 2. Using Fig. 7 as for (iv), join 2 on the right-hand b scale to 10 db on the pad loss scale. Mark intersection on reference line. Draw line through this point and 5 kc/s on f_R scale. This gives $L_2 = 24$ mH and $C_2 = 0.043$ μF.

The components for the shunt circuit are therefore 139 ohms, 12 mH and 0.086 μF.

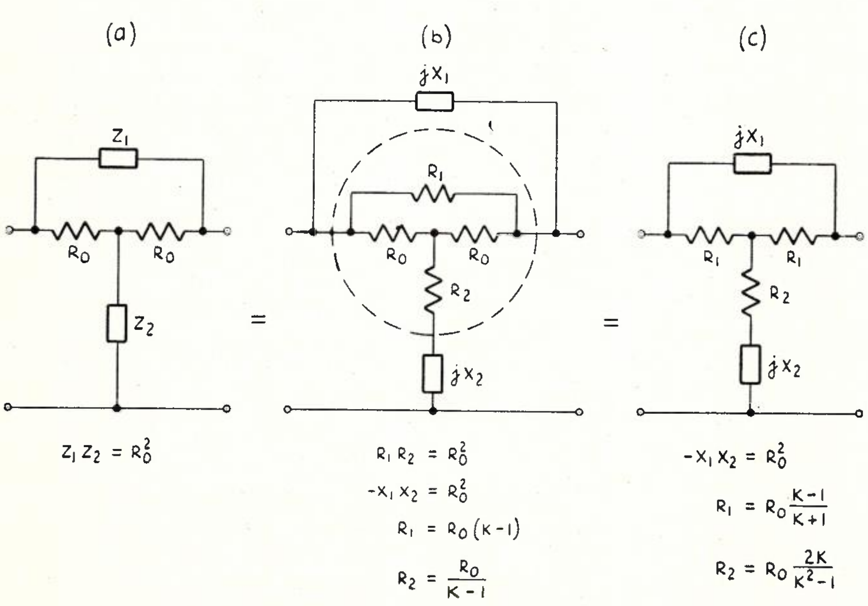


Fig. 4.—Derivation of Simplified Bridged-T Networks.

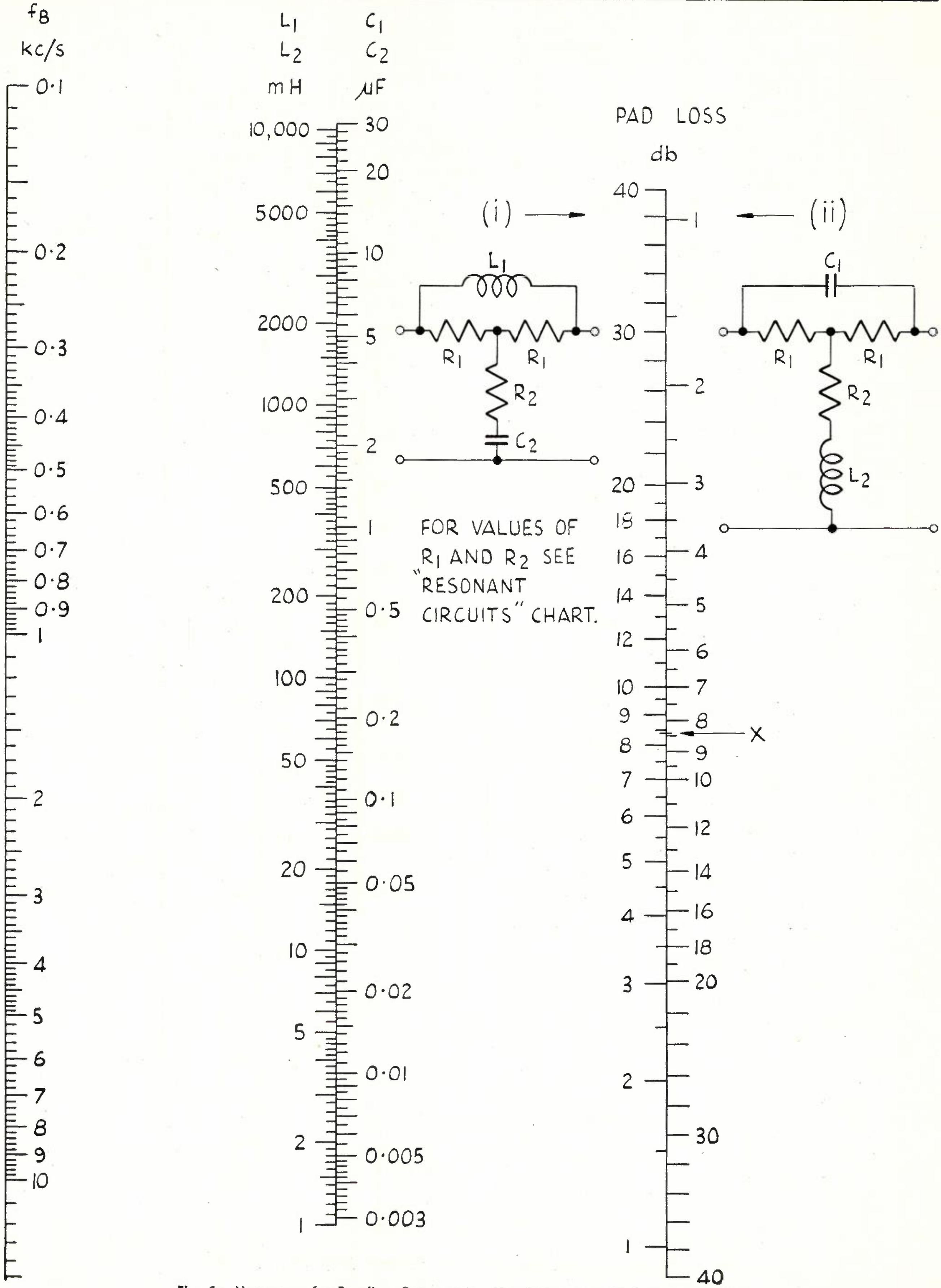


Fig. 6.—Nomogram for Equaliser Components—Non-Resonant Circuits, Z_0 = 600 ohms.

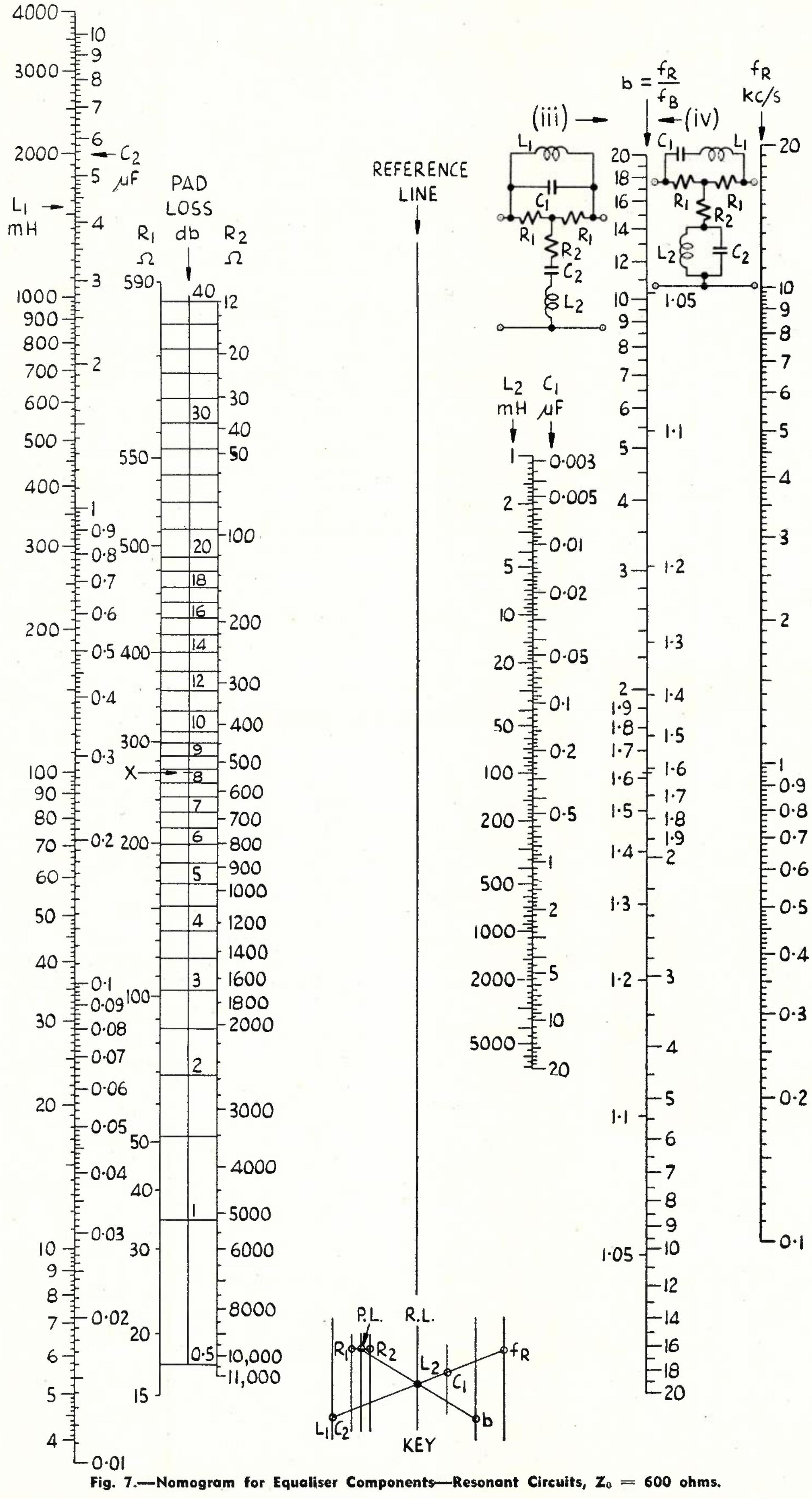


Fig. 7.—Nomogram for Equaliser Components—Resonant Circuits, Z_0 = 600 ohms.

(d) Design a 150 ohm bridged-T equaliser of Type III(c) of Fig. 1 with inverse impedances as in Fig. 2(iii). The resonant frequency giving infinite loss is 100 kc/s and the loss is 3 db at 40 kc/s.

The resistance arms are each R_0 or 150 ohms. The ratio $a = f_R/f_A = 100/40 = 2.5$.

The reactive components for 600 ohms impedance are found from Fig. 7 by using the value of a or 2.5 on the left-hand b scale. Join this point to the mark "X" on the pad loss scale, and mark the intersection on the reference line. Since f_R is 100 kc/s which is beyond the scale limits, use 10 kc/s on the f_R scale. Drawing a line through 10 kc/s and the intersection point gives the values—

$L_1 = 20$ mH $L_2 = 4.6$ mH
$C_1 = 0.0125\ \mu F$ $C_2 = 0.056\ \mu F$

Multiplying by 10/100 or 0.1 gives—

$L_1 = 2.0$ mH $L_2 = 0.46$ mH
$C_1 = 0.00125\ \mu F$ $C_2 = 0.0056\ \mu F$

To obtain the values for 150 ohms impedance, multiply inductance values and divide capacitance values by 150/600 or 0.25. This gives—

$L_1 = 0.50$ mH $L_2 = 0.115$ mH
$C_1 = 0.0050\ \mu F$ $C_2 = 0.0224\ \mu F$

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Mr. J. L. SKERRETT

Congratulations are extended to Mr. J. L. Skerrett on his appointment as Director, Posts and Telegraphs, Victoria, on 2nd August, 1957. Mr. Skerrett has always taken a keen interest in the activities of the Telecommunications Journal, having contributed several articles at various times. He was a sub-editor for a period of approximately four years from 1944-1948.

Mr. Skerrett's rise in the Department has been a rapid one. He first entered the service in 1928 as a junior mechanic in-training. During the depression he was transferred as an assistant and served as a telephonist and lineman for a period, being finally appointed as a mechanic in 1936. He passed the open engineering examination in 1937 and was engaged on telephone equipment engineering in the Melbourne office for about two years thereafter. Upon transfer to the Headquarters staff he joined the section, then known as the Transmission and later Long Line Equipment Section, being promoted to Divisional Engineer during 1948. During this year he transferred to the Buildings Branch as Senior Buildings Officer and was promoted through the various grades until he became Director, Buildings, in 1955.

Mr. Skerrett's pleasing personality and ability to concentrate on the core of a problem being dealt with will no doubt be of great benefit to the Victorian Administration.

CORRECTION—MR. R. V. McKAY, M.I.E.(Aust.), F.I.R.E.(Aust.).

In the February, 1957, issue of the Journal Mr. R. V. McKay was credited only with Associate membership of the Institution of Engineers, Australia. It has been brought to our notice that Mr. McKay is both a Full Member of the Institution of Engineers, Australia, and a Fellow of the Institution of Radio Engineers, Australia. The apologies of the Board of Editors are tendered to Mr. McKay for this regrettable error.

DROP WIRE WITH INTEGRAL STEEL BEARER WIRE

*D. P. BRADLEY, B.Sc., B.Com., A.M.I.E.Aust.**

In the post-war years increasing quantities of insulated drop wire have been used for subscribers' distribution work in urban areas, particularly via isolated cable head terminal poles (I.T.P.'s). In this method a 5 pair or 10 pair cable terminal box is fitted on a pole and drop wire leads taken to the houses in the immediate vicinity of the pole. Usually single span leads go to the houses on the near side of the street, while leads to those on the far side of the street are frequently two span using a power supply pole as the intermediate support.

The drop wire used until recently consisted of two .044″ cadmium copper conductors, polyvinyl chloride (P.V.C.) covered in a dumb-bell formation (see Fig. 1). It was generally satisfactory but

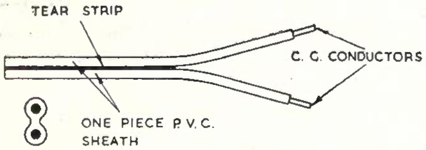

Fig. 1.—Original P.V.C. Insulated Drop Wire.

did not lend itself to a neat and satisfactory termination. This is partly because the P.V.C. coating does not adhere to the copper. Examination of a piece of P.V.C. coated wire will show that the plastic virtually forms a tube inside which the wire is free to rotate and to move lengthwise. Thus if a length of P.V.C. covered wire is held in a clamp and the free end is pulled, the wire pulls through inside the plastic covering and the tension at the clamp is transferred to the plastic which, of course, has a relatively low tensile strength and will fail fairly readily.

A second difficulty was due to "cold flow" of the plastic; this occurs at any point where continual pressure is applied to the P.V.C. which tends to flow away from the point of application of the pressure much like a very viscous fluid. This effect can eventually result in the conductor being bared at that point.

This drop wire was terminated by tieing it off on itself in a bow tie using a separate length of covered wire as a tie. The tie is elaborate but there is evidence that failure can occur and an investigation of alternative methods became essential. Overseas practice is to use a simple pressed steel friction clamp for terminating synthetic rubber covered drop wire but this fitting is not suitable for use with a P.V.C. covered drop wire because of cold flow and lack of adhesion. Synthetic rubber is not prone to cold flow and suitable methods are available for making it adhere to wire.

Attention was then given to the question of using synthetic rubber in place of P.V.C. for coating drop wire. The suitable synthetic rubber is neoprene but neoprene drop wire is considerably more expensive than P.V.C. drop wire, partly because neoprene itself is more expensive than P.V.C. and partly because it has poor electrical qualities and must be used in association with another insulant. The manufacturing processes involved in making neoprene covered drop wire are firstly, lead coat copper conductor; secondly, extrude natural rubber insulation over conductors (the lead coating makes the rubber adhere to the copper); thirdly, vulcanize rubber; fourthly, extrude neoprene sheath over rubber covered conductors; fifthly, vulcanize neoprene (rubber and not P.V.C. is used as the conductor insulant as the heat used to vulcanize the neoprene sheath would melt P.V.C.). By contrast, the manufacture of P.V.C. drop wire involves one process only—passing the wires through the extruding machine together.

Cost investigations showed that the price of neoprene drop wire would be at least twice and possibly three times as much as the P.V.C. covered article, and a search was made for a less expensive alternative. In discussions between Mr. P. R. Brett, Senior Physicist, Research Section, Mr. J. C. Sloss, and Mr. V. J. White Lines Section, Central Office, the question was asked why should the conductors be used to carry the mechanical load? Why not use a separate steel bearer wire to carry the load and so put the termination problem at a point where failure of the plastic would have little consequence? Based on this suggestion Mr. Sloss and Mr. White prepared the design shown in

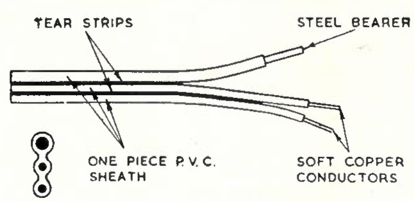

Fig. 2.—New Type Drop Wire.

Fig. 2. This consists of a steel wire side by side with two soft copper wires; the three wires are moulded integrally together in flat formation with the bearer wire on the outside joined to the copper conductors by a tear strip. This is the design which has now been adopted as standard.

Some fears were expressed initially that the new design with its flat ribbon like shape, would be particularly susceptible to the effects of wind gusts. Trial quantities were accordingly made up of an alternative design consisting of two twinned P.V.C. covered conductors laid around a separate steel bearer wire. Exposure test for 12 months in a windy location with both new formations as well as the old one side by side did not show any particular difference in behaviour and the alternative design, which is more expensive, was therefore abandoned. In these tests, the new standard drop wire was given three or four twists per span so that the conductors are supported by bearing on the steel wire and not by the strip of P.V.C. This practice is the standard procedure in service.

To terminate the new drop wire, the bearer wire is separated from the two conductors at the tear strip. The conductors are taken away to their terminal point and the steel bearer wire terminated either by looping it around a hook

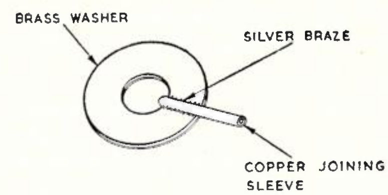

Fig. 3.—Terminating Sleeve.

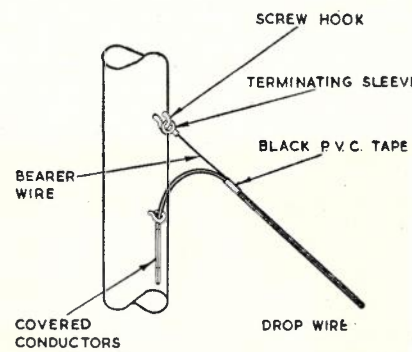

Fig. 4.—Method of Termination.

fitting and binding it off on itself, or else with a terminating sleeve as shown in Figs. 3 and 4. A standard wire jointing tool is used to press the sleeve onto the wire.

The steel bearer wire has an ultimate tensile strength of 788 lbs. and tests on a terminated bearer show that the sleeve type termination will fail at about 600 lbs. The failure occurs at the braze joint; the wire does not pull out of the sleeve.

The immediate advantages and the reason for the development of the new design is the simple and effective termination. A further incidental but most important advantage is the flexibility of design due to the fact that the breaking load and conductivity can be varied independently of each other. The size of the bearer wire is adjusted to the mechanical conditions of usage and the size of the conductors are fixed independently by the prevailing transmission conditions. Thus a drop wire can be specified for long span construction which uses a steel bearer wire of appropriate strength in association with light copper conductors.

By contrast, if a high tensile drop wire is required in cadmium copper or copper covered steel wire, then a conductor diameter larger than required by transmission considerations may be necessary.

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* Mr. Bradley is a Sectional Engineer in the Lines Section, Central Administration.

As copper is expensive and steel comparatively cheap, the new design with separate bearer will meet the same strength requirements at a lower price.

Another important advantage is the ease of termination of the soft copper conductors which can be readily bent around in tight loops and connected to screw type terminals. By contrast, both cadmium copper and copper coated steel wire are springy and hard to terminate on simple screw terminals.

Drop wire currently in use has 20 lb. soft copper conductors (.036″ diameter) and a high tensile steel bearer wire of .080″ diameter. Most requirements would be met by 6½ lb. (.020″ diameter) conductors and a .080″ mild steel bearer wire (ultimate strength about 300 lbs.). This formulation is appreciably cheaper than the 20 lb. type and field trials are about to commence with it. The major difficulty is in stripping the insulation off the light copper wire without nicking or cutting the wire. The most effective method is to use a type of termination which squeezes the insulation off an unstripped wire when the terminal is screwed up. It has been found that the screw terminal on the standard cable terminal box is effective for this purpose; if an insulated wire is inserted in the wire hole and the terminal is screwed up, the screw face squeezes the P.V.C. off the wire and makes effective contact with the copper without damaging it.

NEW PROCESSES USED IN THE MANUFACTURE OF HAND POSTMARKERS

*H. J. LEWIS**

Two interesting processes were recently introduced in the manufacture of hand postmarkers in the Melbourne Workshops. Postmarkers were made previously by a commercial engraver, all characters on the head and number wheels being cut by hand tools. These hand methods were costly and resulted in irregular and faulty marking. To overcome these factors, advantage has been taken of the process of investment casting, which has been developed in recent years to assist manufacture of precision parts in the very tough steels and alloys used in turbo-jet engines.

The investment casting process is used to make the body, which normally includes the "State" and "Country" lettering. The "Town" lettering is added by hand engraving. The process is a simple one which results in an accurate product requiring little or no finishing treatment. The Workshops cast a "pattern" in the form on an injection moulding of polystyrene. This is set in a quick hardening ceramic paste. When the ceramic has hardened, the polystyrene is removed by heat and replaced with the desired metal. There is little limit to the metal which can be cast in this manner, and some of the high-tensile alloys such as stainless steel and chrome steel, are actually preferred. When the mould has cooled, the ceramic is broken away, leaving an accurate reproduction of the original polystyrene pattern.

The other new process is the injection moulding of nylon (polyamide) number wheels instead of hand-engraving steel ones. Nylon is a particularly tough and durable material which is ideal for this work. The moulding process ensures an accurately reproduced shape which can be consistently and cheaply made. However, the shape of these wheels is very complex, and the die to mould them, likewise complex. A very accurate die was made in the Melbourne Workshops which should provide many thousand wheels for both the hand postmarker and other machines to which they can be fitted. This die has removable radial pins which carry the reverse engraving of the desired numbering. These pins are set around the cavity of the die, facing in, and are automatically withdrawn slightly as the die opens, to free the moulding so that it can be removed from the die. The radial pins can be changed to provide any combination of numbers or characters required on the different types of number wheel. This also enables any faulty character to be replaced and so produce a near perfect product, while maintaining a tolerance of plus nothing minus two thousandths of an inch in the overall diameter of the wheel.

The first postmarker produced by these processes was the special one for the Antarctic Expedition in 1957. The face engraving does not carry the normal State and Country investment-cast characters, as this postmarker had special wording. The postmarker is fitted with a red moulded handle with a flattened upper radius which conveniently fits the palm of the hand. The resultant article is a durable and attractive one which will be supplied complete at approximately half the cost of the former type.

A system of batch manufacture of the basic postmarker has been established, whereby the annual requirements of postmarkers are held in the Melbourne Workshops and the "Town" lettering added in accordance with requests from the Postal District Officers throughout the Commonwealth.

1. Complete Postmarker for 1957 Antarctic Expedition. 2. Polystyrene Pattern for Investment Casting of Body. 3. Investment Cast Nickel Steel Body. 4. Locking Pin. 5. Number Wheel Shaft. 6. "Nylon" Number Wheels, Before, After Trimming Sprue. 7. Details of Engraving as Normally Investment Cast. 8. Polystyrene Pattern.

* Mr. Lewis is a Divisional Engineer in the Telegraphs and Workshops Section, Central Office.

FACTORS AFFECTING THE DESIGN OF BIMOTIONAL SWITCH WIPERS

A. A. SMITH*

INTRODUCTION

A bimotional switch as used in automatic telephone exchanges can be no better than its wipers, and although, over the years, much attention has been given by designers to these wipers, this important component persists as a major source of performance trouble and contributes significantly to exchange maintenance costs. This situation is not surprising in view of the complexity of the design problem involved in this deceptively simple looking piece of mechanism. Many requirements affect its design and it is possible to overlook some of these in appraising a particular design, with the result that virtues and defects may tend to obscure each other. This article presents, under four main headings—namely, performance, interchangeability, manipulation and cost—a list of factors affecting the design of bimotional switch wipers, and discusses each briefly.

PERFORMANCE

(a) **Stability of Blades when in Motion off the Bank Contacts.** Freedom from oscillation which can cause crashing is of major importance. Conditions for trouble in this regard are present in the discriminating selector repeater in accordance with circuit drawing CE.133 due to fleeting loops, in line finders due to quick cut-in after vertical search, in SE.50 and pre-2000 type switches due to rotary rebound after rotary release, in 2000 type switches at the end of vertical release, and in all switches having automatic cut-in after vertical stepping. The design problem here is to meet this requirement without degrading requirements after cut-in, and existing designs achieve only compromises, to varying degrees. For example, stiff blades may control oscillation effectively but they are unfavourable in respect of pressure gradient; limiting stops to be effective can result in depriving the blades of tracking latitude. These factors are discussed later.

(b) **Clearance from Bank during Vertical Motion.** This requirement limits the maximum width of the wiper tips, see "b" dimension, Fig. 1, but other requirements of the tip shape, discussed under (c), (d), (g), (k), are degraded progressively as the width is reduced. The optimum width appears to be in the vicinity of .130".

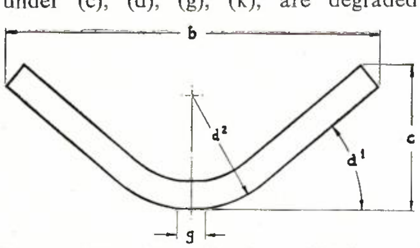

Fig. 1.—Wiper tip section tangential to contacting arc.

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(c) **Flare of Tips.** Dimension c of Fig. 1 refers. The maximum for this dimension is limited by required clearance from adjacent levels when the wiper is entering and is entered on the contacts; the minimum is limited by required latitude for cut-in. This latitude is affected by:—

- Alignment errors in adjusting.
- Irregularities in spacing of bank levels at entry, and irregularities in spacing of vertical detent teeth, requiring compromise adjustment of wiper height.
- Vertical detent wear (tip or bearings) causing fall subsequent to wiper adjustment.
- Tip wear, resulting in the blades being brought closer together in re-adjusting to correct the tip gap.

The optimum dimension for the overall height of an unworn tip appears to be in the vicinity of .050".

(d) **Contact Bounce.** This requirement is regulated by flare angle of the tip (see d^1 of Fig. 1), by transition curve radius of the tip (see d^2 Fig. 1), by contact pressure (d^3) and by the inertia (d^4) of the blades concerned in their spreading as they enter and traverse the bank level. Flare angle and transition curve are regulated by requirements under (b), (c), (g) and (k). The object is to have the flare angle (flare to horizontal) as small, and the transition curve as gradual as possible within the limitations. The characteristics concerned in d^1 and d^2 affect bounce on cut-in, but d^1 is not so operative during the movement from contact to contact. Flare angle and transition curve are discussed further under (g). Contact pressure (nominal) is regulated by surface area of contact. For satisfactory contact resistance the area of the contact should not be too great, as electrical resistance increases as the pressure per unit area decreases. If contact area is increased, and pressure is also increased to avoid reduction in pressure per unit area, the force required to move the wipers is increased. This is disadvantageous in respect of the switch operation, especially in releasing (by restore spring), and it also calls for a more robust wiper with consequent detriment to the inertia factors (d^4) and (l). Small contact area, low inertia and moderate contact pressure are indicated as desirable characteristics. Wiper tips giving true double contacting would be advantageous provided they were designed in such a way that they did not bounce in unison. Evaluation of contact bounce by oscilloscope or equivalent is necessary.

(e) **Pressure Gradient.** This refers to the rate of variation of contact pressure with vertical displacement of the bank contacts relative to the wiper assembly mounting. Wipers having a low, and consequently desirable, pressure gradient would be those in which vertical displacement within the required limits had little effect on contact pressure. In the ideal case, displacement would have no effect on pressure. If the pressure gradient is unsatisfactory, i.e. too steep, contacting will become defectively light on the one hand and destructively heavy on the other, within the limits of displacement which can be encountered. Displacement can occur due to the factors listed under (c) and due also to the following:—

- Progressive rise or fall of bank levels from contact 1 to contact 11.
- Irregularity of level of vertical detent teeth (or equivalent).

A pressure gradient of 1 gram for 5 mils displacement from a normal contact pressure of 30-35 grams is considered satisfactory.

(f) **Tracking Latitude.** This term refers to the measure of the ability of the wipers to accommodate themselves to variations in the height of a bank level relative to the height of the wiper mounting at that level before one or other blade contacts an oscillation limiting device, causing contact cut-off, or before deflection otherwise reaches the limit for satisfactory contacting. Examples of limiting devices are the limiting stops of SE.50 wipers and the tongue of the insulating plate of 22 type wipers. It should be specially noted that the nominal clearance between the blades and their limiting stops is not a measure of the latitude for displacement before a blade meets its stop. For example, the nominal clearance on either side of the tongue of the 22 type wipers provides for 30 to 35 mils displacement of the tips before a blade meets the tongue, but this dimension can be absorbed in fact by a combination of the six conditions listed under (c) and (e) above and by a seventh, viz.:—

- Blades not central between or about their limiting stops, allowing greater displacement of one blade before it meets its stop at the expense of the other, notwithstanding that total displacement may be normal.

Wide clearances between blades and limiting stops are necessary to avoid contact cut-off, but wide clearances conflict with the requirement under (a).

(g) **Resistance to Wear.** Design characteristics affecting wear of wiper tips and the bank contacts are:—

the metals used in combination; pressure per unit area; contact bounce; tip form; other factors, such as the effects of dust and lubrication, being common influences.

The objectives are: slow rate of wear for both wiper and bank contact, particularly the latter, and retention of original tip form despite wear.

The question of the most suitable combination of metals is contentious but it can be said briefly that, for wipers, the two most generally satisfactory metals used in Australian exchanges to date have been nickel silver and phosphor bronze, of particular composition and

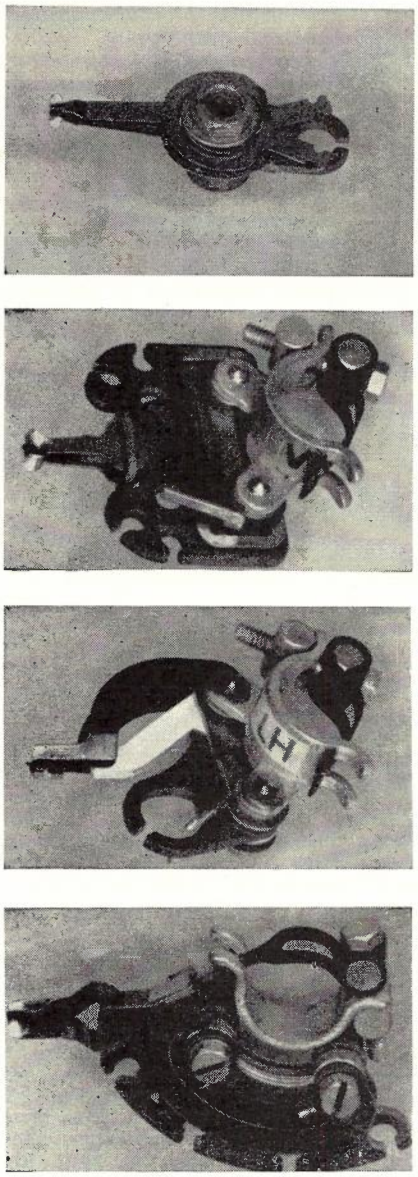


Fig. 2.—Wiper Types referred to in this Article. They are from the top down, pre-2000 type, A.T. & E. Co. 22 type, A.T. & E. Co. 51 type and G.E. Co. S.E. 50 type 6.

hardness in each case. Consideration of metals for wipers must include regard for factors such as contact resistance, ductility for forming, cost, etc., as well as wear. The case for small contact area derived under (d) above is not in conflict with the resistance-to-wear requirement, but tip shape is relevant. Flare of tips has been considered under (c) and flare angle and transition curve under (d), but there is a further characteristic of the tip section—the contacting area, which can be referred to as a flat (see g, Fig. 1). If a flat is not present at the outset, one is quickly produced by wear, and this can result in correspondingly rapid increase in tip gap spacing and in reduction of contact pressure (see (i) below in this connection), flare dimension, and thickness of metal available for wear.

It therefore appears desirable to start with a flat by design, but introduction of a flat within the limitations set by tip width and flare will degrade the flare angle and/or the transition curve to some extent. Compromise is necessary, and in Fig. 1, which is drawn to scale, a flat .010″ wide is accommodated in a construction .130″ wide, .050″ high, having a 40° flare angle and a transition curve radius of .040″.

Inherent in pressure per unit area, as affecting wear, is the pressure gradient factor as discussed under (e). For any given displacement, the steeper the pressure gradient the more the possibility of wear. Referring to contact bounce, greater wear can be expected on private wipers than on line wipers because current switching is involved in the former and wear is considerably aggravated by any sparking present. Sparking is aggravated by contact bounce which, therefore, has this disadvantage additional to its interference with proper circuit functioning. The tip form must be capable of production in manufacture without any appreciable reduction of the metal thickness at the area of contact due to the forming operation.

(h) **Behaviour when Tip Worn Through.** The form of the tip should be such that when depth of wear equals the thickness of the material the wiper does not break and also does not catch on the bank contacts.

(i) **Contact Pressure System.** Depending on the contact pressure system employed, the tip gap dimension, either as set initially or as increased by wear, also variations which do occur in the dimension between surfaces of upper and lower contacts of a bank level, can have much or little effect on contact pressure, and consequently on wear.

Pressure gradient is again involved here but, as distinct from the pressure gradient factor discussed under (e), it concerns in this case the rate of increase or decrease of contact pressure as affected by changes in the extent to which the blades are spread by the bank contacts due to the factors mentioned above. Fulcrum systems, such as employed in the 22 type and SE.50 type designs, are less advantageous in this regard than the simpler lever system of pre-2000 type and 51 type designs, in which contact pressure derives directly from the tensioning of the two blades towards each other.

In the simple lever system, the pressure gradient under discussion would be identical with the pressure gradient discussed under (e). For example, 5 mils wear on a tip in this case would cause only the same reduction in contact pressure as 5 mils vertical displacement of the bank contact relative to the wiper mounting would cause. Also, with this system, tip gap may be set wider than with a fulcrum system, with consequent advantage for cut-in and without disadvantage to contact pressure. In the fulcrum systems, the effect of tip wear on contact pressure is distinct from and greater than the effect of displacement to the same extent. For example, a tip gap variation of 8 mils in the 22 type causes a contact pressure variation of about 7 grams, but 8 mils displacement of the contact relative to the wiper mounting causes only 1.5 grams variation.

Nevertheless, it cannot be assumed that a particular wiper design is necessarily superior in respect of this characteristic because it employs the simple lever system. Due to stiffness of its blades, it could have a displacement/pressure gradient worse than the tip gap/pressure gradient of an alternative design employing the fulcrum system and, in this event, would have the double disadvantage.

(j) **Contact Resistance and Stability.** Contact bounce, as discussed under (d), is an instability factor affecting the electrical performance of the wipers during rotary stepping, but trouble due to unstable contacting is probably more commonly manifest in the state when the wipers are at rest on the contacts. This trouble can range in severity from complete circuit interruption down to background noise interference on the line heard as formless frying or as noise patterns originating in vibration from adjacent switches. Microphonic wiper contacting probably accounts also for much of the discordance often heard in the receiver as switching occurs during the progress of dialling.

Contacting effectiveness is regulated by a number of physical factors including the choice of metals used for wiper and for bank contact, pressure per unit area actually exerted, pressure of dust or other deposits opposing conduction, ability of the tip, by nature of its form, to penetrate such deposits and the frequency of the opportunity to do this, and by vibration present. A detailed consideration of all factors affecting contacting is beyond the scope of this article but it is necessary here to observe that the ability of wipers to maintain satisfactory contact pressure per unit area under the full range of conditions encountered is of paramount importance to their electrical behaviour. In other words, factors discussed under (d), (e), (f), (g) and (i) above have a vital bearing on contacting effectiveness.

Double contacting wiper tips, as mentioned under contact bounce (d) would be notably advantageous also for the static contacting state. However, double contacting implies full independence of the two contacts and, as opposed to the case of uniselector wipers, it appears impracticable to achieve true double contacting with flat-spring wipers of bimotional switches because of the limitation imposed on their width as discussed under (b). Practicability would be enhanced by the use of wire to form the wiper springs.

(k) **Bridging.** This refers to the necessity to avoid bridging of adjacent bank contacts by the wiper tip during its progress from one contact to the next. The wiper tip must be safe in this regard, not only when unworn but also when worn to an extent acceptable in other respects. This requirement affects those relevant to tip construction discussed under (b), (c), (d), (g), but it is likely that, if the earlier requirements are satisfied, the tip will be satisfactory in respect of the bridging factor.

(l) **Inertia.** The weight of a wiper assembly and the location of its centre of gravity are of some importance. Stated simply, these factors affect the ability of the electro-mechanism to start and transport the wipers and to stop them without overshoot, and, consequently, they also have a bearing on wear of switch parts and stability of switch adjustments. They are significant because of the rapid acceleration and deceleration involved when the wiper carriage is removed.

Only weight is concerned in vertical stepping, but weight and distance between centre of gravity and axis of the switch shaft are both relevant to the rotary movement, in which wiper overshoot is more commonly concerned. Wiper overshoot is also concerned in the vertical movement in the case of the linefinder, which involves search on a vertical bank, and weight of the wipers has a bearing on this too.

(m) **Points of Wear other than Tips.** Designs employing a fulcrum system, unlike those using the simple lever system, can involve wear and casualty at points other than the tips. An example is the slotted moulding carried at the forked extremities of SE.50 type blades. Wear at the slots, due to normal and abnormal forces encountered by the tips, would affect contact pressure, and breakages of moulding and spring prongs could also occur.

(n) **Wiper Cords.** Provision for guiding and holding wiper cords should be such that there is no likelihood of cords fouling the wiper blades. Provision for terminating the cords at the wipers should give security of connection without entailing damage to the cords. In this regard, soldering entails the risk of weakening the cord where it leaves its tag, due to heat and due to impregnation with the solder flux, causing loss of flexibility.

(o) **Mounting.** The device for securing the assembly to the switch shaft or tube should meet the requirements under Manipulation, and should not cause damage to the shaft or tube.

(p) **Stability of Characteristics.** Wear and breakage is mentioned above, and these and other factors affecting stability require evaluation by life testing.

INTERCHANGEABILITY

This affects costs of manufacture, storage and maintenance, and the following characteristics are desirable:—

(q) **Wiper Assembly Parts**—

(i) Where two or more parts of the assembly have a common function, these parts to be identical. The two blades constitute the prominent example.

(ii) Any part capable of being positioned for assembly in more than one way to be equally suitable, by virtue of symmetry, for positioning in at least two of these ways.

(iii) The assembly of parts, less mounting device, to be symmetrical to the extent that either side can take the upper or lower position when presented for attachment to the mounting device.

(r) **Wiper Assembly**—

(i) The one wiper assembly, complete with mounting device, to be suitable for mounting in any bank position on the switch shaft or carriage.

(ii) The one wiper assembly, with adapting mounting device where necessary, to be suitable for use on SE.50, 2000 type and pre-2000 type switches. Factors to be considered here are—two different releasing systems; bi-directional wipers are required for SE.50 and pre-2000 type switches, and these switches also involve rotary rebound; smaller clearance available between lowest wiper assembly and bridge plate of 2000 type switch compared with SE.50 switch; no bridge plate in pre-2000 type switch; private wiper bridging is intended in the pre-2000 type switch.

MANIPULATION

The following characteristics are desirable for economic maintenance:—

(s) **Adjustment of Blades.** There should be clear access for pliers or bending tool used for tension adjustment and tip gap adjustment. Presence of a fixed part extending towards the tips is desirable for a visual reference to assist in adjusting the plane of the wipers at right angles to the shaft.

(t) **Alignment of Assembly.** The facility should be present for precise positioning of the wipers by permitting movement in vertical and rotary directions under full control before final tightening. Latitude for rotary positioning should be ample, and rotary movement must be concentric with the switch shaft. There should be no shifting of the assembly when the clamping device is finally tightened.

(u) **Renewal of Blades.** Because of the labour content of the cost involved in changing wiper blades, the extent to which a design facilitates this operation should be considered as a major factor in the appraisal of that design. No design used to date has fully exploited the possibilities in this regard, which include the following:—

(i) Portion only of a blade renewable, including the tip.

(ii) Complete blades renewable but provision made for their removal and refitting by loosening, not removing, the screws which clamp them.

(iii) Reduced number of parts comprising the assembly, e.g., no loose insulating bushes to complicate the assembling operation.

(iv) A low-cost unit consisting of blades moulded in or otherwise secured to an insulating body which may be readily detached from the remainder of the assembly and discarded as a unit, with or without disturbing cord terminations.

(v) Not necessary to unsolder and resolder cord terminations.

(vi) Removal of blades or whole assembly not to entail disconnection of cords to other wipers, and not to be impeded by cords or their own terminals.

(vii) Easy dismounting of assembly from shaft.

COST

Cost must take into account purchase price, handling costs, cost of fitting, length of service life and maintenance during that life, including attention resulting from performance faults. All of these factors are regulated by the characteristics listed above, and it would follow that a design satisfying service requirements under Interchangeability and Manipulation would be similarly advantageous in respect of manufacture.

CONCLUSION

Bimotional switch wipers of existing types, and any of new design to be considered, may be appraised against the above information but, to arrive at quantitative evaluations, it would be necessary to equate the factors by allocating an importance rating to each and to award a points score to each type against each factor. Totals would indicate the order of acceptability of the various types.

Opinions on importance ratings and on evaluations appropriate for each wiper type against each factor may differ to some extent, depending on usage requirements and individual outlook. Assessments have not been attempted here, but it can be stated that no type of bimotional switch wiper at present in use in Australian exchanges is favourable in all the characteristics. Common performance deficiencies derive from the apparent conflict between two basic requirements—rigidity when off the contacts and flexibility when on the contacts.

ANSWERS TO EXAMINATION PAPERS

Examination Nos. 4445, 4446 and 4465: Senior Technician, Telephone, Research and Radio and Broadcasting. July, 1956.

ELECTRICAL THEORY AND PRACTICE

Q.4.—(a) List the important points to be observed in the maintenance of a secondary battery.

(b) What is the usual reason for a cell in a secondary battery having a lower specific gravity and voltage than the other cells.

(c) How would you proceed to rectify the trouble referred to in (b).

A.—(a) The following are important points in battery maintenance:—

(i) Be careful to avoid overcharging, as this is wasteful of energy and shortens the life of a battery.
(ii) Do not allow the battery to over-discharge (that is, to discharge below its normal lower voltage limit of 1.85 volts per cell).
(iii) Do not let the battery remain in a discharged condition as this causes abnormal sulphation with a consequent loss of capacity.
(iv) Do not charge the battery at an excessively high rate, particularly towards the end of charge, as this causes excessive gassing and waste of power.
(v) Do not allow the sediment to reach the bottom edges of the plates as this is liable to cause short-circuiting of the plates.
(vi) Do not have a battery room either over-ventilated or too hot, because both of these causes produce an increase in the rate of evaporation.
(vii) The plates must always be kept covered with the electrolyte. To maintain the level of the electrolyte add only pure water.
(viii) Use only water and acid of a recognised standard of purity for the electrolyte.
(ix) Observe indications of irregular operation and take corrective action immediately. Attend promptly to weak cells. Clear internal short-circuiting immediately.
(x) Acid must not be added to a cell until the cause of the low specific gravity has been found.
(xi) When preparing the electrolyte always add the ACID TO WATER and never the water to acid.

(b) When a cell in a battery has a lower specific gravity and voltage than others the trouble is generally due to a short circuit, which may be caused by:—
(i) adjacent plates buckling and contacting;
(ii) spongy lead between plates;
(iii) contact with a lead-lined box; or
(iv) sediment.

A short circuit in a cell is indicated by the following symptoms:—
(i) Lack of gassing in line with the remainder of the cells on charge;
(ii) high temperature;
(iii) low specific gravity when the short-circuit has been on for some time.

(c) It is often possible to locate a short circuit in glass cells by placing an incandescent lamp behind the cell and examining the plates from the other side of the cell.

If a small compass mounted on a piece of insulating strip is placed between the connecting lugs of the plates one after another so that it rests on the smaller suspending lugs of the opposite plates, as long as the plates are free from short-circuits the needle shows little or no variation in its deflection as it is moved from lug to lug. When a plate is reached on which a short-circuit exists, the deflection suddenly changes and it retains its new position up to the other end of the cell. This plate is marked and the lugs on the opposite side are tested in the same way in order to determine between which pair of plates the short exists.

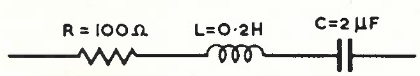
Having located the short-circuit, it may be removed by using a suitably shaped insulated tool. It may be necessary to remove the plates to straighten them or to clear the sediment from the bottom of the tank.

Q.5.—(a) Define—
Impedance
Conductance
Effective Resistance

(b) for the series circuit shown hereunder state the formula for its impedance.

(c) Calculate the current flowing in the circuit if a voltage of 2 volts at 796 cycles per second is applied to it.

(d) What is the power factor of the circuit.



Q.5.—Fig. 1.

A.—(a) **Impedance** is the total opposition expressed in ohms offered by a circuit to the flow of A.C.

Conductance may be defined as that property which a body has for conducting electricity. It is the converse of resistance and is measured by the reciprocal of resistance. Thus, a wire of R ohms resistance has a conducting power of 1/R units of resistance.

Effective Resistance. The definition of the resistance of a circuit by means of Ohm's Law is really equivalent to the statement that all the electrical energy supplied to the circuit is directly converted to heat; this ceases to hold for A.C. as part of the energy supply to an A.C. circuit is transferred to neighbouring circuits by induction and radiation. Capacitor losses, eddy currents and hysteresis also cause energy loss.

The idea of the resistance of a circuit as being merely the D.C. resistance of its conductors has, therefore, to be generalised. The resistance of a circuit can be defined as $R = \frac{P}{I^2}$ which holds for both D.C. and A.C.

This resistance no longer obeys Ohm's Law and so the resistance as above defined varies with current and frequency. This resistance, as stated above, is termed the Effective Resistance or A.C. resistance and must not be confused with Impedance.

(b) The formula is $Z = \sqrt{R^2 + \left(2\pi fL - \frac{1}{2\pi fc}\right)^2}$

(c) $Z = \sqrt{100^2 + \left(5000 \times 0.2 - \frac{10^6}{5000 \times 2}\right)^2}$

$= \sqrt{10{,}000 + (900)^2}$
$= \sqrt{820{,}000}$
$= 905\ \Omega$

Current $= \frac{2}{905} = 2.2$ mA

(d) The power factor of the circuit

$= \frac{\text{Resistance Component}}{\text{Total Impedance}}$

$= \frac{100}{905} = 0.11$

Q. 6.—(a) Describe with the aid of a sketch the construction of a typical indirectly heated 3 electrode thermionic valve and state the purpose of each of the electrodes.

(b) In a screen grid valve a 4th electrode is provided. What is the purpose of this additional electrode?

(c) What peculiar effect is noted in the anode current of a screen grid valve as the anode voltage is raised? What is the cause of this effect?

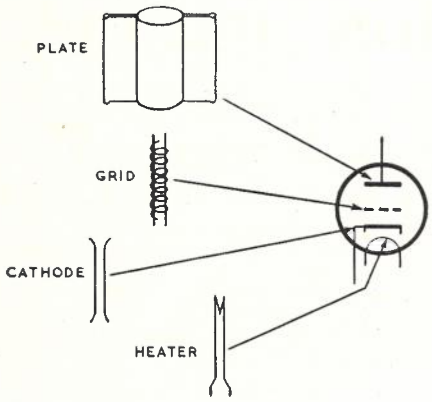
A.—(a) The three elements are—

(i) The cathode heater combination which, when raised in temperature by a current through the heater, emits electrons from the specially prepared surface of the cathode.

(ii) The grid, which is an open coil of fine wire surrounding and insulated from the cathode. It is used to control the flow of electrons from the cathode and normally is worked at a potential slightly negative to the cathode. Small fluctuations in this potential produce corresponding variations in the electron flow and, therefore, in the normal current flowing through the valve.

(iii) The anode, which is a cylindrical plate electrode surrounding and insulated from the grid and cathode. The anode is operated at a positive potential to the cathode and collects the electrons which travel from cathode to plate through the grid.

The whole internal structure described above is sealed in an envelope, usually made of glass, which is evacuated.



Q.6.—Fig. 2.

(b) Because of their construction the grid and anode of thermionic valves form a small capacitor, which couples the input and output circuits which are connected respectively to the grid and anode. At radio frequencies this capacitive coupling has undesirable effects. The insertion of another grid between the control grid and the anode, connected to the cathode has the effect of reducing the anode grid capacity to a very small value. If the screen grid, as this extra grid is called, is operated at a potential just lower than the anode potential it increases the amplification factor.

The screen grid is connected to the cathode by means of a small condenser which, while providing an A.C. path between the grid and the cathode, avoids short-circuiting of the D.C. supply.

(c) As the anode voltage is raised from zero the anode current first rises rapidly then, after reaching a particular value, commences to fall. At a slightly higher value of anode voltage the anode current again commences to rise and continues to do so as the voltage rises.

This dip in anode current is caused by secondary electrons emitted when the anode is bombarded by high velocity electrons from the cathode. The secondary electrons are absorbed by the screen grid which is at a higher voltage than the anode, and this causes the anode current to fall. When the anode voltage reaches a higher potential it is able to attract and recapture the secondary electrons and, therefore, the anode current is increased.

Q.7.—(a) The number 4 detector is fitted with a milliameter having a full-scale deflection with 10 mAs. flowing through it and an internal resistance of 10 ohms. Draw the circuit and show the value of the components in use when the detector is connected to measure—

(i) 500 mAs.

(ii) 5 volts.

(b) Describe a method of using the No. 4 detector to obtain a quick reading of the resistance of an odd unknown resistor assuming that a dry cell is available.

A.—(a) (i) Actual circuit of No. 4 detector set for 500 mA.

(ii) Actual circuit of No. 4 detector set for 5 volts.

(b) First set the No. 4 detector on the 5-volt scale and connect it across the dry cell. A reading of, say, 1.5 volts will be shown. Now connect the unknown resistor in series with the cell and the meter. A lower reading, say 1 volt, will now be obtained. The value of the unknown resistor is obtained from the formula—

$$R = V \left(\frac{D_1}{D_2} - 1\right)$$

where V = internal resistance of the detector

D_1 = meter reading without the resistor

D_2 = meter reading with the resistor

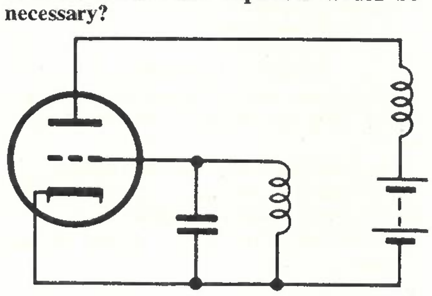
In the example $R = 500 \left(\frac{1.5}{1} - 1\right)$

$= 250$ ohms.

Q.8.—(a) Draw the circuit of a simple thermionic valve oscillator and explain how it operates.

(b) How is the frequency of the oscillator controlled?

(c) If the circuit oscillates at a frequency of 1,000 cycles per second with a tuning capacitor of 2 uF, how would you connect an additional capacitor to change the frequency to 2,000 cycles per second? What value capacitor would be necessary?



Q.8.—Fig. 3.

A.—(a)

Tuned Grid Oscillator. The tuned circuit which determines the frequency at which the oscillations will occur is connected between the grid and cathode of the valve. Oscillations set up in the tuned grid circuit are amplified by the valve and fed back into the grid by inductive coupling. The phase change between the oscillations in the grid circuit and the oscillations fed back is 360° at the tuned frequency, and this causes the oscillations to be sustained.

(b) The frequency of an oscillator is controlled by a parallel tuned circuit consisting of an inductor and a capacitance. At the resonant frequency of the L.C. circuit the potential at the terminals of the circuit is high and, therefore, it is at this frequency that the greatest amplification occurs in the valve. The effect of the tuned circuit is to pick out a particular frequency for amplification, the oscillation occurs at that frequency and other frequencies are suppressed.

(c) To increase the frequency of the oscillator from 1,000 to 2,000 cycles per second it will be necessary to connect an additional capacitor in series with the 2 microfarad capacitor in the tuned circuit.

The resonant frequency of a parallel tuned circuit is $\frac{1}{2\pi\sqrt{LC}}$ i.e., it is proportional to the reciprocal of the square root of the capacitance. In order to double the frequency it is necessary to reduce the capacitance to a quarter of its initial value. Using the formula for capacitors in series the value of the capacitor required is determined as follows:—

Let C = required additional capacitor

$$\tfrac{1}{2} + \frac{1}{C} = \frac{1}{\tfrac{1}{2}}$$

$$\frac{1}{C} = 2 - \tfrac{1}{2} = \frac{3}{2}$$

$$C = \frac{2}{3} \text{ uF}$$

Q.9.—(a) Briefly describe the construction and the method of operation of an electrolytic capacitor.

(b) Why is it possible to obtain a much higher capacity in this type of capacitor than in other types having similar dimensions?

(c) What are the limitations in the usefulness of electrolytic capacitors?

(d) When a capacitor is charged by connecting it to a D.C. potential it can be disconnected and discharged some time later. How is the charge stored in a capacitor?

A.—(a) The electrolytic capacitor may be either of the wet or dry type, the latter having practically superseded the former. The electrolytic capacitor consists of 2 aluminium electrodes separated by an electrolyte such as boric acid. In the dry type electrolytic capacitor the +ve and –ve electrodes consist of a large area of aluminium foil separated by a thin layer of absorbent insulating material which holds the electrolyte. The dielectric of the electrolytic capacitor is a very thin layer of oxide formed on the surface of the +ve electrode. This oxide layer will remain in position so long as the electrode on which it is formed is maintained at a +ve potential to the electrolyte. If the polarity is reversed the layer will be rapidly destroyed and high currents will pass through the capacitor.

(b) Electrolytic capacitors have a much higher value of capacitance for their size compared with paper foil types because the dielectric is very thin.

(c) The use of an electrolytic capacitor is limited to conditions in which the polarity of the potential applied to the capacitor remains unchanged. Electrolytic capacitors are used extensively in smoothing circuits, as by-pass capacitors and in all circuits where a high capacity is required and the polarity remains unchanged.

(d) The charge in a capacitor is stored in the dielectric in the form of a mechanical strain.

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