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The
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LONG DISTANCE TELEPHONE AND TELEGRAPH INSTALLATIONS IN AUSTRALIA DURING THE WAR

G. O. Newton

Introduction: The exigencies of the war resulted in many calls on the Postmaster-General's Department in Australia, and its contribution to the war effort, in the light of the staff and means available to it, and the need to give a reasonable civilian service at the same time, was very substantial.

Adequate, reliable telecommunication facilities being so highly important for war needs, the Department's efforts throughout the war were largely directed to the provision and maintenance of such facilities for the Forces (including Allied Forces and the Royal Navy, as well as the Australian Forces) and for other organisations associated with the war effort. This work covered a wide field, and much could be written regarding its various phases. This article will, however, be confined to the provision of long distance communications by means of wires and carrier systems.

From the close of the depression, about 1934, to the outbreak of war in Europe, a steady, overall expansion of trunk telephone and telegraph communication facilities had taken place, although this was somewhat slow in relation to the expansion of local line and exchange plant. Based on pre-war standards, these facilities were, however, reasonably adequate, having in mind the comparatively small population to be served and its disposition, the long distances involved and the limited community of interest between many centres in the Commonwealth.

With the national change from peace to a war footing, the need for considerable expansion of the trunk telephone and telegraph facilities quickly became evident. As a result, several major undertakings became necessary in the early part of the war. Following the outbreak of hostilities in the Pacific and the arrival of Allied Forces in this country, the demand for extra facilities for both organisational and strategic needs increased greatly beyond all previous conceptions of such needs. This, together with the fact that in most instances there was a very short time limit for the completion of the service, placed a heavy strain on the Department's organisation and its resources.

Many of the works undertaken in this period were landmarks in the history of the telecommunication facilities of this country, and would normally have received considerable publicity. War needs, unfortunately, imposed complete or almost complete silence in most cases; and although they are now receiving some of the publicity they deserve, the lapse of time has removed some of the interest and the satisfaction and pride in their achievement that would have resulted if this publicity had been permitted at the time they were undertaken.

As is to be expected in a country with a large area and comparatively small population, most of the long distance services in Australia are provided by the use of open-wire routes. In the main, this method of provision continued during the war, and it must inevitably be the method of provision on the majority of routes for many years to come.

Prior to the war, however, trunk cables were provided between Melbourne and Geelong (46 miles), between Melbourne and Dandenong (20 miles); while installation of carrier type, star quad trunk cables between Sydney, Newcastle and West Maitland (116 miles) was commenced in 1939 and completed in 1940, and between Melbourne and Seymour (60 miles) in 1940 and 1942 respectively. War conditions, however, did not permit any substantial expansion of trunk cables on the heavier routes where such cables would have been justified under normal conditions; but short trunk cables were commenced and, in some cases, completed during the war, between Melbourne and Frankston (27 miles), Adelaide and Gawler (26 miles), Sydney and Penrith (35 miles), Perth and Midland Junction (11 miles), and Brisbane and Ipswich (21 miles).

Considerable use had been made of carrier telephone systems, involving frequencies up to 30 kC/s., to augment the voice frequency channels on the various aerial routes prior to the war. Carrier transposing of the copper pairs on

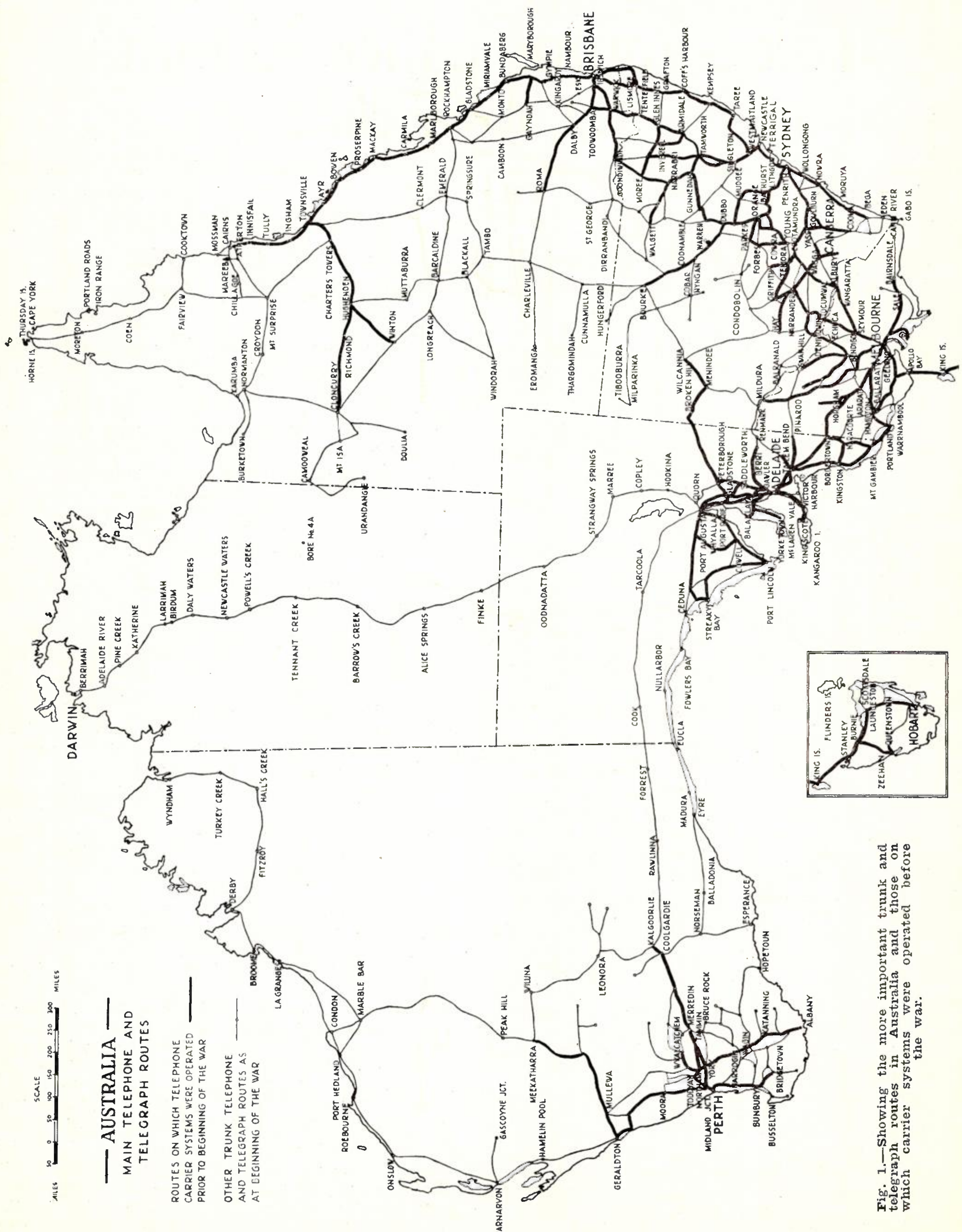

Fig. 1.—Showing the more important trunk and telegraph routes in Australia and those on which carrier systems were operated before the war.

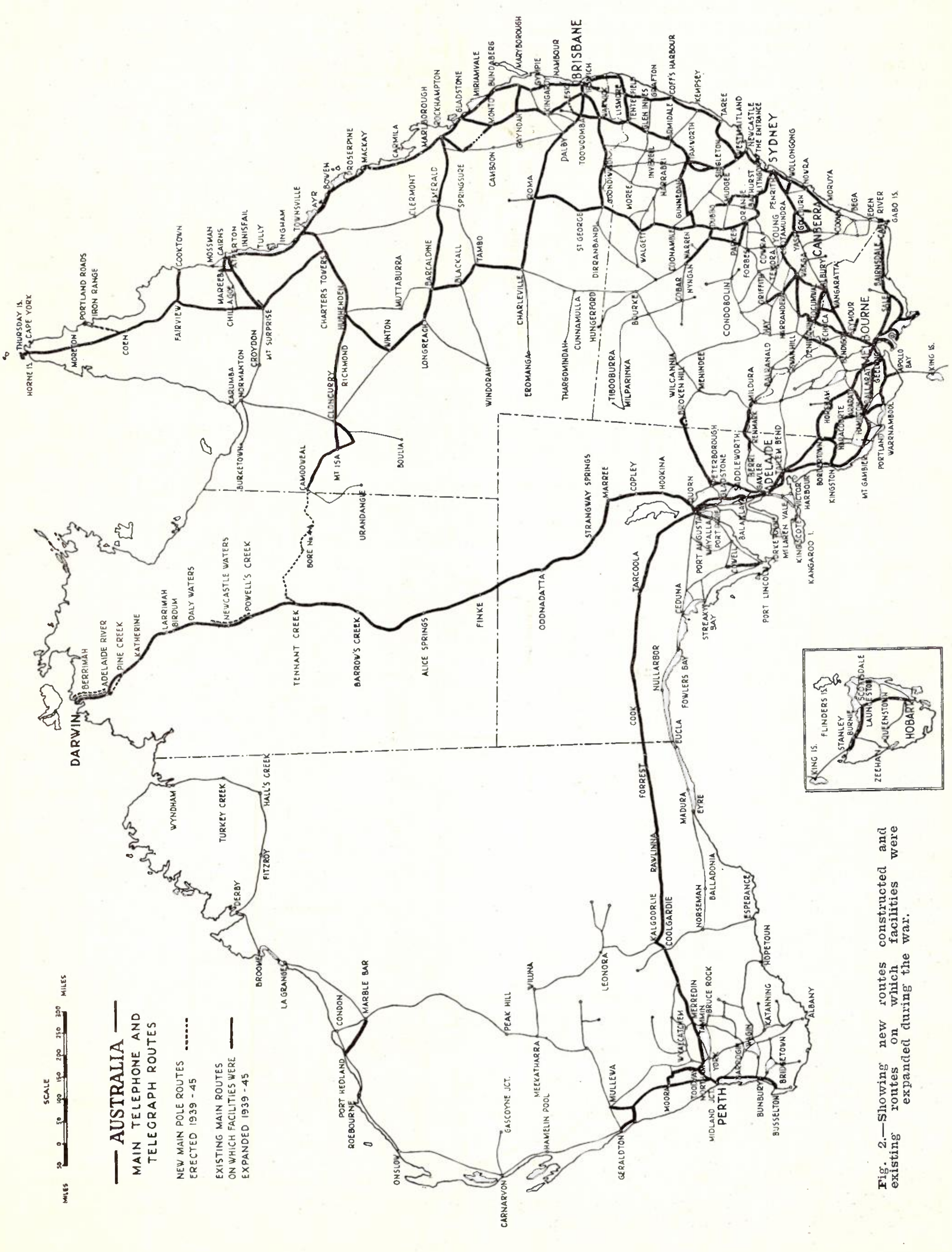

Fig. 2.—Showing new routes constructed and existing routes on which facilities were expanded during the war.

such routes, however, had only been undertaken to a very limited extent; and, for the most part, the carrier systems were operated on pairs transposed for voice frequency operation only, and often having considerable irregularities in the separation of wires and transpositions. Depending on the number of pairs available, on their disposition on the crossarms and on the extent of the irregularities, it had generally been found possible to operate up to two 3-channel carrier systems and, occasionally, three or more on each of the voice frequency transposed routes. In some cases, where a greater number of systems than this was required, it had been found possible to meet the position by the use of alternate routes.

On the whole, however, a condition of saturation existed on the more important routes at the beginning of the war. Either all suitably transposed pairs were in use, or the limit had been reached in the use of voice frequency transposed pairs. To meet this situation, several works were in hand, or contemplated, to augment the available carrier transposed pairs or provide some where none was available. This was done mainly by re-transposing existing wires, which usually involved re-spacing and often re-arranging the wires, as well as the insertion of new transposition types, erection of additional poles to reduce irregularities in transposition spacing, and often substantial rearrangement of existing transposition sections. The last also involved re-transposing of all telephone circuits on the poles. In some cases, it was necessary to augment the available copper pairs to provide sufficient bearer circuits.

The length of most of the long distance facilities provided for war needs naturally necessi-

TABLE I.

SHOWING NUMBER OF CARRIER SYSTEMS ON MAINLAND INTER-CAPITAL AND BRISBANE-TOWNSVILLE-CAIRNS ROUTES

(a) At outbreak of war in 1939.
(b) At end of 1945. Figures in brackets indicate additional systems in process of installation at that time.
The figures include all "through" systems on alternate and main routes except where otherwise specified and all systems from terminal points to intermediate centres on main route or to routes branching from intermediate centres. Systems between intermediate points are not included.

Route		Telephone Carrier			Telegraph Carrier
		12 ch.	3 ch.	1 ch.	
Sydney-Melbourne	(a)	1	9	—	1-18 ch. V.F. and 1-8 ch. B.
	(b)	2(2)	18	5	3-18 ch., 1-12 ch. and 1-9 ch. V.F.
Sydney-Canberra	**(a)**	—	2	—	—
	(b)	—	5	—	1-18 ch. and 1-9 ch. V.F.
Melbourne-Canberra	(a)	—	1	—	—
	(b)	—	4	—	1-18 ch. V.F.
Melbourne-Adelaide	(a)	—	5	6	1-10 ch. B.
	(b)	—(1)	8	5	1-18 ch., 1-12 ch. and 1-9 ch. V.F. 1-4 ch. B.
Adelaide-Perth*	**(a)**	—	6	8	1-4 ch. V.F. and 1-5 ch. B.
All sections	(b)	—	10	8	1-18 ch., 1-12 ch. and 1-4 ch. V.F., 1-6 ch. B. and 1-2 ch. Hilo.
Adelaide-Perth	(a)	—	—	—	1-5 ch. B.
Pt. Augusta-Kalgoorlie Section only	(b)	—	2	—	1-18 ch. V.F.
Sydney-Brisbane†	(a)	—	12	3	1-18 ch. V.F. and 1-4 ch. B.
	(b)	—(2)	20	7	3-18 ch. and 1-9 ch. V.F.
Brisbane-Townsville	(a)	—	3	—	—
Coast Route	(b)	—(1)	9	3	2-18 ch. and 1-9 ch. V.F.
Brisbane-Townsville	(a)	—	—	3	—
Via Charleville and Hughenden‡	(b)	—	9	4	1-18 ch., 2-9 ch. and 1-4 ch. V.F.
Townsville-Cairns	(a)	—	1	—	—
(Coastal and Inland Routes)	§(b)	—	5	1	1-12 ch. V.F.

*Excludes Adelaide-Berri and Adelaide-Broken Hill routes.

†Includes carriers with southern terminal at West Maitland, but—
(a) excludes 8-3 channel and 2-1 channel aerial telephone systems serving Sydney-Newcastle-West Maitland section only;
(b) excludes 6-17 channel and 12-9 channel systems on cable between Sydney, Newcastle and West Maitland, installed during war, which replace most of the aerial carrier channels in service on this section previously. Terminals of these aerial systems listed in (b) were moved to West Maitland when Sydney-West Maitland trunk cable completed;
(a) and (b) exclude Brisbane-Kingaroy and Brisbane-Charleville routes included in Brisbane-Townsville via Charleville and Hughenden.

‡Excludes Townsville-Cairns routes via Charters Towers and Mt. Surprise included in Townsville-Cairns route (Coastal and Inland).

§Includes 1-3 channel Townsville-Atherton and 1-3 channel Townsville-Cairns via Charters Towers and Mt. Surprise, also 1-1 channel Cairns-Atherton.

tated a large number of additional carrier systems. It was practicable to operate a few of these over existing copper wires without alteration, whilst others were met by completion of the works referred to in the previous paragraph. In the remaining cases, it was necessary either to re-transpose existing wires or to erect new wires and, in many instances, do both before the new carrier systems could be brought into operation. In a few instances, entirely new routes were involved, whilst the re-transposing work involved major reconstruction work on portions of some routes. As a result, the volume of line work associated with the carrier installations was substantial.

The more important trunk telephone and telegraph routes of the Commonwealth, and those on which carrier systems were operated before the war, are indicated in Fig. 1. Those routes on which expansion of existing facilities (except those of a comparatively minor nature) took place during the war, are indicated in Fig. 2. On several of these, modern trunk telephone facilities were provided for the first time. Entirely new routes constructed during the war are designated separately. It will be seen that all the basic routes were affected, and that much expansion took place in the northern and north-eastern parts of the continent, which formed the main defence front of the Commonwealth. The extent of the increase in carrier systems on the more important routes is shown in Table 1.

The additions to the trunk telephone and telegraph facilities can be divided into two main phases:—

(i) Those initiated prior to 1942, before the entry of Japan into the war and the arrival of large Allied Forces in Australia.

(ii) Those initiated in 1942 and after.

The major portion of such works is included in the latter phase. Some works included in (i) were still proceeding when works included in phase (ii) were commenced, and were, in some cases, well advanced.

Works Initiated Prior to 1942

The first route to require major attention, from both the lines and carrier equipment aspects, was that between Sydney and Melbourne, which serves the two largest cities of the Commonwealth, and is linked with Canberra by branch routes from Yass and Goulburn. This route, with the links to Canberra, forms the backbone of the trunk telephone and telegraph network of the Commonwealth. This was followed in succession by an expansion of facilities between Adelaide and Darwin, and between Adelaide and Perth, whilst, concurrently, an extra 3-channel carrier system was provided between Melbourne and Adelaide.

Sydney-Melbourne Route: The heavy increase of traffic on this route, prior to the war, had led to consideration of the progressive installation of trunk cable throughout, a total distance of over 580 miles. The advent of war, however, necessitated the deferment of the full scheme and, to date, trunk cable (carrier type S.Q.T.) has been installed only on the Melbourne-Seymour section (60 miles), where the extent of the demand for channels for Army needs was such that they could not all be provided in a practical manner by use of the existing aerial route. The position for the most part, therefore, has been met by expansion and adaptation of the aerial route.

Some of the copper pairs on this route had been carrier transposed for operation to 30 kC/s. prior to the war; but all pairs giving a sufficient grade of crosstalk attenuation were in use to accommodate 3-channel carrier systems by 1940. An order had been placed for a 12-channel Western Electric type J1 carrier system (the first in Australia) about the middle of 1938; and the installation of this system, which was delivered during April, 1939, was completed immediately after the outbreak of war.

By the end of 1940 the increase of trunk traffic on this route was so heavy that further action was necessary, and proposals involving a second 12-channel system between Sydney and Melbourne, and seven additional 3-channel carrier systems (four at the Sydney end, and three at the Melbourne end) were immediately initiated. Two of the 3-channel carrier systems, one at each end, were required to serve Canberra from Sydney and Melbourne respectively. The others were required to serve intermediate centres from Sydney to Melbourne.

The proposal to instal a second 12-channel carrier system involved more intense re-transposing of existing carrier transposed pairs, whilst the additional 3-channel systems required the re-transposing of other available pairs and/or the erection of new bearer circuits over the whole of the route. In association with this work, it was also necessary to take further steps to reduce the extent of the irregularities in the spacing of transposition poles. As well as the work on the main route, most of the available copper pairs on the branch route to Canberra from Goulburn, were re-transposed for carrier operation. At a later stage, similar work on the branch route from Yass was undertaken.

In association with the installation of the second 12-channel carrier system, it was necessary to provide new repeater stations at Yass Junction and Albury, as well as to extend original installations at the remaining terminal and repeater stations along the route. The second 12-channel carrier system (type J2), the delivery of which was somewhat delayed on account of war demands in other areas overseas, was put into service early in 1944.

It will be of interest to note that the erection of further wires and additional re-transposing have been proceeding recently on the Sydney-Melbourne route and the branch routes to Canberra, to provide for the third and fourth 12-channel carrier systems between Sydney and Melbourne, which are due to be cut into service early in 1946, and for five other 3-channel carrier systems to serve intermediate centres. The latter include additional systems between Sydney and Canberra and Melbourne and Canberra. At the same time, development is so heavy that consideration is already being given to other methods of serving these important centres, pending the installation of trunk cable throughout, as contemplated prior to the war.

Adelaide-Darwin Route: The original construction of this historic route, which is over 1900 miles long, has been discussed at some length in the issues of the "Journal" for June and October, 1945, pages 189 and 283. Some reference to the route has also been made in the issue of the "Journal" for February, 1939, page 161.

There are several alternative ways of routing services between Adelaide and Port Augusta (201 miles), from which centre pole routes radiate west to Ceduna and Perth, south-west to Whyalla and Port Lincoln, as well as north to Darwin. By the use of the alternative routes (all of which were transposed for voice frequency operation only) it had been possible, prior to the war, to provide substantial trunk telephone and telegraph facilities by both open-wire and carrier; but a stage had been reached where carrier transposing was necessary, and action accordingly was initiated in 1941 over the main route from Adelaide to Port Augusta, via Balaklava and Gladstone.

Along the Darwin route, north of Port Augusta, the following trunk telephone facilities were available at the beginning of 1941:—

(i) A short 100 lb. H.D.C. metallic circuit trunk line to Hookina (51 miles).
(ii) A 200 lb. H.D.C. metallic circuit trunk line to Copley (162 miles), thence a 400 lb. iron metallic circuit trunk to Marree (68 miles).
(iii) An isolated iron metallic circuit trunk line of mixed gauges from Darwin south to Pine Creek (147 miles).
(iv) Phonopore telephone facilities on a single 400 lb. iron metallic morse line, No. 2, between various points along the route from Marree to Pine Creek (1340 miles).

It will be seen that, except for a short distance at the southern end, there were no trunk telephone facilities of any real value.

The telegraph facilities between Adelaide and Darwin consisted of a hand-speed circuit No. 2, operating mainly over a 400 lb. iron wire, except between Copley and Marree, and between Pine Creek and Darwin, where it operated as a cailho channel on the iron trunk lines, and a high-speed duplex circuit operating on a 265 lb. H.D.C. wire No. 40 throughout (see June, 1939, issue of "Journal," page 251, article by H. Hawke).

Between Port Augusta and Darwin the route consisted largely of 19 ft. Oppenheimer steel poles spaced, for the most part, about 20 per mile. Wooden crossarms were fitted between Port Augusta and Oodnadatta and between Pine Creek and Darwin. Over most of the remainder of the route there were only the two morse wires on the poles, the iron wire being on the top pin and the copper wire on a bracket. The poles on the Strangways Springs-Oodnadatta section (145 miles) belong to the Commonwealth Railways, which authority also has separate iron pole routes along the railway between Oodnadatta and Alice Springs and between Birdum and Pine Creek. The pole routes carrying the Departmental circuits are situated along the railway, for the most part, between Port Augusta and Oodnadatta and between Pine Creek and Darwin. On other sections, the Departmental route is, for the most part, situated away from any available roads; and, between Oodnadatta and Alice Springs, and between Birdum and Pine Creek, is mostly well away from the railway line. As a result, travelling conditions along the route are mostly very difficult, particularly in the sandy sections of the centre and, after rain, over many sections in the northern part.

Prior to the war, the growing importance of Darwin as a civil aviation centre for overseas services, and as a defence centre, had led to some consideration of the provision of modern trunk telephone and increased telegraph facilities; but, mainly on account of the high cost involved, the work had been deferred. However, the substantial growth of the Northern Territory as a defence centre, and strategic considerations associated with the deterioration of the international situation in the Pacific, made it imperative to take action early in 1941. As a result, approval was given for the following work, in April, 1941:—

(i) Provision of copper bearer circuit suitable for 3-channel carrier operation from Gladstone (127 miles north of Adelaide) to Darwin. (A suitable pair for carrier purposes was available between Adelaide and Gladstone).
(ii) Purchase and installation of two 3-channel telephone carrier systems, one between Adelaide and Alice Springs, and the other between Alice Springs and Darwin, with a total of 9 intermediate repeater stations.
(iii) Purchase and installation of two 9-channel V.F. telegraph carrier systems, to operate over one channel of each of the 3-channel telephone carrier systems.

The line work covered by (i) was of a substantial nature, and consisted of:—

Gladstone-Port Augusta, 74 miles:
Erect two 200 lb. H.D.C. wires on existing arm.

Port Augusta-Quorn, 24 miles:
  Erect two 265 lb. H.D.C. wires on existing arm.
Quorn-Oodnadatta, 453 miles; Alice Springs-Larrimah, 635 miles; Pine Creek-Darwin, 147 miles:
  Erect one 265 lb. H.D.C. wire to pair with exisitng circuit 40, and effect minor alterations and re-arrangements.
Oodnadatta-Alice Springs, 293 miles; Larrimah-Pine Creek, 165 miles:
  Fit crossarm on railway poles, transfer railway wires thereto, and erect two 300 lb. H.D.C. wires.

Concurrently with this work it was necessary for local defence purposes to erect four additional 200 lb. H.D.C. wires between Darwin and Noonamah (27 miles) and a similar number between Darwin and Adelaide River (77 miles), and to carry out substantial strengthening of the route between the latter centres at the same time. Substantial repairs and strengthening on some other sections of the route were also necessary, and steel towers had to be provided at a number of river crossings.

On account of the better accessibility for maintenance purposes, it was decided to place the wires on the railway poles between Oodnadatta and Alice Springs and between Larrimah (5 miles north of Birdum) and Pine Creek. On these sections 300 lb. copper wire was erected in lieu of the normal 200 lb. H.D.C. wire for such services in order to obtain the advantage of increased strength in the isolated area and to overcome attenuation difficulties in case it became necessary to operate the carrier system without one of the intermediate repeaters. Repeaters were provided at Port Augusta, Marree, Oodnadatta, Finke, Barrow Creek, Tennant Creek and Newcastle Waters, initially, and at later stages at Larrimah and Pine Creek. New buildings for these, of a factory-made, ready-to-erect type, similar to that shown in Fig. 12, were provided at centres other than Port Augusta, Oodnadatta and Pine Creek.

A work of this magnitude, in an isolated location, and coming at a time when the war situation was critical, was naturally beset with many difficulties. The first serious problem was that of obtaining large supplies of material and equipment at short notice under war conditions and in competition with direct and often more urgent defence needs. This was followed by serious transport difficulties. Notwithstanding this, sufficient material was obtained, moved into position and staff arranged to commence operations on the southern portion by the end of June, and on the northern portion by the end of July.

The entry of Japan into the war late in 1941 necessitated urgent action to give some additional facilities to the Darwin area; and, by deferring certain phases of the line work, the additional copper wire was finally linked between Adelaide and Darwin on 14/12/41 to give an extra telegraph channel. The remaining line work was completed early in 1942; and sufficient carrier equipment installed to give the additional services to Alice Springs by 6/3/42. The bombing of Darwin early in 1942 necessitated a revision of plans for the location of the northern carrier terminals, and these were installed at Larrimah in April, 1942. This terminal equipment was shifted to Adelaide River about a year later, and finally removed to Berrimah, eight miles south of Darwin, about the middle of 1944, when operational needs required the change.

To fit in with the availability of equipment, some temporary arrangements for the telegraph carrier channels were necessary. In the final arrangement it was also necessary to expand the voice frequency telegraph carrier system between Adelaide and Alice Springs to 12 channels. This aspect is referred to in the articles on "Telegraph Carrier in Australia," in the June and October, 1944, issues of the "Journal," pages 1 and 91.

Although staff for the line work was drawn from several States, the Department had some difficulty in providing sufficient men to complete the work in the desired time. As a result, the co-operation of the Army Signals Units was sought, and 66 Army Signals personnel, out of a total staff of about 280, were employed on the work. This Army staff was mainly used on the Alice Springs-Birdum section, and operated under the technical supervision of Departmental officers. The Army also greatly assisted the Department by arranging rations, water and petrol supplies north of Alice Springs, and transporting material over the section between the railheads at Alice Springs and Birdum. Motor transport for the working parties was also provided by the Army on the Alice Springs-Darwin section.

Fig. 3.—Showing typical view of the Overland Route prior to the war, between Daly Waters and Birdum.

The work, with its attendant difficulties associated with food and water supplies, transport, climate, nature of the terrain, general isolation of the route and lack of telephone communication, called for considerable organisation. These conditions also added considerably to the burdens of those employed on the work. Its successful conclusion early in 1942 reflected great credit on all those who took part.

Since modern telephone facilities were provided to Alice Springs and the Northern Territory, as well as intermediate centres, for the first time, the completion of this work was an historic event. Fig. 3 shows a typical view of the route as it was before the war, and Fig. 4 after the work was completed.

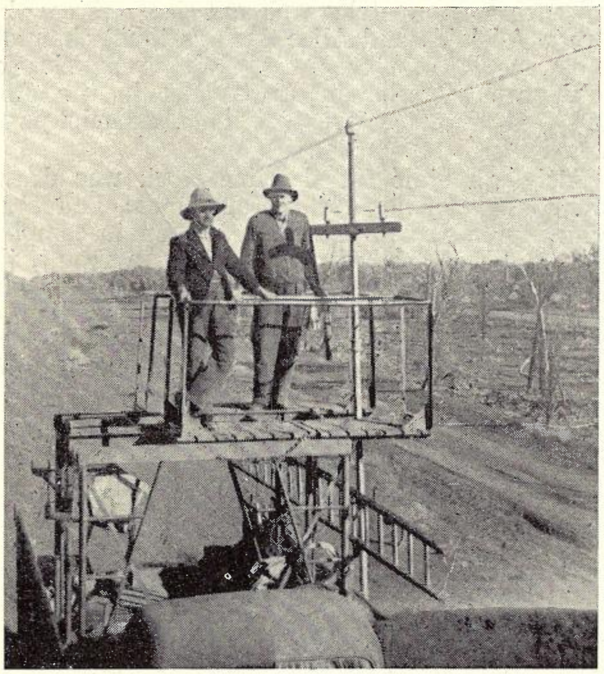

Fig. 4.—Showing typical view of the Overland Route on completion of the additional copper wire north of Alice Springs. This photograph shows truck fitted with special sliding platforms as used to facilitate work.

There were considerable additions to the route north of Alice Springs later on in the war, and these will be described in more detail subsequently.

Adelaide-Perth Route: The original route between Adelaide and Perth, which provided telegraph facilities only, was via Port Augusta and centres located along the Great Australian Bight. This carried three through wires, of which only one was of copper throughout. Owing to the isolated location, poor accessibility, involving slow restoration of service in the case of faults, heavy leakage troubles arising from the salt-laden atmosphere along the coast, and the age of the construction, the route was finally abandoned for interstate purposes about 1927, and the telegraph channels transferred to three 300 lb. H.D.C. wires on poles belonging to Commonwealth Railways along the Transcontinental Railway between Port Augusta and Kalgoorlie. The railway route had been erected at the time of the construction of the railway, about 1917, and consisted of 22 ft. Siemens tubular steel poles spaced, for the most part, 25 to 27 per mile.

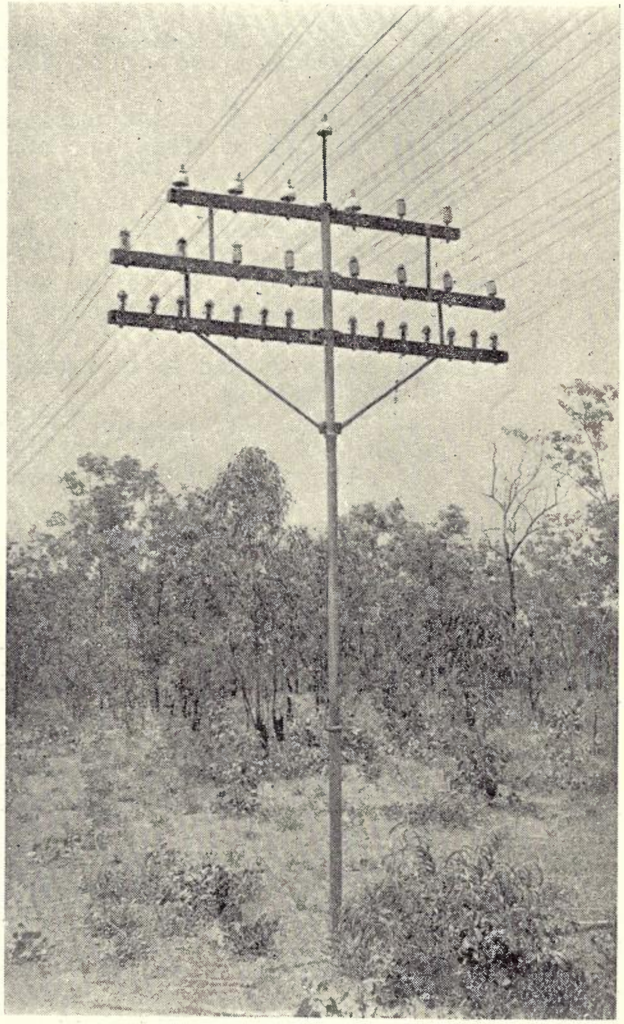

Fig. 5.—Showing typical view of the Overland Route near Darwin at the present time. Originally the poles on this section carried four wires, including one belonging to the Commonwealth Railways.

Until 1930, a telegraph service only was provided between Adelaide and Perth; but at this time greatly improved facilities were provided, including a voice frequency trunk telephone line and a uni-directional (east to west) broadcast programme channel. These facilities, and the the action taken to increase them during the war, have already been discussed, from the carrier equipment aspect, in an article by Messrs. R. E. Page and F. E. Ellis, in the February, 1943, issue of the "Journal," page 129. That article also indicated that it was intended to operate finally two 3-channel carrier systems, with one voice frequency carrier telegraph system (18-channel), and to instal an additional repeater station at Forrest. All of these are now in operation.

The line work associated with the carrier equipment installation consisted of:—

(1) Erection of one pair of 200 lb. H.D.C. wires on Departmental route between Adelaide and Port Augusta (201 miles), in association with the carrier transposing of this section of the route to permit other carrier installations, including a 3-channel carrier system to Whyalla from Adelaide.

(2) Erection of a fourth 300 lb. H.D.C. wire on Commonwealth Railway poles from Port Augusta to Kalgoorlie (1050 miles), and the transposing of this with the three existing wires to a new transposition design to give a high grade of crosstalk attenuation between the two copper pairs.

(3) Erection of one pair of 200 lb. H.D.C. wires, or the pairing of an existing 200 lb. H.D.C. wire throughout practically the whole distance from Kalgoorlie to Perth (381 miles). This item was also associated with carrier transposing of a considerable portion of the route between Kalgoorlie and Perth.

Although authority was given for this work, mainly on account of Defence needs, in July, 1941, it was not practicable to commence the line work before May, 1942, and to complete it before the beginning of 1943, owing to the many other urgent Defence needs which arose. As a result, action was taken to instal the first 3-channel carrier system, as indicated in the article referred to above, whilst the line work along the route was in progress. Largely owing to the demands for carrier systems for other urgent purposes, it was not practicable to instal the second 3-channel carrier system until the early part of 1945, whilst the 18-channel V.F. telegraph carrier system was only brought into operation late in 1945. In the meantime, telegraph service was given by the use of the original B type telegraph carrier, modified to give 10 channels and to operate on one channel of the telephone carrier system. This is referred to in articles in the June, 1942 (page 27), February, 1943 (page 129), and June, 1944 (page 1), issues of the "Journal."

The most difficult and interesting part of the line work was the section along the Transcontinental Railway between Port Augusta and Kalgoorlie, which traverses open desert country over most of the distance. The three Departmental wires on this section were originally arranged on a 6-pin wooden crossarm, with a view to the ultimate completion of the phantom group of four wires. American hat-rack or Australian double spindle type transpositions had been inserted in the wires when originally erected on the route in 1927. This wooden crossarm also accommodated a single 200 lb. H.D.C. telegraph wire belonging to the Commonwealth Railways. The poles also carried a tubular steel crossarm above the wooden crossarm, on which were erected two 400 lb. G.I. wires for railway staff control and telephone purposes.

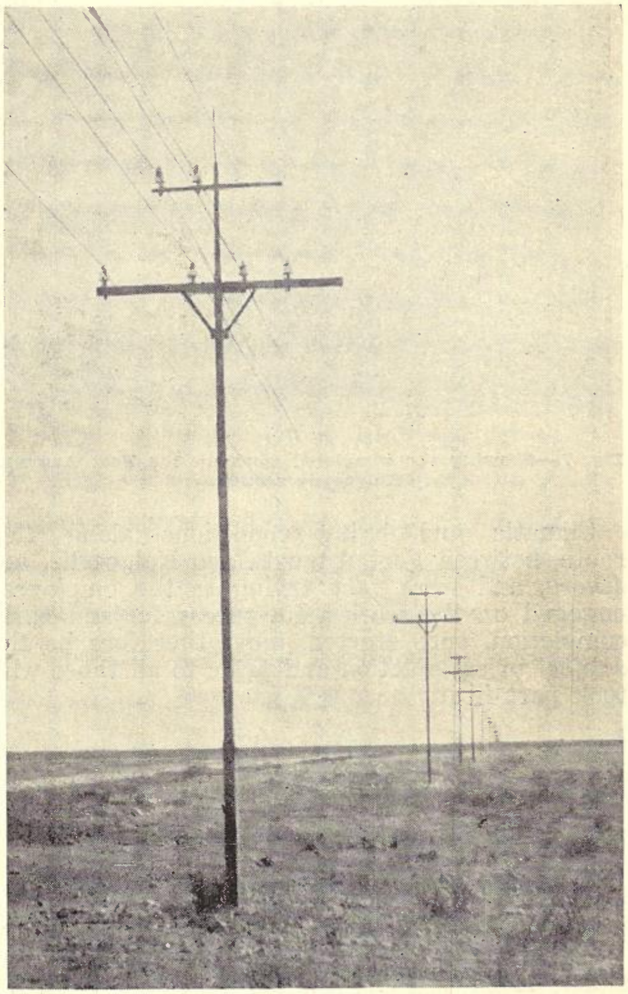

Fig. 6.—Showing a view of the Adelaide-Perth Route near the border of S.A. and W.A. prior to the war.

The work carried out in 1942 consisted of the re-arrangement of the existing wires and the erection of the fourth wire, to form two widely separated pairs on the ends of the wooden crossarms, and the transposing to a new design of these wires, using point type transpositions. This necessitated the shifting of the railway telegraph circuit. To meet the needs of Commonwealth Railways for improved train control arrangements, action was taken concurrently to pair this telegraph circuit in the pin positions each side of the pole. As the poles were, for the most part, regularly spaced, very little pole work to reduce irregularities in transposition spacing was necessary. Fig. 6 shows a view of a route before the work was put in hand, and

Fig. 7 shows the completed work. Fig. 8 shows a view of a typical repeater station along the Transcontinental Railway. The whole of the work between Adelaide and Perth was undertaken by Departmental labor.

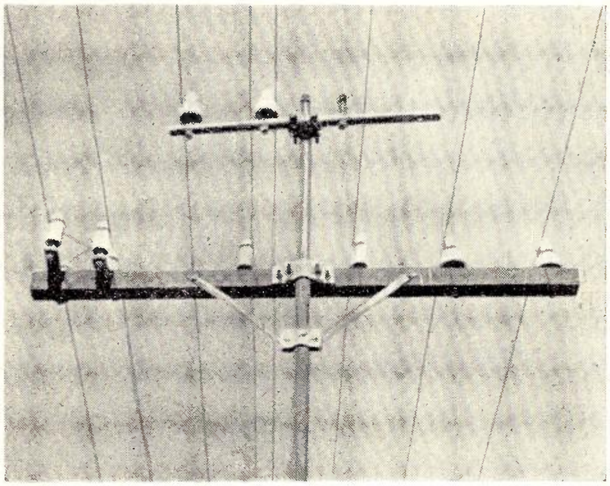

Fig. 7.—Showing the completed work on the Port Augusta-Kalgoorlie section.

Climatic and living conditions along this route, between Port Augusta and Kalgoorlie, are severe, and were very trying to the employees engaged on the work. Its successful and early completion, once started, must therefore be the subject of satisfaction and pride to all those who took part in it.

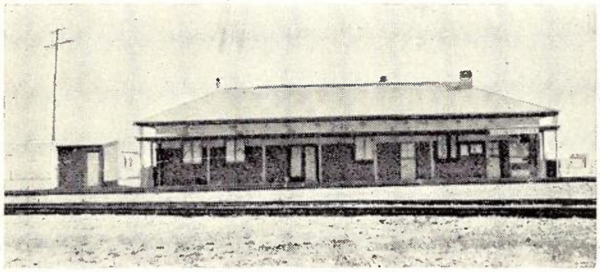

Fig. 8.—Showing the repeater station and P.O. at Rawlinna. This is similar to the other repeater stations between Port Augusta and Kalgoorlie except at Forrest, which is similar to that shown in Fig. 12.

The Old Adelaide-Perth Route: It is of interest to note that the old coastal Pole Route between Adelaide and Perth was brought into use again during the war to meet Defence needs. Following the transfer of the telegraph circuits to the railway route in 1927, circuits on the old route, via the Great Australian Bight, had been modified to provide trunk telephone facilities of a low grade, as far as Nullarbor on the South Australian side, and to Balladonia, from Norseman, on the Western Australian side. On the section between Nullarbor and Balladonia, the copper wire had been leased to local pastoral stations for private telephone services, whilst most of the G.I. wire had been dismantled and sold. On some sections between Nullarbor and Balladonia little attention had been given to the route by the lessees, particularly between Madura and Balladonia, where a considerable portion of the route had fallen into a bad state of repair.

About the middle of 1941 the Defence authorities decided on the improvement of existing road conditions, involving new road construction along tracks used infrequently in pre-war days by motorists, and following the general direction of the old pole route, via Ceduna, Eucla and Norseman.

To provide for communication on the road work, and to meet possible Defence needs, the copper wire between Ceduna and Norseman (740 miles) was taken over and renovated by the Defence authorities. Amplifiers were provided at Ceduna, Eucla, Norseman and Coolgardie, and the terminal of an existing single-channel carrier system between Port Augusta and Streaky Bay was shifted from the latter place to Ceduna to permit a reasonable grade of conversation between the various points on the road work and from these points to the nearest capital city.

Following the completion of the road work, the service was retained by the Defence authorities for a period, but was finally closed down about the latter part of 1943, after which the circuit reverted to the former arrangements, except that the carrier terminal has remained at Ceduna.

Works Initiated in 1942 and After

The intense organisation of the community as a whole for the prosecution of the war, and the arrival of large Allied Forces in this country following the outbreak of hostilities in the Pacific area, resulted in heavy demands for telephone and telegraph service to a greatly increasing extent.

In the beginning, these demands were necessarily met, to a very large extent, by the allocation of existing channels for the exclusive or partial use of the fighting services. In a number of cases it was necessary to shift existing carrier systems to routes where the need was more urgent, whilst many of the new carrier systems ordered for normal use on specific routes had to be diverted to Defence needs. This involved drastic curtailment of civilian services of a non-essential nature, and the adoption of a priority system for the use of the long distance facilities which remained. The needs of the fighting services and other organisations associated with the war effort became so great, however, that there was no option but to embark on an extensive programme of works to augment and improve the available facilities.

Generally, the trunk telephone and telegraph works undertaken in 1942 and the following years, can be divided into two groups:—

(i) Provision of services to meet the more important organisational needs, as well as probable strategic needs.
(ii) Provision of services to meet local organisational needs.

Whilst a number of works of an important nature, and considerable size, were included in the latter group, most of them consisted of comparatively short lines, which were readily handled by local Departmental staff or by local Defence personnel operating under the technical supervision of Departmental officers. All the largest and more important works were included in the first group, and the remainder of this article will be mainly concerned with these.

The preparation of the programme of works covered by (i) was generally a joint effort of the Signals Services of the Forces and of this Department. The essential needs of the various Defence Services were jointly examined in the light of the available facilities and the practicability of augmenting these by various means within the available time. After modification of the needs in the light of the joint discussions, a programme of works was prepared and submitted for the approval of the appropriate authorities. This programme of work, which was added to as the war progressed and as further needs arose, generally became known as Project 2071, and was divided into Phases I. to VI. The initial programme consisted of Phases I. to III., whilst Phases IV. to VI. were added later.

Most of the detailed planning of these works was carried out by officers of the Postmaster-General's Department. The provision of the necessary material was also a Departmental responsibility. The extent of the line works, however, was such that sufficient Departmental line staff for a small proportion only could be made available and the works were, for the most part, executed by the Signals personnel of the U.S.A. Forces and the Australian Military Forces, under the general supervision of officers of the Department. In such cases, Army officers were responsible for a large amount of organisational work. Equipment was mostly installed by Departmental personnel.

Certain of the facilities proposed and approved for execution were not implemented in the end, since changes and general improvement in the war position removed their need before they could be undertaken. On the equipment side, considerable modifications became necessary on account of the general shortage of carrier equipment and delays in the receipt of new supplies, whilst at times temporary expedients giving partial facilities became necessary to meet urgent needs during the progress of the works.

In the first place, the general scheme of defence and, later, the use of Australia as a base for offensive operations, required substantial communication facilities in the Northern and North-Eastern areas, which are sparsely populated, and therefore had very limited facilities available. Most of the works were, therefore, designed to provide facilities in these areas and to establish some alternate inland routes as a measure of security against the vulnerability of the main routes, which are largely situated along the East Coast. They also included the linking of the North Queensland and Northern Territory areas, which were previously without direct land-line link. Outside the main project, the Signals Sections of the Australian Military Forces also undertook considerable augmentation of facilities in the Northern Territory, and in the Cairns and Townsville areas.

Briefly, the various phases of Project 2071 covered the provision of the following services:—

Phase I.:

(i) Erection of one 200 lb. H.D.C. pair, Townsville to Cape York, via Charters Towers and Mt. Surprise (nearly 900 miles), with loops from Fairview to Cooktown (78 miles) and Coen to Iron Range (121 miles).
(ii) Erection of one 200 lb. H.D.C. pair, Townsville to Cairns, via Charters Towers, Mt. Surprise and Atherton (462 miles).
(iii) Installation of one 3-channel telephone and one 4-channel telegraph carrier system between Townsville and Cape York, and repeaters at Charters Towers, Mt. Surprise, Fairview and Coen; and one single-channel telephone carrier system between Townsville and Mareeba, with repeaters at Charters Towers and Mt. Surprise.

Phase II.:

(i) Erection of one 200 lb. H.D.C. pair, Dalby to Charleville and Longreach to Stamford (near Hughenden), and re-transposing of some or all existing copper pairs between Dalby and Townsville, via Charleville, Longreach and Hughenden (1135 miles).
(ii) Provision of 3-channel telephone carrier systems between Brisbane and Hughenden (1032 miles), and between Hughenden and Townsville (238 miles), with 18- and 9-channel telegraph systems respectively.
(iii) Erection of new pole route, with four pairs of 200 lb. H.D.C. wires and other light gauge wires for local purposes, along the road between Adelaide River and Darwin (72 miles).

Phase III.:

(i) Minor re-transposing work and erection of new wires over a short distance to complete a suitable carrier pair between Brisbane and Coonamble, via Goondiwindi (555 miles).

(ii) Installation of a 3-channel telephone carrier system between Brisbane and Coonamble, via Goondiwindi, to link up with a Departmental system between Sydney and Coonamble (365 miles), to give alternate inland routing between Sydney and Brisbane.

(iii) Augmentation of facilities between Sydney and Brisbane (660 miles), and Melbourne and Adelaide (460 miles), by installation of 12-channel telephone and 18-channel telegraph carrier systems on each route, and a further 3-channel telephone carrier system on the former. This involved considerable re-transposing of existing wires and erection of new wires on certain sections.

The approved work under this phase also included provision of 3-channel telephone and 12-channel telegraph carrier systems, and a suitable bearer circuit throughout, on an alternate inland route between Melbourne and Bathurst, via Narrandera, between Sydney and Bathurst, and between Bathurst and Charleville, via Bourke. This portion of the phase was not, however, implemented.

Phase IV.:

(i) Provision of suitable extra bearer pair for carrier between Cloncurry and Hughenden (245 miles), by re-transposing existing wires and the erection of a 200 lb. H.D.C. pair between Gilliat and Cloncurry (67 miles).

(ii) Erection of two 200 lb. H.D.C. pairs on existing poles, strengthening of existing pole route, and deviations of the route between Cloncurry and Camooweal (209 miles).

(iii) Erection of new pole route and two 200 lb. H.D.C. pairs between Camooweal and Tennant Creek (300 miles).

(iv) Erection of one 200 lb. H.D.C. pair on a new pole route along the road between Powell Creek and Johnson's Lagoon (99 miles), and on existing poles, with modifications of transpositions of existing circuits, over remaining sections between Tennant Creek and Adelaide River (547 miles).

(v) Provision of additional 3-channel telephone and 18-channel telegraph carrier systems between Hughenden and Adelaide River, via Tennant Creek (1300 miles).

(vi) Provision of 3-channel telephone carrier systems between Melbourne and Sale (130 miles), and between Perth and Mullewa (275 miles). The latter installation was carried out in conjunction with the erection of additional wires and re-transposing work undertaken as a Departmental project. A 9-channel telegraph system was also installed on this route.

Phase V.:

(i) Erection of two 200 lb. H.D.C. pairs on existing coastal route between Brisbane and Townsville (850 miles), with associated re-transposing and other modifications of the route.

(ii) Installation of two 3-channel and one 12-channel telephone carrier systems between Brisbane and Townsville.

The original plan under this phase also included the erection of additional wires and/or re-transposing on the Brisbane-Townsville route, via Charleville, Longreach and Hughenden, and on the Townsville-Mt. Surprise-Cape York route, with augmentation of the carrier facilities (all additional to those included in Phases I. and II.); but this work was not implemented. This phase also included the installation of five K type 12-channel cable carrier systems on the Melbourne-Seymour trunk cable; but delivery of this equipment has not yet been effected, and other arrangements for augmenting the channels on this cable are about complete.

Phase VI.:

(i) Erection of two 200 lb. H.D.C. pairs on existing poles between Charters Towers and Mt. Surprise (210 miles), and one pair between Mt. Surprise and Atherton (108 miles).

(ii) Erection of three 200 lb. H.D.C. pairs on existing poles between Townsville and Cairns, along the coast (213 miles), and the general re-transposing of the route for carrier operation.

(iii) Provision of one 3-channel telephone carrier system between Townsville and Cairns, on the inland route via Charters Towers and Mt. Surprise, and one on the coastal route, together with one 12-channel telegraph system on the latter.

(iv) Provision of 3-channel telephone carrier systems between Brisbane and Rockhampton (404 miles), between Rockhampton and Longreach (430 miles), and between Hughenden and Townsville (238 miles). (A 3-channel carrier system, which was installed early in 1943, was available to complete the link between Longreach and Hughenden. Suitable bearer pairs were available on the first and last of these sections, and between Barcaldine and Longreach, as the result of work under Phases V. and II respectively. An existing voice frequency transposed pair was used between Rockhampton and Barcaldine, this being the first carrier installation on this section).

Although the various phases were approved in the order indicated, they were not carried out in this order, mainly on account of subsequent changes in their relative urgency.

In addition to the foregoing, a number of single and three channel telephone, and various sized telegraph carrier systems, were installed on certain routes, including some of those covered by Project 2071, as purely Departmental works, but space will not permit the enumeration of all of these.

Townsville-Cape York Route: The isolation and generally difficult nature of a great part of the terrain traversed, the absence of roads over a great part of the route, and the serious problems associated with the organisation and transport to the job of large numbers of men and of large quantities of supplies, rendered the line work on this route, as covered by (i) and (ii) of Phase I., the most difficult undertaken during the war. Furthermore, the defence need was urgent, and it was essential that the work be completed before the heavy summer rains arrived. Notwithstanding these difficulties the work, which was only initiated in June, 1942, was commenced at the southern end by the middle of August, and the connection to Cape York was completed early in November, whilst the whole of the line work was completed before the end of November.

The work between Townsville and Charters Towers was along the main western route, which also serves Hughenden and beyond, and was carried out in conjunction with the re-transposing of existing 200 lb. H.D.C. pairs, as covered by (i) of Phase II., and the erection of a copper pair for the Queensland Railway Department. On account of the very heavy load of wires already existing on the route, opportunity was taken to remove some of the 400 lb. G.I. telegraph wires and operate these circuits over cailho channels on the new wires. The work on this section also covered the later needs of Items (iii) and (iv) of Phase VI.

North from Charters Towers, the work was along a telegraph route provided nearly 60 years ago to serve Cooktown, Thursday Island and the Gulf Area, and consisting mainly of light Oppenheimer or Siemens poles, except on Mt. Surprise-Fairview section, where the poles were mostly of wood. On the Charters Towers-Fairview-Cooktown section 4-chain spans predominated, whilst north of Fairview to Cooktown the spans averaged about 5 chains in length. Between Charters Towers and Mt. Surprise there were four 400 lb. G.I. and one or two 200 lb. H.D.C. wires. From Mt. Surprise to Fairview there were two or three 400 lb. G.I. wires, whilst north of Fairview there was a single wire, partly of 400 lb. G.I., but mostly of 200 lb. H.D.C. or 237 lb. C.C. wire. Short crossarms were fitted as far as Tate Junction, north of Mt. Surprise, thence brackets or a short crossarm to Fairview, thence top pin only to Cape York.

To provide for the new wires, 8-pin arms were fitted from Charters Towers to Fairview and Cooktown, and from Coen to Iron Range. On other sections, 6-pin arms were fitted. New sections of pole route were associated with the lead out from Mt. Surprise on the Cairns side (5 miles), and between the turn-off to Iron Range, and Iron Range (69 miles). This last section of pole route was extended with three pairs of wires a further distance of 15 miles to Portland Roads. Between Coen and the turn-off to Iron Range, where three pairs of wires were erected, the existing 5-chain spans were reduced to half by the erection of an additional pole in the centre of each span. The new poles were mainly an 18 ft. tubular (3½ in. external diameter) type, specially manufactured in Australia for this and similar works. Typical views of the completed line work are shown in Figs. 9 and 10.

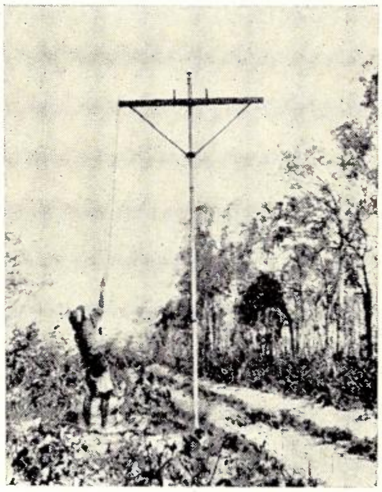

Fig. 9.—Showing typical view of the Cape York Route on the northern side of Fairview, where one pair of wires only was erected.

The section between Townsville and Charters Towers was carried out jointly by P.M.G. staff and Signals personnel of the U.S.A. Forces; whilst Signals personnel of the U.S.A. Forces carried out the section of work between Charters Towers and Fairview, together with the links from Mt. Surprise to Cairns and from Fairview to Cooktown. Signals personnel of the A.M.F. carried out the section of work north of Fairview. This was the most difficult and arduous portion of the job. In addition to the erection of wires and crossarms on existing poles, under the conditions referred to previously, there was the construction of a new pole route through unsurveyed country largely covered by tropical growth. The completion of the work in such a short space of time called for excellent organisation, and must be regarded as a most creditable performance.

In addition to the carrier systems referred to under (iii), Phase I., telex services were provided between Townsville and Mareeba, using a physical throughout; between Townsville and Cairns, using the single-channel carrier from Townsville to Mareeba, thence physical to Cairns; between Townsville and Iron Range, with intermediate points at Cooktown and Coen, using physical throughout; between Iron Range and Cape York, via Coen, using a physical pair throughout; and between Townsville and Cape York, using one channel of the 3-channel system. The repeater station buildings provided on this route, and the terminal buildings at Cape York, were similar to those installed on the Adelaide-Darwin route, and were erected by the Australian Army.

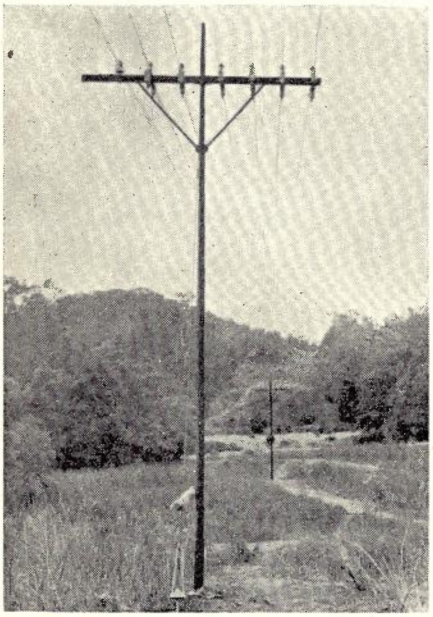

Fig. 10.—Showing a typical view of the Cape York Route north of Coen, where three pairs of copper wires were erected, including the two pairs which branch off to Iron Range, 52 miles north of Coen.

The completion of the circuits to Cape York was followed by the installation of submarine telephone cable to provide extensions to Horn and Thursday Islands and others in the vicinity. At a later stage, a submarine telegraph cable was laid to New Guinea, and connected to the mainland system at Cape York. This was the first physical link to be established between Australia and New Guinea. These works were mainly planned by the Australian Army, but installation work was carried out by submarine cable staff of this Department, under the direction of the Army.

The work covered by Item (i) and part of (iii) of Phase VI. was also along portion of the same route. The former consisted of replacement of the four iron telegraph wires with 200 lb. H.D.C. between Charters Towers and Mt. Surprise which, in addition to providing for a further carrier pair and a patch pair, considerably eased the load on the light pole route. On the route into Cairns from Mt. Surprise, a further pair of wires was erected as far as Atherton. This line work, under Phase VI., was also carried out by Signals personnel of the U.S.A. Forces, and was commenced early in October and completed about the middle of November, 1943.

The northern terminal of the single-channel system which had been provided between Townsville and Mareeba under Phase I., was later shifted back to Atherton, and the system was finally replaced by a 3-channel system about August, 1943. The 3-channel system for the inland route between Townsville and Cairns, under Phase VI., was installed early in 1944.

Hughenden-Tennant Creek-Darwin Route: Up to 1943, the only link between Queensland and the Northern Territory was by the very circuitous route via Brisbane, Sydney, Melbourne, Adelaide and Alice Springs. By this time, military needs gave rise to an urgent demand for extra services on a more direct route, apart from the desirability of having an alternate route for security reasons.

The completion of the line work on the Townsville-Cape York route was, therefore, quickly followed by the works included in Phase IV., preceded by Item (iii) of Phase II., which was also needed for local organisational needs in the Darwin area. The scheme was linked at Hughenden with the channels provided under Phase II. on the Brisbane-Charleville-Longreach-Hughenden and Hughenden-Townsville sections so as to provide Brisbane-Townsville, Brisbane-Darwin and Townsville-Darwin channels. These arrangements reduced the distance Brisbane-Darwin from 3640 miles to 2400 miles, and Townsville-Darwin from 4490 miles to 1610 miles. In addition to alterations and extra wires on the existing routes between Hughenden and Camooweal, and between Tennant Creek and Darwin, it was necessary to provide an entirely new pole line over the 300-mile section between Camooweal and Tennant Creek.

Brief details of the line work are as follow:—

Hughenden-Cloncurry (245 miles): Re-transposing of existing wires (1 to 3 pairs) and erection of an extra pair of wires on a section carrying a single pair between Gilliat and Cloncurry (67 miles).

Cloncurry-Camooweal (209 miles): The existing route consisted of light Oppenheimer poles, 16 per mile, carrying one 400 lb. G.I. wire. This was strengthened by an average of 16 additional poles per mile; and deviations of the route were arranged for short distances at each end and over a 25-mile section on the east side of Mt. Isa. Two pairs of 200 lb. H.D.C. wires were erected throughout, one for carrier purposes and one for local and patch purposes.

Camooweal-Tennant Creek (300 miles): An entirely new route of tubular steel poles (minimum size, 18 ft. x 3½ in. external diameter, similar to those used on the Cape York route), 32 per mile, with an average of 7 ground stays per mile and two pairs of 200 lb. H.D.C. wires, was provided throughout.

Tennant Creek-Larrimah (312 miles): Erection of an additional pair of 200 lb. H.D.C. wires, on new poles, along the road between Powell Creek and Johnson's Lagoon (99 miles), and on existing poles over the remainder of the section. This involved re-arming of existing poles, and re-arranging existing copper wires.

Larrimah-Adelaide River (235 miles): Erection of an additional pair of 200 lb. H.D.C. wires on existing poles throughout.

Adelaide River-Darwin (72 miles): Erection of new pole route, mainly of 7 in. x 3½ in. steel beams, 32 per mile, along the road, with four pairs of 200 lb. H.D.C. wires and a varying number of wires of lighter gauge beneath.

New carrier repeater stations similar to those erected on the Adelaide-Darwin route were provided at Cloncurry, Camooweal and Bore 4A (see Fig. 12). Repeaters were also provided in the existing buildings at Tennant Creek, Newcastle Waters and Larrimah and, later on, at Pine Creek. Initially the distant carrier terminals were installed at Adelaide River, but were removed to Berrimah, near Darwin, early in 1944. This removal was greatly facilitated by the availability of mobile (truck-mounted) carrier equipment. In the first place, a 9-channel telegraph carrier system was installed, but this was replaced by an 18-channel system about the middle of 1944.

The section of the line work between Hughenden and Cloncurry was carried out mostly by Departmental personnel, with minor assistance from the Forces. The section between Cloncurry and Tennant Creek was carried out by U.S.A. personnel, whilst the remainder of the work was carried out by A.M.F. personnel and some Departmental personnel.

The outstanding items of the line work were on the Cloncurry-Darwin section. Between Cloncurry and Mt. Isa, the existing Departmental route was mainly over rough country, rendering transport most difficult; and largely for these reasons the deviations of the route mentioned were undertaken. Between Mt. Isa and Camooweal less difficult conditions prevailed, since on this section the route was not far removed from a newly-constructed road, and actually followed it for limited distances. Between Camooweal and Tennant Creek a new road (the first and only one between these centres) had been constructed for defence reasons, and the new pole line generally followed this road. The country on this section was mostly open plain, and presented little difficulty beyond that of its isolation.

The U.S.A. Forces assigned to this work commenced surveys at the end of November, 1942, and construction work about the middle of December, 1942, and had completed it by the end of February, 1943. In carrying out this extensive work in such a short space of time they were naturally greatly assisted by the large amount of mechanical equipment with which the U.S.A. Signals Battalions were normally provided.

As mentioned earlier, the Overland Route is largely away from existing roads. On account of the distance from the existing roads and the difficult travelling conditions, especially after rain, it was considered inadvisable to place further circuits on the existing route over the section between Powell Creek and Johnson's Lagoon, and a new pole line along the road was accordingly provided over this section, in conjunction with the new pair of wires.

On the Adelaide River-Darwin section the existing pole line along the railway (see Fig. 5), although strengthened, was already carrying a very heavy load of wires; and, in view of the danger from cyclonic conditions and, generally, to give an added measure of security, it was decided to provide a new pole line along the roadway, which was a little shorter than the railway.

The survey work between Tennant Creek and Darwin was commenced in December, 1942. Construction work commenced in January, 1943, and was completed in May, 1943. Fewer personnel were available for this section of work than on the Cloncurry-Tennant Creek section, and they were severely handicapped by the wet conditions which prevailed and the heavy rock sinking involved on the sections where new pole routes were erected.

In conjunction with the foregoing work, the erection of other wires on the Overland Route was authorised outside Project 2071. This included a second pair, with new arms, from Alice Springs to Tennant Creek; a third pair from Tennant Creek to Daly Waters, and two or more extra pairs north thereof. At a later stage, the needs in the Darwin area were so great that a second pole route became necessary between Pine Creek and Adelaide River, and a third one between Adelaide River and Darwin. Almost all of these works were carried out by the Australian Army.

When compared with the original single iron and single copper wires south of Pine Creek, and two iron and single copper wires north of Pine Creek, the growth in the services in the Northern Territory is remarkable. The number of heavy gauge copper pairs now varies from two at the Alice Springs end to nine at the Darwin end, whilst there are up to 14 light gauge pairs for local circuits on the Katherine-Adelaide River section, and up to 35 such pairs on the Adelaide River-Darwin section. On the carrier side, there are now three 3-channel telephone and one 18- and one 9-channel telegraph carrier systems terminating in the Darwin area.

Fig. 11 is a typical view of the route on the west side of Mt. Isa, showing the new type of pole used and one of the existing Oppenheimer poles. Fig. 12 is a view of the repeater station and windmill generators at Bore 4A.

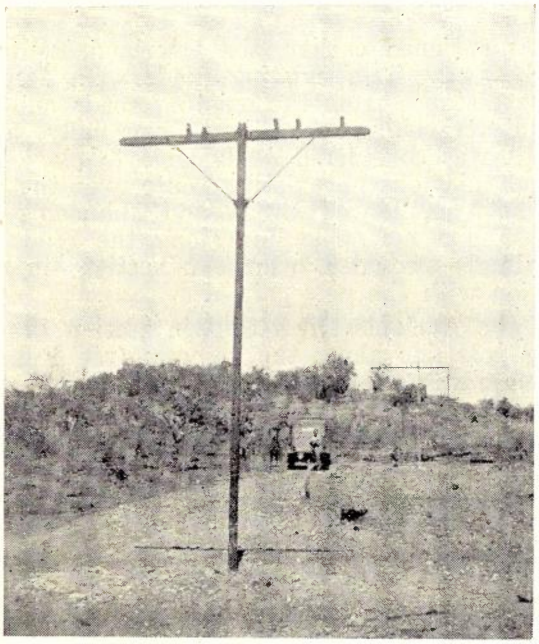

Fig. 11.—Showing a typical view of the Cloncurry-Tennant Creek Route on the west side of Mt. Isa. The new type of pole used on the Cape York and Tennant Creek Routes is shown in the foreground, whilst one of the original Oppenheimer poles is shown beyond.

Brisbane-Hughenden Route, via Charleville and Longreach: This route was adopted as an alternate route to North Queensland in case of interruption of the coastal route from natural causes or enemy action. Being so far inland, it was well placed from the security aspect. The line work, as covered by (i), Phase II., was a joint effort of P.M.G. staff and Signals personnel of the U.S.A. and Australian Military Forces.

A suitable pair for the desired carrier system was available between Brisbane and Dalby, which route had been carrier transposed prior to the war. From Dalby to Charleville it was necessary to erect a pair of 200 lb. H.D.C. wires and re-transpose two other pairs, as well as reduce irregularities in transposition spacing. From Charleville to Longreach, the re-transposing of two pairs of copper wires, which were the total number available over the greater part of the distance, together with some reduction in irregularities of transposition spacing, was necessary. From Longreach to Hughenden, the re-transposing of the existing wires throughout (mostly only one pair) and the erection of a second pair between Longreach and Stamford, were necessary. Between Hughenden and Townsville, bearer pairs were provided by re-transposing of existing pairs, the section between Charters Towers and Townsville being done in conjunction with the Townsville-Cape York work. The whole of this line work was completed about the middle of 1943.

At a later stage, an extra pair of 200 lb. H.D.C. wires was erected between Townsville and Hughenden by U.S.A. Signals personnel for Army use, and an extra pair for carrier thus became available on this section.

On the carrier side, it was found possible to give a partial service about the end of 1942. The complete telephone carrier service was arranged about the middle of 1943. Initially, only a 9-channel telegraph carrier system was available for installation, but this was replaced by an 18-channel system early in 1944.

Sydney-Brisbane Route: Prior to the war, these centres were served by two routes—the Coastal, via Grafton and Lismore, and the Tableland, via Tamworth and Warwick, carrying three through 3-channel systems and a 4-channel B telegraph system. The completion of Items (i) and (ii) of Phase III., early in 1943, provided two extra channels on an alternate inland route, via Coonamble. About this time the 4-channel B telegraph carrier system was replaced by an A.P.O. 9-channel system. An 18-channel telegraph carrier system had been installed between Melbourne and Brisbane, via Sydney, in the second half of 1942, to meet urgent defence needs (see "Journal," June, 1944, page 1).

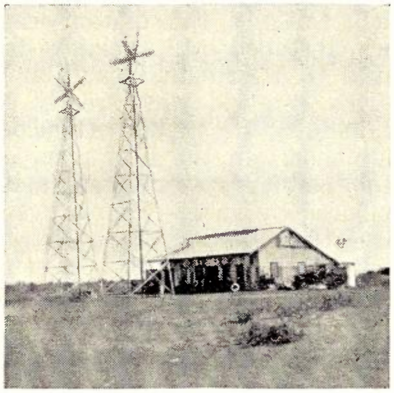

Fig. 12.—Showing repeater station and windmill generators at Bore 4A on Cloncurry-Tennant Creek Route. This installation is similar to others installed on the Adelaide-Darwin and the Charters Towers-Cape York Routes during the war.

To provide for Item (iii) of Phase III., and to meet other Departmental needs, considerable re-transposing of existing wires and erection of new wires was necessary between West Maitland and Brisbane, in addition to the special lead-in arrangements for the 12-channel telephone carrier system. All of this work was undertaken by Departmental personnel.

The 3-channel telephone carrier system (the fourth between Sydney and Brisbane) covered by Project 2071 was brought into use about

April, 1943, and the 18-channel telegraph carrier about May, 1944.

The 12-channel telephone carrier equipment was only received early in 1945 and installation, which was commenced soon after, is now complete. A second 12-channel telephone carrier, which was received about the same time, is also now being installed.

Melbourne-Adelaide Route: Prior to the war, these centres were served by two 3-channel telephone and a 10-channel B telegraph carrier systems on the direct route, via Horsham and Bordertown. In 1942, a third 3-channel telephone carrier system was installed on an alternate route, via Hamilton and Kingston. Following the installation of temporary smaller systems, the 18-channel telegraph carrier system was installed in November, 1944. The B system has lately been withdrawn and replaced by a 12-channel V.F. telegraph system and further 3-channel telephone carrier placed in service on the route.

Similar line work as for the Sydney-Brisbane route has been undertaken throughout between Melbourne and Adelaide to provide for Item (iii) of Phase III., and for other Departmental needs, this work being undertaken solely by Departmental personnel also.

The 12-channel telephone carrier system in this case also was only received in the early part of 1945, and installation is now about to be completed. A second such system is proposed for this route and will be installed in the near future.

Brisbane-Townsville Route: In the early part of 1943 it became apparent that, notwithstanding the installation of a third 3-channel telephone carrier system about May, 1943, and the availability of an 18-channel telegraph carrier system on the direct coast route, as well as channels via Charleville and Hughenden, several additional channels would be necessary between Brisbane and Townsville for Defence needs. The extent of the demand was such, however, that a large amount of work was necessary; and after a study of the route it was decided that the most practicable arrangement, and the one least likely to give rise to serious interruption, was the erection of two 200 lb. H.D.C. pairs throughout on the direct coast route between Brisbane and Townsville, a total distance of about 850 miles, to provide for two further 3-channel systems and, at a later stage, a 12-channel carrier system, when the equipment became available, in accordance with Items (i) and (ii) of Phase V.

To give some additional service pending completion of this work, to provide for odd point-to-point channels, including a Brisbane-Rockhampton channel, action was taken to advance Item (iv) of Phase VI., which necessitated limited line alterations between Bundaberg and Rockhampton, which were included in the work under Item (i) of Phase V.

The available wires on the two top crossarms on the route between Brisbane and Rockhampton had been carrier transposed prior to the war, and were, for the most part, in use for such purposes by this time. Any further re-transposing of existing wires on this section would have involved extensive re-arrangements of the existing wires and arms to obtain the desired vertical separation. Spare positions for the new wires could be readily arranged on the two top crossarms for a considerable portion of the route; but between Petrie (15 miles from Brisbane) and Gympie only one such position was available, whilst between Gladstone and Rockhampton there were none. On the former section the second pair of new wires was therefore erected on an extension arm fitted to the carrier transposed arm in the third position on the western side of the poles, whilst on the latter section extension arms were fitted on each side. These arms were of such a length that the new pairs were given a similar horizontal separation from the existing outside pairs to that prevailing between the existing pairs on each side of the pole, viz., 19 in. Fig. 13 is a view of the route just north of Petrie, showing the extension arm arrangement. One pole shows the single extension arm fitting, whilst on the nearest pole a new long arm has been fitted, which makes provision for a similar pair on the opposite side.

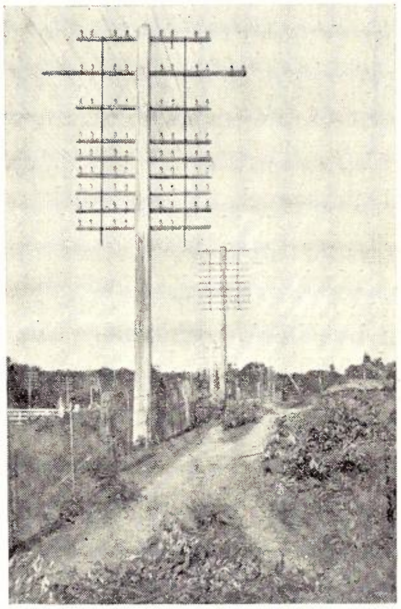

Fig. 13.—Showing a view of the Brisbane-Townsville Route just north of Petrie, near Brisbane. The second pole shows the extension arm arrangement fitted on most of the poles, whilst on the nearest pole a new long arm has been fitted, which makes provision for a sixth pair in the third-arm position if required at a later date.

North of Rockhampton only a limited amount of carrier re-transposing had been carried out, and further action in this direction was necessary, in association with the erection of the new wires, for which spare positions were available over the greater portion of the distance. On some sections, however, chiefly between Proserpine and Bowen, over about 32 miles, major reconstruction was necessary, since the arms were of a 4-pin type, with wide separation between the wires of pairs and non-standard vertical separation, and the existing wires were not suitably grouped. At various other locations re-arrangements of wires and crossarms were necessary; and on most sections a number of additional poles was required to reduce irregularities in transposition spacings.

On some sections extra pairs of wires were also erected to meet other needs, whilst on others the availability of odd 200 lb. H.D.C. telegraph wires permitted a reduction in the total number of new wires erected, by the transfer of the telegraph circuit to a cailho channel.

On account of the involved nature of some of the line alteration and reconstruction work, it was necessary to allocate a large number of Departmental personnel to the work and, since these were not available in Queensland, substantial transfers of staff from other States were necessary. Most of the work on the Brisbane-Rockhampton and Bowen-Townsville sections was undertaken by U.S.A. personnel. The work between Rockhampton and Bowen, together with short sections of work on the remainder of the route, was undertaken by Australian Army Signals and Departmental personnel.

Although the work was of such a substantial nature, all planning was completed between the end of June and the early part of August, whilst the work itself was commenced at the beginning of August, and the majority of it completed by the end of the year. The U.S.A. personnel commenced operations at the beginning of August, and completed the portions of the work allocated to them by the end of October, 1943.

Having in mind the extent of the line work, the large number of men employed thereon, and the comparative lack of experience of most of them in operating on an important trunk telephone and telegraph route already carrying a large number of Defence channels, there was a remarkable freedom from interruption of existing services, and all the staff employed on the work deserve commendation from this aspect.

The first 3-channel carrier system under this scheme (the fourth on the route) was installed and operated over one of the new pairs of wires soon after receipt in the early part of 1944; but, owing to changes in the situation, the urgency for the second 3-channel system ceased, and this has not yet been installed. The equipment for the 12-channel carrier system only started to come forward in 1945, and installation work on this is now proceeding. In addition to existing repeater stations at Gympie, Bundaberg, Rockhampton, Mackay and Bowen, new repeater stations for the 12-channel carrier are now being provided at Nambour, Maryborough, Miriam Vale, Gladstone, Marlborough, Carmila, Proserpine and Ayr.

Townsville-Cairns Direct Coast Route: Whilst the work on the Brisbane-Townsville route was in its early stages, the need for a large number of additional channels between Townsville and Cairns arose, and this gave rise to Items (i), (ii) and (iii) of Phase VI. The provision of the channels via Charters Towers and Mt. Surprise has already been discussed, in connection with the construction work on the Townsville-Cape York route; but, as this was insufficient, it was decided to provide further channels on the direct Coast route.

Up to this date, two 3-channel carrier systems had been installed on the Coast route, on 200 lb. H.D.C. pairs which, for the most part, were transposed for voice frequency operation only; but, owing to substantial irregularities in the route, crosstalk conditions were far from satisfactory, and tests had shown that a further system could not be operated under the existing transposition arrangements. To improve the existing bearer pairs and provide the new bearer pairs by re-transposing existing wires, involved substantial re-arrangement of circuits on account of the irregularities in pole configuration. The execution of such work, even with skilled and experienced workmen, was likely to give rise to a serious risk of interruption to the very important defence channels on the route.

After considering all factors, it was decided to erect three new pairs of 200 lb. H.D.C. wires on existing or new crossarms throughout, and that this work, together with any additional poles required for the reduction of irregularities in transposition spacing, would be undertaken by U.S.A. Signals personnel. The existing carrier systems would then be transferred to these wires and a new 3-channel system operated on the third pair. Departmental staff would follow up this work with the general carrier transposing of some existing pairs and the regularising of the route so that additional suitable pairs would be available for patch purposes and further carrier systems. This latter work involved extensive replacement of 4-pin arms with the standard 8-pin carrier-spaced arms and re-arrangement of wires.

The Army portion of the work was commenced in November, 1943, and completed in the following April, after much interference due to the advent of the wet season. The third 3-channel carrier system was installed about March, 1944, and it was found possible to operate it just before the completion of the Army portion of the line work. On account of its less urgency and the demand for staff for other works, the re-transposing work proceeded at a more leisurely rate, and was not completed until some months later.

Conclusion

The foregoing briefly covers the more outstanding and important works associated with long distance telecommunications carried out during the 1939-1945 period. Space will not permit mention of others which were associated with war needs, and which would have been regarded as worthy of more notice in pre-war days.

The installations which have been discussed, together with a large number of smaller works not mentioned, resulted in an increase of about 25,000 miles of wire for trunk telephone and telegraph use in the Commonwealth for the period 1939-1945. The carrier channel mileage increased over two and a half times and over seven times for trunk telephone and telegraph facilities, respectively.

Whilst this large increase in telecommunication channels might give rise to the thought that it would obviate the need for any substantial increase on many of the routes for several years to come, it is very unlikely that this will be so. The public tendency to become more telephone conscious has been accelerated by the war and this, coupled with the tendency towards a "no delay" basis for the provision of channels, is likely to result in greatly increased demands for facilities. In the circumstances, it is most probable that substantial expansion of long distance telecommunications, possibly even greater than that experienced during the past six years, will continue throughout the Commonwealth for at least several years to come.

TELEPHONE CABLE MANUFACTURE

K. J. Kirkpatrick, A.M.I.E.E., Assoc. A.I.E.E., and C. F. Bennett, B.Met.E.

PART II.

5. MANUFACTURING OPERATIONS AND EQUIPMENT

Paper-Insulated Cables

Paper Cutting: For use on the insulating machines narrow, accurately cut ribbons of paper, with clean edges, are required, covering a range of sizes from $^3/_{16}$ in. wide by .0025 in. thick to $\frac{1}{2}$ in. x .005 in. The cutting is accomplished by the scissors action of two sets of saucer-shaped, hardened steel knives, which are positively located on their spindles and carefully ground in before use.

The paper is led from a suitably braked supply roll through the cutters to a take-up mandrel, where it is reeled up in the form of flat pads, 10-12 in. diameter. The mandrel is fitted with a long key projecting slightly above its surface so that, on withdrawal of the key, the set of pads can be easily removed.

Printing of the identification lines on plain paper is effected, just before the cutters are reached, by a rubber stereo. and the necessary inking rollers. For subscribers' cable insulation the same mark is printed across the full width of the roll; but for trunk cables, marks 1, 11, 111 and 1111 are printed simultaneously, and the pads are suitably numbered after cutting so that the relevant requirements mentioned in Section 2—Special Precautions Observed in the Manufacture of Trunk Cables—can be met without confusion during insulation.

Paper Lapping: The method of issuing the coils of bare copper wire to the insulating machines is to split them on the basis of the weight required to make a given length of cable, taking care, in the case of trunk cables, that the two wires of a pair are cut from the same coil. The wire is ticketed before issue to facilitate identification during insulation and subsequent processes.

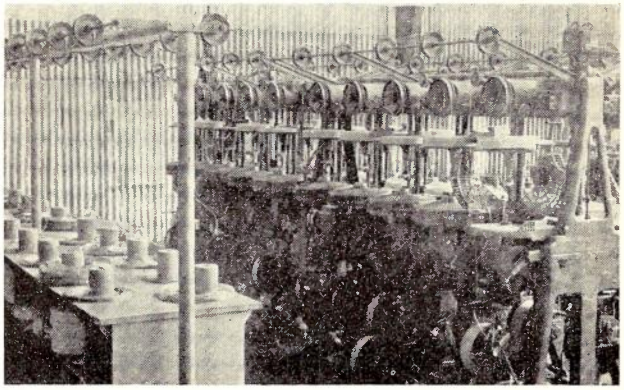

Fig. 5.—Ten-head subscribers' cable insulating machines.

Figure 5 illustrates two 10-head subscribers' cable insulating machines side by side, which incorporate a number of interesting features designed to give easy and efficient operation and high outputs.

Each machine has 5 heads on either side, and all working parts are gear-driven, enclosed and positively lubricated. The heads are independently controlled by clutches, and the discs make 2700 r.p.m., enabling the wire to be drawn through the machine at a rate of about 160 feet per minute. Owing to the high disc speed and the thin, narrow papers used on the finer wires, a very light and uniform paper tension is essential. To provide this, the centre over which each pad fits is equipped with a small, spring-loaded, slipping clutch, whose braking effect is controlled by a lever around which the paper passes on its way to the lapping point. This device enables the papers to be run off with little trouble; but if a break does occur the wire is easily pulled back for repair after turning a release knob on the capstan spindle.

The covered wire leaving the capstan passes over a tension arm which controls the slip of a clutch which drives the take-up spool. In this way, the entire spool is wound at an even tension, without risk of stretching the wire. To simplify the changing of spools, the brackets on which they are mounted swing outwards clear of the machine.

A brazing transformer for splicing the wire when necessary is provided either side of the machine, and the length insulated is checked by a counter near each capstan.

For trunk work, the insulating machines are arranged so that the paper string and the paper can be applied in one operation. Figure 6 shows a 4-head machine of this type, with the canisters which carry the packages of string mounted beneath the paper discs. The insulated wires are taken from the capstans to take-up spools at the back of the machine.

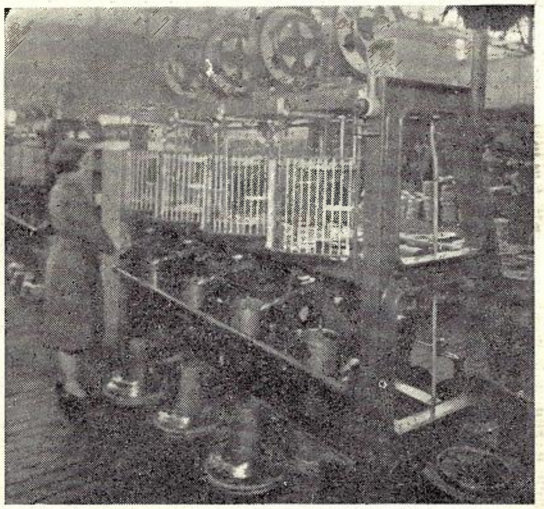

Fig. 6.—Four-head trunk cable insulating machine.

Using string and paper lays of the order of $^1/_3$ in. and $\frac{3}{4}$ in. respectively, a paper disc speed of about 1000 r.p.m. is a reasonable maximum consistent with the very even insulation required and low string breakage. It is important that any such breaks should not pass unnoticed, as the absence of the string from even a few yards of wire may have a serious effect on the capacity unbalances. Each head is therefore equipped with a contactor bearing lightly on the string lapping, which completes a relay circuit through the wire and stops the head if the string is missing.

Twinning and Quadding: The twinning machines differ only in the number of wires twisted, and in minor mechanical respects, from the quadding machine, now to be described. This machine, designed to produce subscribers' cable quad on the principles outlined in Section 4 and Figure 4e, is illustrated in Figure 7. The flyer, running at 500 r.p.m., is of light tubular construction, and is equipped with easy-loading facilities on the three floating spool cradles within it. Each cradle is fitted with a braking device which imposes a light tension on the wire and prevents over-running.

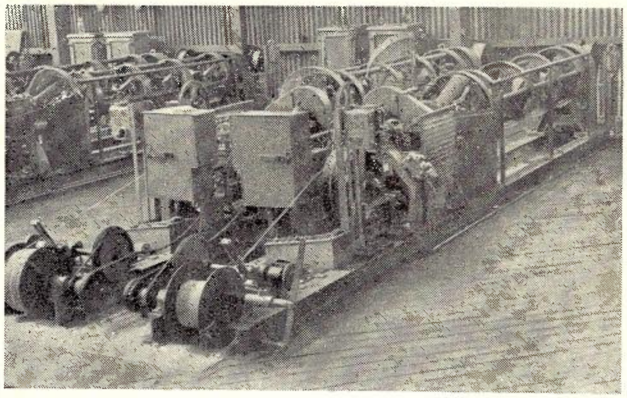

Fig. 7.—Subscribers' cable quadding machines.

The centralising string is carried on another floating holder, mounted in the front of the flyer, and arranged so that the string is led centrally through the front flyer bearing, with the four wires spaced around it.

After leaving the flyer, the wires are closed on the string in a die; the whipping is then applied from a rotating canister, before the quad passes to the capstan. The speed of the capstan relative to the flyer, and hence the twist length of the quad, is determined by a change gear in the capstan drive; a useful feature here is an indicator which shows positively which particular gear is in use.

A measuring wheel is mounted over the capstan, and the quad passes finally to the take-up spool, which is driven by a slipping clutch. Provision is made for winding spools of half the normal width, should these be required for the stranders.

A pair of trunk quadding machines is shown in Figure 8, and it will be noted that the flyers are equipped with floating spool cradles along the lines of Figure 4d. For the type of work performed, it is found undesirable to brake the supply spools, as this is likely to cause inequalities in tension; trouble from over-running is avoided and uniform twisting assisted by limiting the flyer speed to about 100 r.p.m.

The quad centre string in this machine is brought through the hollow spindle of the flyer from the rear and passes through the centre of the lay-plate used to locate the wires before they pass into the closing die.

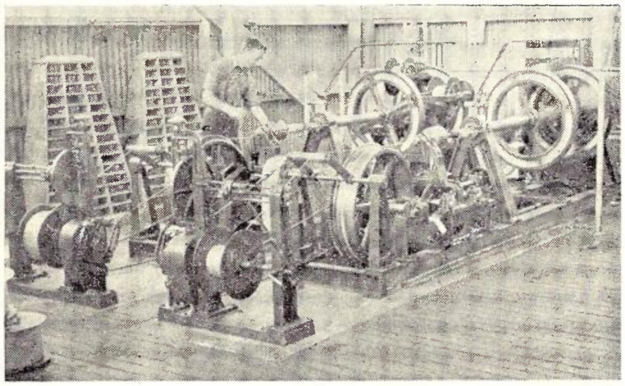

Fig. 8.—Trunk cable quadding machines.

The whipping head and capstan gear call for no comment; but reference may be made to the device used to give precise control of the take-up tension. This takes the form of a counter-balanced roller over which the quad passes, and which, through levers, automatically adjusts a brake on the cage of a differential gear whose two spindles are connected to the main drive and the take-up spool respectively.

Stranding: On the machine shown in Figure 9, four flyers are provided, having a total capacity of 252 full-size spools. Each flyer can be used to apply one layer only, so that several stranding operations are necessary for the larger cables. The procedure in such cases is to strand the inner layers on a smaller machine, passing the core from this operation through the large machine once or twice as necessary.

The stranding of the largest cables raises another problem, in that the spool capacity of the machine may be insufficient for the outer layers. In these instances, the expedient is adopted of loading two of the half-spools referred to under Twinning and Quadding on to the required number of spindles.

The method of leading the quads through a lay-plate and die is clearly shown at the right of the photograph. From this point the cable passes through a paper-wrapping head to the capstan and take-up stand. A measuring wheel is also fitted near the capstan, but this is for check purposes only, as the need for cables to be of exact length is so fundamental that one of the centre quads is always marked before stranding by direct measurement through a scaled trough.

The stranding of carrier cables is of some interest, because they are generally provided with a greater thickness of overall wrapping papers than would be required merely for insulation from the sheath, the increased separation being provided to reduce eddy current losses in the sheath at high frequencies. Two lapping heads, capable of applying up to four papers each, are used. They are basically similar to Figure 4b; but the paper pads are mounted with their axes parallel to the cable, and adjustable guide pins are fitted to lead the papers on to the cable at the correct angle.

The flyers of the machine illustrated are about 8 ft. in diameter, and are therefore limited in speed to about 25 r.p.m. In operation, an appreciable part of the time is unavoidably devoted to re-loading the spools at intervals; nevertheless, the overall output of strand, when working on full loads of quadded cable, reaches the substantial figure of 250 wire miles per hour.

Drying: The steel drums of strand are first placed in air ovens at 70°-80°C. for a few hours, and are then transferred to steam-heated vacuum ovens, maintained at about 115°C. and under a vacuum of 28 in. or better. A condenser, of water-cooled, tubular construction, is provided in the line from the ovens to the vacuum pumps. As insulating paper normally carries about 8% water, the condensate from a large cable may amount to several gallons.

The two essentials for drying are heat, and the means for removing the water vapor, i.e., the condenser. Drying then continues so long as the vapor tension in the oven exceeds the saturation value for water at the temperature of the condenser. The primary purpose of the vacuum pump, in this case, is not to remove the water vapor, although it does this to some extent, but simply to accelerate its evaporation; and the effectiveness with which this is achieved may be

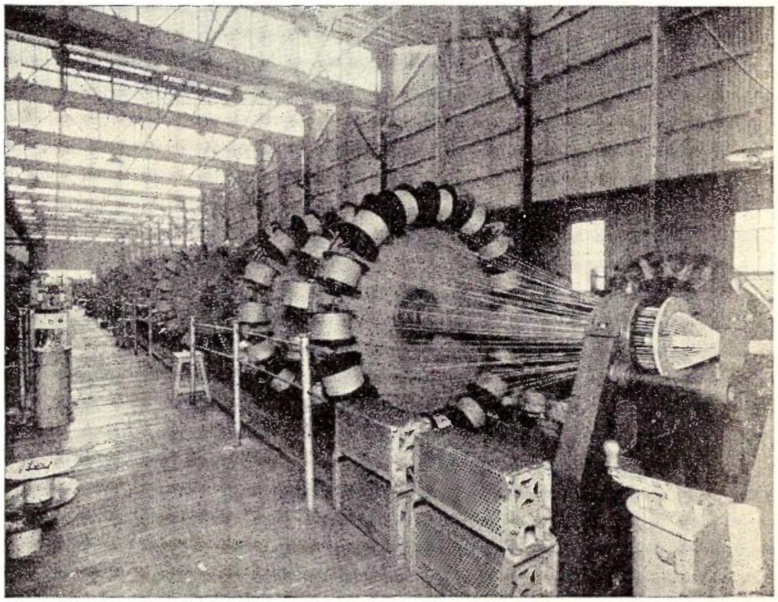

Fig. 9.—Telephone cable stranding machine.

gauged from the fact that the drying time with vacuum is about one-third of that without vacuum.

The cables are kept under vacuum for from 12 to 24 hours, and before removing them from the ovens the vacuum is broken by admitting desiccated air.

It is quite feasible to heat the cables in the ovens by passing electric currents through the conductors. This process effects a marked saving in drying time; but, on the other hand, requires expensive equipment and very close supervision. Its adoption in any particular factory depends largely on the condition and capacity of the existing plant.

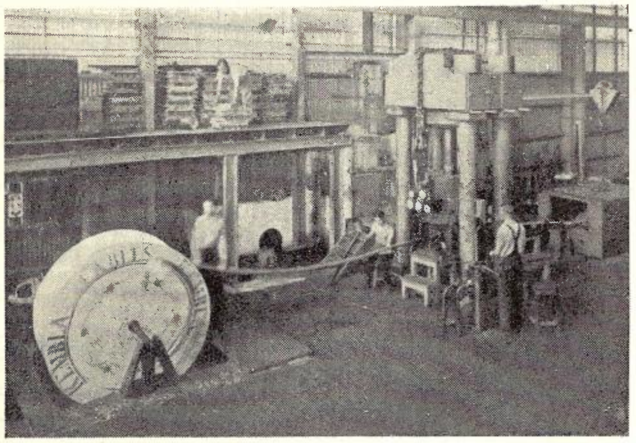

Fig. 10.—Lead press.

Lead Covering: The general arrangement of a vertical lead press capable of exerting a total load of 3000 tons is shown in Figure 10. The cable to be covered is placed in a steam-heated oven to minimise moisture pick-up from the air; and, after the sheath has been applied, is reeled on to a wooden drum whose speed is determined by a manually controlled hydraulic variable speed gear. The pipe is inspected all around with the aid of a mirror during extrusion. In the foreground are seen the press control valves, and beside the press the oil-fired lead-melting furnace, whose crucible is equipped with a bottom pouring valve for running the metal down a portable steel launder into the press when required.

The main parts of the press (Figure 11) are the fixed ram, the lead container, the die block containing the pipe-forming tools, and the water ram, which works in a vertical hydraulic cylinder below floor level.

The cable enters the die block through a hollow core sleeve, which carries at its inner end a steel "core" having the form of a hollow, truncated cone. The "die," inserted from the outlet end of the block, is a circular steel ring, whose bore and position are such that an annular space exists between it and the steel core, and it is through this space that the lead, in a plastic state, is extruded to form the pipe. Both the bore of the die and the minimum diameter of the conical part of the core are made a little larger than the desired external and internal diameters respectively of the finished pipe; this allowance is made because a "vena contracta" effect occurs during extrusion. The correct selection of dies and cores, therefore, requires considerable experience; but the effect has one useful consequence, in that it allows a small clearance to be provided between the paper insulated cable and the inside of the core, thus preventing any catching or stripping of the wrapping papers. Within limits, the core may be moved in or out to reduce or increase the wall thickness of the pipe, and the die-holder is fitted with four external adjusting screws (not shown in the figure) for centralizing it with respect to the core.

It will be noted that the passage of the lead through the upper part of the block is shown by dotted lines; this is correct for the sectioning plane taken, because the opening in the top of the block is spanned by a bridge which divides the lead into two streams, one either side of the centre line of the cable. These streams meet again and are autogenously welded near the upper and lower surfaces of the core sleeve.

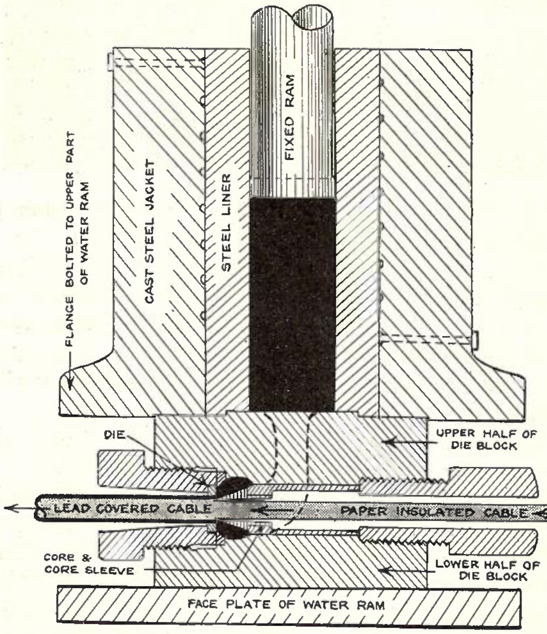

Fig. 11.—Vertical medial section of lead press container and die block.

The lead in the container is cooled by circulating water through an annular passage surrounding the liner. In the block the weight of lead is less, so that, in order to prevent chilling of the metal during idle periods, this portion of the press is heated. The maintenance of these temperatures, and that of the molten lead, at their correct values is a principal factor determining the soundness and uniformity of the pipes produced. Consequently a careful watch is kept on the indicators shown on the front of the press in Figure 10.

The process of extrusion is intermittent, and forms part of the following sequence of operations: Filling the container with molten lead, allowing this column of lead to set under a gauge pressure of about 1000 lbs. per sq. in., raising the pressure to 5000-6000 lbs. per sq. in. on the water ram and so extruding the charge and, finally, moving the container down clear of the fixed ram for re-filling. With good melting and filling practice, no difficulty is experienced in extruding sound pipe over the region representative of the junction between old and new charges.

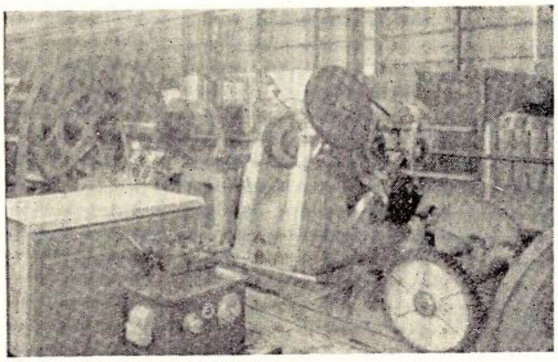

Fig. 12.—Steel tape armouring head (wire armouring flyer on left).

In starting a length of cable, its end is simply pushed in to the core of the press block and, after a few feet, the frictional resistance between the inside of the pipe and the cable draws the latter from the supply drum without further attention.

Equipped with a 9⅛ in. diameter fixed ram, and having a working stroke of 27 in., the press shown in Figure 10 has an overall output of about 1 ton of pure lead pipe per hour, and is chiefly used for large cables. Three smaller presses complete the lead-covering equipment.

Armoring: An armoring machine consists of a number of rotating flyers carrying the various materials, with steam-heated bitumen pots between them, and the usual supply and take-up stands and capstan gear. These components are arranged in line so that the cable may be drawn through them in turn.

The jute flyers are of simple form, each consisting of a circular ring carrying pins on which the impregnated jute packages are mounted, and whence the strings are led radially to the cable.

For applying steel wire armoring, the spools of wire are mounted in a flyer generally similar to that of a large stranding machine, but having the spool cradles floating. Two flyers are installed to allow of two layers of wires being applied in one operation, if required.

A typical steel-tape head is shown in Figure 12; this head holds two pads, from which the tapes are applied to the cable with a gap of about 25% between turns and with the outer tape centrally over the gaps in the inner one. The pads are large—about 22 in. diameter—to give a reasonable length of run, and as each tape is exhausted the outer end of a new pad is electrically welded to it.

At the take-up end of the machine the cable passes through a revolving drum containing the powdered limestone, which is last applied.

The machine described has sufficient jute flyers and bitumen pots, both before and after the main armoring heads, to cater for practically all types of armoring and, as a result, occupies the considerable length of about 170 ft. A smaller machine is equipped to apply the ordinary single-wire armored protection only.

Cables are likely to show a rise in mutual capacity during armoring, but the compression which causes this can often be reduced or eliminated by filling the cables with dry compressed air beforehand.

5. TEXTILE-INSULATED SWITCHBOARD CABLES

Insulating, Twinning and Stranding: The machines used for textile-covering the enamelled wires follow the principles enunciated in Section 4—Lapping. One machine may comprise eight groups of three gear-driven heads, the latter being mounted one above the other so that two silk or rayon coverings and one cotton covering may be applied in one operation. The lappings are necessarily applied with a short lay, and the use of machines constructed on precision lines to run at head speeds of 3500 r.p.m. is therefore justified. Under these conditions, the wires are drawn through the machines by capstans at the rate of 30 ft. per minute.

The twinning of ordinary pairs calls for no comment. Three-wire units are formed in one operation by running the third wire in straight, between the flyer and the capstan of the twinning machine, and binding the unit with a open whipping of cotton.

In stranding, the only differences from paper-insulated cable practice are the use of generally shorter lays in the interests of flexibility and the substitution of cotton tape wrappers for paper.

Impregnating, Lead-covering or Braiding: The cables, on steel drums, are dried and immersed in a steam-heated tank of compound for one or two hours. Lead-covered cables are led direct from the tank to the press, where a pipe of thinner wall than is usually adopted for paper-insulated cables is applied.

Cables requiring the flame-resistant braided finish are removed from the bath after impregnation and lapped with oiled paper, impregnated cotton and cotton tape. The cotton braid is applied in a machine having two sets of cotton carriers running in opposite directions around the cable in slots cut in the main platform of the machine. The slots are of sinuous form, so that the carriers of one set pass alternately inside and outside those of the other set, thus effecting the crossing and re-crossing of the threads characteristic of braids. An improved machine, having a considerably higher output than the 30 or 40 yards per hour to which the "maypole" type described above is limited, has an outer and inner set of carriers running in plain circular paths. In this case, the crossing of the threads is performed by light deflecting levers, in conjunction with an ingenious method of bringing the cottons under the inner carriers without at any time leaving the latter unsupported.

The flame-resistant paint is applied after braiding, and the cable is wound on to a large skeleton drum in a single layer to allow the paint to dry. The cable is finally coiled, or wound on to wooden drums.

6. TESTING

Manufacturing, inspection and testing consist in the supervision of the loading and adjustment of all machines, the checking of mechanical details of construction at each stage, and the carrying out of preliminary and final electrical tests. It is with the last-mentioned operations that this section of the paper is mainly concerned.

Preliminary tests begin after quadding, when the individual spools are tested for continuity and absence of contacts. Tests of this type are carefully repeated immediately after stranding.

Following lead covering, the ends of each cable are sealed while it is still hot, and the whole immersed in water for several hours. Under these conditions, water will be definitely sucked in through the smallest sheath fault.

The final electrical tests are carried out in a building artificially maintained at 50% relative humidity or less and, as an additional step towards reducing moisture absorption during testing, the cable ends are dipped in hot paraffin wax immediately after opening.

The drums are placed by a crane in the required part of the testing space, and the test leads brought through a wall from an adjoining room, also air-conditioned, where the instruments are located. Communication between the tester and the "connector-on" is carried out by a simple system of buzzers and signal lamps.

Every wire of every cable is tested for insulation resistance, the wires being grouped for testing so that all wires which could possibly be adjacent are placed in different groups. The insulation of the groups from one another and from the sheath is measured by a sensitive galvanometer, in conjunction with a 400 volt battery, a universal shunt and a standard calibrating resistance.

Twin cables only are tested for mutual capacity by the D.C. charge method, using a 50 volt battery, and carrying out the calibration of the ballistic galvanometer on a standard condenser.

The D.C. resistance of a proportion of the wires of all cables is measured on a Wheatstone bridge, a number of wires being taken in series for each test. The resistance unbalance of all trunk cable pairs is likewise measured by a D.C. method, using a slide wire bridge calibrated to read the unbalance directly as a percentage of the loop resistance. A continuity test completes the D.C. testing.

A.C. mutual capacity and capacity unbalance measurements are made at 800 c/s. on all trunk pairs and on a proportion of subscribers' cable pairs. Bridge methods of testing are used throughout, using headphones to determine the balance point. A complete account of the construction and operation of the testing sets would be too long; but brief mention may be made of the refinements necessary to secure accuracy and speed of testing. These comprise chiefly the use of precision fixed or variable air condensers wherever possible, elaborate double or triple screening of certain of the components and wiring; and, for speed, multi-position rotary selecting switches to reduce to a minimum the changing of connections at the cable.

The testing of carrier cable involves considerable additional work. In the standard 12 quad cable the mutual impedances for all pair-pair combinations are measured on each length—276 readings in all, per length. This test is carried out at 5 kC/sec. as the moduli of the couplings generally have their greatest values at this frequency; a heterodyne detector-amplifier is used to give a readily audible signal. The testing set is, in principle, an A.C. potentiometer, used to measure the complex ratio of the e.m.f. induced in a disturbed pair to the current supplied by the set to a disturbing pair, and calibrated in terms of inductance and resistance (i.e., impedance) rather than of potential difference.

With a small change in connections, the above set may be used to measure the self-inductance and effective resistance of carrier pairs over a range of frequencies up to about 100 kC/sec. The mutual capacity and leakance of the same pairs may be measured on a high-frequency admittance bridge. Occasional tests of this kind are carried out to ensure that the ordinary low-frequency tests are not giving a false indication of the performance to be expected of the cables at high frequencies. These parameter tests are limited to test lengths of about 15 yards only, from considerations of the electrical length of carrier circuits at high frequencies.

Cables to be armored are tested completely before armoring; and the mutual capacity, continuity and insulation resistance tests are repeated thereafter. The other characteristics are unlikely to be affected by the armoring operation.

After testing, the cable ends are cut off flush and capped, a Schrader valve generally being installed in the seal of trunk cables, as this type is frequently required to be delivered under a pressure of dry air of 20 lbs. per sq. in. The drums are then lagged with wooden battens, awaiting shipment.

Though hardly a manufacturing operation, it will perhaps be of interest to refer to the process of allocation of trunk cables to definite sections of the route for which they are intended. The allocation is carried out on the basis of the test results, with the objects of obtaining a finished route having as smooth a characteristic impedance curve as possible, and achieving the most effective reduction of capacity unbalances at the selected joints made during laying. The necessity for allocation arises from the fact that, in spite of the extreme care in the manufacture of the cables, it is impossible to avoid the effects of random variations in materials, minor machine adjustments, and even weather conditions. As a result, a series of lengths may show a considerable "spread" in their general level of characteristics. Allocation matches the lengths to one another, results in the route being initially of higher electrical quality than it otherwise would be and, more important, provides a wider margin to cover the deterioration which inevitably occurs if at a later period lengths are replaced for any reason. Allocation is naturally most effectively carried out when a large proportion of the cables is of the same drum length.

7. OTHER TYPES OF COMMUNICATION CABLE

Paper-pulp Insulated Cables: In this very striking American development, the paper insulation of subscribers' cable is formed direct on the wires, eliminating the paper slitting and lapping operations. The process is one of great technical refinement; and this has an important consequence, namely, that an economic installation is necessarily one having a high output, both in order to keep the capital investment per unit output low, and to justify the appointment of the specialist supervisory, operating and maintenance staff required to obtain efficient working of the plant.

The large output referred to is, unfortunately, very much greater than present Australian requirements, so that the application of the process in this country will probably be impracticable for some considerable time.

A complementary development to the pulp-insulating process in America was the introduction of special wire-drawing machines, capable of practically continuous operation and delivering the finished wire at speeds of 10,000 or more feet per minute on to spools holding 300-400 lbs.

On a single pulp-insulating machine, 60 wires are insulated simultaneously at a speed of 130 feet per minute. Continuous operation is essential, and means are provided for changing all spools without stopping the machine. The wires are first electrolytically cleaned, then pass through a modified single-cylinder paper-making machine, where each wire is embedded in a narrow strip of pulp. The pulp is partially dried, shaped into a circular form and the drying completed at a high temperature. The intense heat explodes the remaining moisture from the paper, thus lifting it away from the wire and overcoming the disadvantage of high mutual capacity that cables made by this process had in the early stages.

"Unit" Cables: The larger subscribers' cables in America and, to some extent, in England, are now stranded on the "unit" system; that is to say, each finished cable comprises a number of previously formed units of 50 or 100 pairs, the main idea underlying this construction being to simplify installation. In America the 100-pair units are made up on a flyer strander following the principles of Figure 4f, while in England a conventional strander is used, arranged so that the layers are all applied in the same direction. For stranding the units together a special machine is necessary, based on a modification of Figure 4c, in which the capstan and take-up drum are fixed inside the flyer instead of the supply drums.

Co-Axial Cables: For carrier telephone communication on land, the air-spaced co-axial construction is finding favor. In the latest design adopted by the British Post Office a co-axial pair consists of a 0.104 in. diameter copper wire located centrally inside a tubular return conductor by means of hard rubber discs spaced about $1\frac{1}{4}$ in. apart. The return conductor is formed from a 0.010 in. thick copper tape having notched edges, which engage with one another during the forming operation. The tube, having an internal diameter of about $\frac{3}{8}$ in., is finally lapped with two thin, mild steel tapes. A typical cable is built up from two co-axial pairs of the above type, with ordinary paper-insulated trunk quads occupying the interstices, to give a circular core. If required, one or more layers of paper-insulated quads is then applied. Drying and sheathing, etc., are carried out as usual. The two-tube co-axial systems are designed to provide, ultimately, 600 go and return circuits with an operating frequency range of 0.5 to 3 mC/s., and a maximum repeater spacing of 6 miles. This compares with the 576 channels available from two 12 quad 40 lb. paper-insulated carrier cables, operated with 24 channels on each pair and a maximum repeater spacing of 16 miles.

Submarine Cables: In the shallower marine waters the principal types of telephone cable used have been, in the order of their introduction, a single 4-core unit insulated with solid gutta percha or balata and wire armored; and wire armored cables of paper-insulated, lead-covered type incorporating mechanical features such as double lead sheaths.

For deep-sea work, a single core with solid insulation is the only mechanically practicable construction; and, with the development of carrier frequency technique, the co-axial type with copper return tapes over the insulant and inside the armor became pre-eminent. The economic installation of long circuits was greatly assisted by the introduction of the insulant known as paragutta, which has superior electrical characteristics to both gutta percha and balata.

As an alternative core insulation for submarine co-axial cables, lately developed plastics have interesting possibilities. For example, a short experimental length was recently made in Australia of a cable employing an 0.082 in. diameter copper central conductor insulated with the plastic, Polythene, to an overall diameter of 0.296 in., and having a return conductor consisting of 34 .029 in. diameter copper wires closely applied with a long lay. The whole was lightly armored and, under test, showed the satisfactory attenuation of 1.5 db. per nautical mile at 30 kC/s.

8. CONCLUSION

With the exception of the greater part of Section 7, the manufacturing methods described in the paper are typical of those practised at Metal Manufacturers Limited, Port Kembla, and may also be taken as broadly representative of the work of small or moderate-sized factories elsewhere. The photographs likewise show equipment installed at Port Kembla.

The authors wish to thank the Company for permission to publish the paper.

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CROSSTALK REDUCTION IN TELEPHONE CABLES

J. C. Brough and O. J. Connolly, B.Sc.

Introduction: The limitation of crosstalk between circuits in a telephone cable is determined by two main considerations:—

(a) control of the manufacture;
(b) field manipulation of unbalances during installation, normally referred to as cross-splicing or "capacity" balancing.

Manufacturers have adopted a number of measures to reduce the couplings between the pairs in a cable. These measures include:—

(i) grouping of wires by twisting together in pairs or quads;
(ii) use of different lengths of twisting pitch;
(iii) rotation of successive layers of the cable in opposite directions during the laying-up process.

Although the couplings between pairs can be reduced to relatively small amounts by these means, and by careful control of the mechanical processes to prevent crushing of the quads and consequent irregularities between the wires, the crosstalk in a completed cable may still be excessive unless planned joints are introduced at regular intervals with the object of balancing the couplings in one section of cable against adjacent sections.

The reduction of crosstalk during the installation of voice frequency cables is achieved solely by reducing capacity unbalances, the effect of other unbalances such as resistance, mutual inductance and leakance being unimportant at that frequency. Such cables fall into two categories:

(1) Junction and long subscribers' cables;
(2) Minor trunk cables.

Carrier cables operating to 60 kC/sec. and higher, have superseded the voice frequency type as main trunk cables. In such cables resistance, leakance and mutual inductance characteristics also become important, and it is necessary to take them into account in the balancing procedure.

In this paper an outline will be given of the factors influencing cable crosstalk, both voice frequency and carrier, and their measurement, followed by a description of the procedure adopted for unbalance testing during installation of the three main classes of cable. The first section will deal with voice frequency cables, including junction and long subscriber cables (class 1), and minor trunk cables (class 2), and the second section with carrier cables (class 3).

Part 1.—Voice Frequency Cables

Capacity Unbalance Characteristics: Star quad type cable, in which the 4 wires forming 2 pairs of diagonally opposite wires are twisted uniformly about a common axis, is used practically exclusively, having superseded twin and multiple twin types about 1935. For short entrance cables leading open wire routes into towns, trunk type star quad is used, but for all other voice frequency purposes local type star quad, with more liberal manufacturing tolerances, is standard. Phantom circuits are not derived on the latter type of cable, and this further simplifies the balancing procedure.

Normally, the cables concerned under this heading do not exceed about 35 miles for minor trunk cables, 10 miles for junction cables between two exchanges and 5 miles for long subscribers' cables.

The star quad arrangement results in a much closer proximity of the 2 pairs than in the earlier twin cable which was used for junction and subscribers' purposes. In addition, the star quad involves 2 pairs with the same twist, whereas in the twin type, adjacent pairs have different twist lengths. For this reason, the within quad capacity unbalances are generally much higher than unbalances between pairs in different quads, even when these are adjacent.

Mutual electrostatic capacity (that is, capacity between the 2 wires of a pair) does not vary sufficiently to warrant special treatment for its control, except in a few special cases, reference to which is made later in the paper.

The electrostatic coupling between different circuits is due to differences (or unbalances) in the capacities between the wires of the different pairs, and results from the displacement of the wires from their correct geometrical position during the manufacturing or installation process. The effect of the unbalances is to produce crosstalk between the pairs. Some idea of the capacity unbalance characteristics involved are given by Table 1, showing the specification limits for 176 yard lengths of local type star quad cable. Actual values obtained on manufactured cable are normally well within these limits. For example, typical figures for within quad unbalances on factory drum lengths of minor trunk cable have been 50 mmfds. average and 300 mmfds. maximum for 250 yard lengths.

Where crosstalk between pairs in adjacent quads is likely to be excessive if quads are "straight" jointed, systematic jointing of quads may be applied; that is, quads which are adjacent in any length are jointed to non-adjacent quads in the next length in a definite order. Figure 1 illustrates the systematic jointing of quads as applied to a 14 pair (7 quad) cable. In this case, adjacent quads in any length resume adjacency only once in every four lengths. In minor trunk cables, where quads are normally not "straight" jointed, but cross-spliced, to give the lowest resultant for within quad unbalances, continuous adjacency of quads is, of course, automatically obviated.

TABLE No. 1

Local Type Star Quad Capacity Unbalance Mmfds. Specification Limits for Lengths of 176 Yards

	In 10% of Lengths		In 90% of Lengths	
	Mean of all Readings	Max. Individual Value	Mean of all Readings	Max. Individual Value
10, 20 & 40 lb. Cables—				
1. Between pairs in same quad	200	1000	125	750
2. Between any other pairs ..	—	200	—	125
3. Between any pair and earth	350	1500	200	750
6½ lb. Cables—				
1. Between pairs in same quad	250	1000	150	750
2. Between any other pairs ..	—	200	—	125
3. Between any pair and earth	350	1500	200	750

Note: The capacity unbalance does not vary directly as the length of the cable, and for lengths other than 176 yards the specification values need to be multiplied by the factor $\frac{1}{2}$ $(L/176 + \sqrt{L/176})$ in the case of pair to pair unbalances, or L/176 in the case of pair to earth unbalances where L = length in yards.

As the problem of capacity balancing voice frequency cables is essentially that of reducing the within quad unbalances, it is convenient at this stage to examine what capacities are involved in the typical case. Figure 2 shows the network of capacities which exist within a quad.

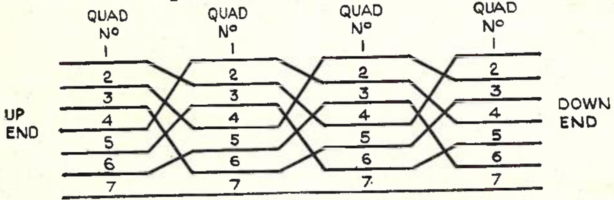


Fig. 1.—Systematic jointing of quads to obtain quad separation.

The 4 wires marked A, B, C and D are also designated by marks I., II., III. and IIII., corresponding to the standard markings on the paper insulation. Wires I. and II. form pair 1, and wires III. and IIII. pair 2. For all practical purposes, capacities a, b, c and d may be regarded as fractionally increasing the values of w, x, y and z, which alone need then be considered. Mutual capacities m and n, of course, do not enter into the question of couplings between the pairs.

In addition, for all practical purposes, w may be regarded as combining with y and, similarly, x with z (the combination, or resultant capacities, being designated by capital letters Y and Z, and the capacity unbalance then becomes simply the difference between Y and Z). If, then, a condenser is added to build the lower value to that of the higher, the capacity of that condenser is regarded as the capacity unbalance between the metallic circuits of the two pairs of the quad; or, as it is generally called, the side to side unbalance. This assumption is, theoretically, not quite correct, but is the accepted definition of capacity unbalance, approved by the C.C.I. and used in Australia and most other countries.

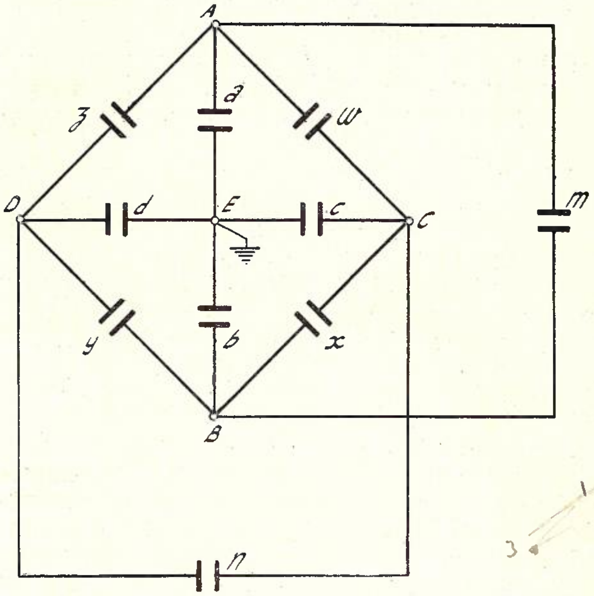


Fig. 2.—Capacitance network of telephone quad.

The technique of measurement of capacity unbalance is the application of the foregoing, whereby a calibrated variable condenser is connected to the quad and adjusted to neutralise the unbalance. The value of capacity necessary is then noted for use in the subsequent operations. Since the unbalance may be due either to Y exceeding Z (that is, capacity between wires II. and III. exceeding that between I. and III.), or vice versa, it is necessary to differentiate between the two cases. This is done by referring to the former as a **negative** unbalance and the latter as a **positive** unbalance.

An illustration of a self-contained, simple bridge used for the measurement is shown in Figure 3, while Figure 4 shows the schematic circuit and also indicates connection to the quad under test. The quad is left open at the distant end so that any coupling which appears between the pairs is due only to capacity unbalance. As the unbalance to be measured is of a small order, the bridge dial is calibrated in micro-microfarads. A tone of 1000 c/s. is applied to pair 1 and a set of headphones connected across pair 2. Very closely balanced fixed condensers of 500 mmfds. capacity are connected between wires I. and IIII. and II. and IIII. respectively. Their purpose is to complete the bridge circuit and, since they increase the values of Y and Z equally, and so do not affect the unbalance being measured, they will not be considered further here. A variable differential condenser with a range of ± 500 mmfds. is connected to wires I., II. and III., as shown. The dial of this condenser is calibrated to read the **difference** between capacities of the moving plates M to fixed plates F1, on the one hand, and M to F2 on the other. Thus if the moving plates are engaged equally with both F1 and F2 there is 250 mmfds. capacity on each side, the dial reads zero and the bridge itself is seen to be balanced; so that if in this condition a tone is heard, it is wholly due to the unbalance between Y and Z of the quad, since the effect of the variable condenser in this position is to add 250 mmfds. equally to Y and Z.

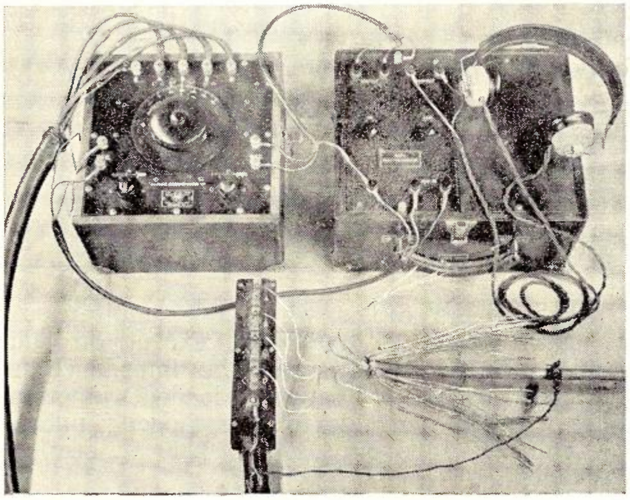


Fig. 3.—Simple capacity unbalance set, combined 1000 c/s oscillator and amplifier, and connecting block.

If now M-F1 is increased to, say, 400 mmfds. (so adding 400 mmfds. to Z) in order to eliminate the tone, then M-F2 will be 100 mmfds. (added to Y), and the dial will read —300 mmfds. (minus sign because the balancing capacity is added to deficient capacity Z to make it equal to capacity Y, which condition has already been noted as a negative unbalance). On the other hand if, say, M-F2 must be made 300 mmfds., M-F1 will be 200 mmfds. and dial reading +100 mmfds., indicating that capacity Z exceeds capacity Y by 100 mmfds. (a positive unbalance).

At this stage one other point must be considered. That is the effect of transposing the wires of either pair separately (not both together) when connecting to the bridge. If, for instance, wires I. and II. are transposed, the bridge will perform as before, but capacity Z will now appear to be that between wires II. and III., and Y that between I. and III., so that elimination of the tone requires the same magnitude of added capacity, but on the opposite side of the differential condenser. In other words, a negative unbalance (which means that Y is greater than Z) applies to an excess capacity between wires I. and III., as against that between wires II. and III. (A similar result will be obtained if wires I. and II. are kept straight as originally, and wires III. and IIII. are transposed instead, but this does not offer any advantage). It can, therefore, be said that the sign of the unbalance will be changed if the wires of pair 1 of a quad are transposed, and this is the all-important fact made use of in balancing operations.

Crosstalk Limits: Most voice frequency cables have loading coils connected to pairs at regular intervals throughout their length, one effect of which is to introduce a phase change at each point where a coil occurs. The circuit is thus separated into a series of sections contained between loading points, the effect of which is to preclude the use of capacity unbalance characteristics in one section to neutralise those in another. It is, therefore, necessary to consider the cable between each successive pair of loading points separately, and this is a very convenient length to work on in practice.

Before setting out to balance a loading section, the degree of balance required must be determined. For junction cables the maximum permissible crosstalk, measured at the end of a completed cable, is specified to be 1000 crosstalk units (a crosstalk unit is the value of coupling between two circuits when, with the passage of a telephonic current in the first pair a current equal to one-millionth part of the former appears in the second pair). Now, 1000 C.T.U.'s equals a crosstalk attenuation of 60 db (db = 120 — 20 $\log_{10}$ C.T.U.), which practical experience confirms to be a satisfactory value in all respects —not low enough to permit intelligible overhearing when listening normally on a quiet cir-

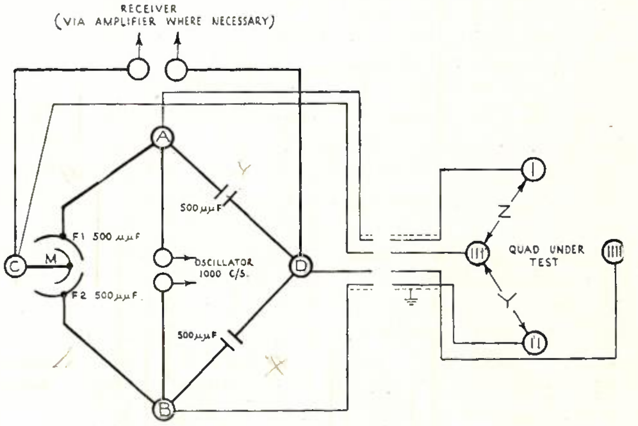


Fig. 4.—Schematic circuit of simple type capacity unbalance set for measurement of side to side unbalance.

cuit, and not so high as to be costly to achieve. (The word "normally" is introduced specially, and infers casual listening for a short period. It is surprising what can be overheard if one listens "searchingly" for a long period, as the ear appears to adjust itself to the demand). Moreover, with a worst value of 60 db., the average value for all quads in a cable is appreciably above this figure.

Now, it is found that the overall summation of crosstalk occurring in a number of loading sections closely approximates to the square root of the sum of the squares of crosstalk in the sections (all expressed in C.T.U.'s); so that, in a junction cable of, say, five loading sections, the overall crosstalk of which is to be 1000 C.T.U.'s, the sectional crosstalk, assuming it will be of equal value in all sections, must not be greater than the value calculated from—

$$1000^2 = 5\ X^2$$

$$\text{i.e., } X = 450 \text{ approx.}$$

That is, in each section, the maximum permissible crosstalk would be 450 C.T.U.'s. However, such a conclusion does not allow for a margin of safety; and it is therefore usual to plan on the basis of the ultimate lengthening of the cable, or the possible condition for crosstalk wherein two connections are set up and the conversations traverse pairs contained in the same quad in two successive junction cables. That increases the number of loading sections in a typical network to the order of 10, and the calculation then becomes $1000^2 = 10 \times X^2$, whence X = 315 C.T.U.'s approximately. Now, crosstalk in a loading section between two pairs having the same impedance is related to capacity unbalance as follows:—

$$\text{C.T.U.'s} = 2\pi f\ (K \times 10^{-6})\ Zo/8$$

where K = capacity unbalance in mmfds. and Zo is the characteristic impedance of the circuits (1100 ohms for the standard loading with 88 millihenry coils spaced at 6000 ft.), so that the capacity unbalance corresponding to approximately 315 C.T.U.'s is 350 mmfds., and that value is set down as the maximum permissible unbalance in each loading section. Where special cases require a greater overall crosstalk separation than 60 db., application of the foregoing calculation will indicate the permissible sectional unbalance. Cables to which loading coils are not being connected initially are balanced with the view to ultimate loading

For minor trunk cables, the limits of capacity unbalances per loading section are shown in Table No. 2.

For convenience in recording, the normal practice is to refer to the side circuits of a quad as S_1 and S_2, the Phantom as Ph, earth as E and pairs not in the same quad as Pr_1, Pr_2, Pr_3, etc. On the Siemens trunk test set (Figure 8), side circuits are designated 1 and 2 and the phantom by the + symbol. Some reduction in the side to phantom and side to earth unbalances is made in these cables in order to prevent crosstalk due to indirect couplings via phantom circuits, and to avoid interference from superimposed circuits such as cailho signalling circuits. It is not intended, however, to use the phantom circuits for telephone circuits, nor is phantom loading provided.

TABLE No. 2

Characteristic	Mmfds.	
	90% of Combinations	100% of Combinations
Side to Side (S_1/S_2) ..	30	50
Side to Phantom (S_1 or S_2/Ph)	500	1000
Side to Earth (S_1 or S_2/E)	500	1000
Pair to Pair ($Pr._1/Pr._2$)	—	50

In subscribers' cables, where the simultaneous use of both pairs of any quad, except on odd occasions, is not likely, and the impedance is appreciably lower than for loaded junction cables, a maximum side to side capacity unbalance value of 1500 mmfds. per 6000 ft. section is accepted.

Capacity Balancing of Junction and Long Subscribers' Cables: For this class of voice frequency cable, which is limited in length by the disposition of exchanges within the metropolitan area boundaries in the case of junctions, and by exchange boundaries in the case of subscribers' cables, it is practicable to provide the required limits by "straight" jointing the quads and limiting the cross-splicing to the wires within the quads. The adoption of "straight" jointing places considerable limitations upon the capacity balancing, but in a large network of junction and subscribers' cables it has considerable field advantages.

After considerable experience in the field, the following conclusions have been reached:—

(a) The use of one central balancing point (with jointing determined by the sign and magnitude of the unbalance) per loading section, with "straight" jointing of the wires of the quads over the remainder of the section is inadequate, and involves condenser balancing on a high proportion of the quads in the cable.

(b) Three capacity balancing points per loading section, based on unbalance measurements of each quarter section, and involving consideration of both the magnitude and sign of the unbalances, are generally sufficient to reduce the worst side to side unbalance to less than 350 mmfds. per loading section, without the need for condenser balancing, except in isolated cases.

(c) Seven capacity balancing points per loading section, based on unbalance measurements of each 8th section, but involving consideration of the **sign only** of the unbalances, are generally sufficient to reduce the worst side to side unbalance to less than 350 mmfds. per loading section for the majority of quads. It is necessary to reduce the capacity unbalance of a small proportion of the quads exceeding 350 mmfds. by the use of a small balancing condenser connected between two appropriate wires in the quad.

(d) The measurement of sign only and not the magnitude of the unbalances, and the cross-splicing within the quad on the basis of tests at seven points for sign only, involves a slightly higher proportion of condenser balanced quads to attain the limit of 350 mmfds. This disadvantage, however, is more than offset by the simpler and more expeditious field operations involved with this method, compared with the measurement and assessment of the magnitude of the unbalances.

In the following, a description will first be given of the method of capacity balancing using the "sign" balancing only, followed by a description of the sign and magnitude method:—

The simple capacity unbalance set shown in Figure 3 measures side to side capacity unbalance only, and to an accuracy of plus or minus 20 mmfds. The set is used by the cable jointer concerned with the actual jointing of the cable under test.

Connecting blocks have also been devised to enable rapid connection and disconnection of each quad to the test set, as most of the actual testing time is taken up in performing these operations. One type is shown in Figure 3, and a second type in Figure 5.

The comparatively low output level from the battery operated oscillator necessitates employment of an amplifier to provide an adequate level of tone in the head receivers, particularly under noisy street conditions.

In making a cable joint, the jointer first tests a quad from one side of the joint to determine the sign of its unbalance. He then tests the corresponding quad on the other side of the joint. If the two signs are opposite, the quad is jointed "straight." If the two signs are the same, the wires of the first pair (marked I. and II.) are crossed. This procedure is repeated at all 7 balancing points. This method of balancing will not ensure the reduction to the required value of extreme values of capacity unbalance, which may be as high as 1000 mmfds. in a length of 176 yards, unless the "sign" balancing be carried out at more than the 7 points, or cross-splicing between quads is resorted to. It is necessary, therefore, to check the overall capacity unbalance of the quads after completion of jointing of each loading section. Any values of capacity unbalance which exceed the limit of 350 mmfds. (or 1500 mmfds. for subscribers' cables) can then be corrected by connecting a small condenser of suitable value between the pairs of the quad. If the unbalance is positive in sign, the condenser is connected between wires II. and III. If the unbalance is negative, the condenser is connected between wires I. and III. of the quad.

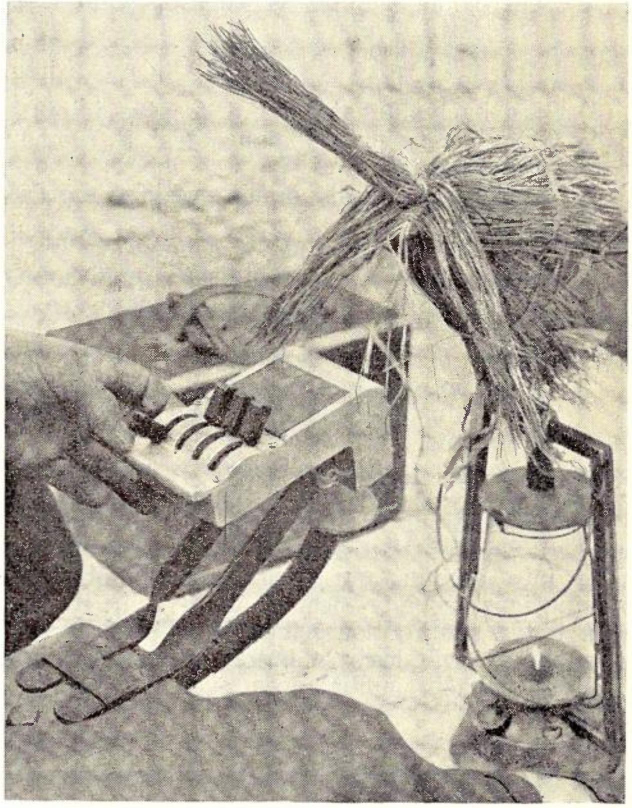


Fig. 5.—Connecting block to facilitate connecting of cable pairs to testing equipment.

Condenser balancing for reduction of phantom and earth unbalances is dealt with when considering the balancing of minor trunk cables.

The condensers used in cable balancing are mica dielectric condensers encased in ceramic containers. The ends of the containers are sealed by a compound of high melting point, to avoid possible melting during plumbing of the cable sheath. Two silk insulated tails are fitted to each condenser. The ends of the tails are jointed to the appropriate wires by means of a three-way joint. After the completion of jointing, the condensers are wrapped in paper and laid back on the joint. The condensers are provided in a range of sizes from 100 to 3000 mmfds. In the case of non-loaded cables, balancing sections of 2000 yards each, divided into 8 sub-sections, are used, and balancing is carried out in the same way as for loaded cables. Due to the lower impedance of non-loaded cables, a somewhat higher unbalance limit per 2000 yard section could be allowed in this case. It is considered desirable, however, to balance these cables to the same specification as loaded cables, to avoid the necessity for rebalancing at some time in the future if installation of loading coils subsequently becomes necessary.

The process of balancing junction and subscribers' star quad cables in a 2000 yard section may be summarised in steps, as follows:—

(1) Sign balancing and jointing by jointer at joints 1, 3, 5 and 7.
(2) Sign balancing and jointing by jointer at joints 2 and 6.
(3) Sign balancing at joint 4 (centre joint).
(4) Overall capacity unbalance test by Senior Technician.
(5) Determination of quads which require condensers.
(6) Selection and tabbing of condensers by a Senior Technician to indicate quad number and wires to which condensers are to be connected.
(7) Fitting of condensers and completion of condenser joint by jointer. Condensers may be installed at either end of the 6000 ft. section.

In the case of the alternative method of jointing, whereby division of the loading section into 4 sub-sections is employed, and the magnitude, as well as the sign, of the unbalances is taken into account, an appreciable number of combinations usually occurs in which, if the "sign only" method described in the foregoing be employed, will leave a large number of high resultant capacity unbalances over the loading section.

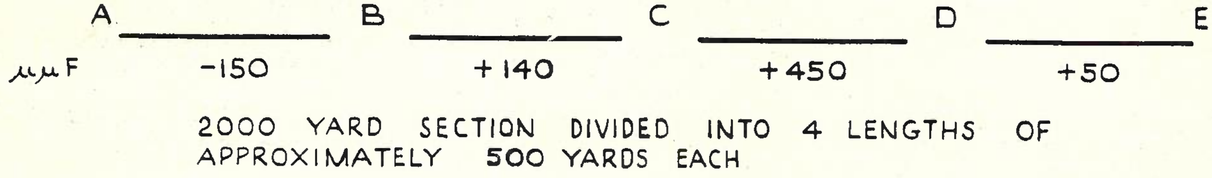


Fig. 6.—Typical s/s unbalances measured on a length of star quad local type cable.

Taking the typical values shown in Figure 6, assume a quad which is to be jointed through from A to E, and on which measurements have been made in the manner described earlier, by testing in both directions at points B and D only, the unbalances being of the sign and magnitude shown. The calculation consists of theoretically combining the lengths into two groups, so that the total unbalance of one is as nearly as possible numerically equal to the other, and then arranging for jointing so as to obtain the desired neutralising effect.

In the example shown it will be seen that the best balance which can be achieved in this case is that which will result from making the unbalances in the first, second and fourth lengths summate to neutralise (partly) that in the third length. The building up of the combination from left to right is carried out as though each jointing step was checked on a capacity unbalance set connected at the end furthest from A (the building up may be done from right to left, but in that case the check would be regarded as being applied at the end furthest from E).

Remembering that a transposition of the I. and II. wires of the quad will change the sign of the unbalance in **the length connected by means of the crossing,** and realising that this fact will hold whether the crossing is right at the test set or at the far end of an intermediate length which is connected straight, the steps are:—

(a) The first and second lengths are made to summate to +290 mmfds. by transposing wires I. and II. at point B. The test set is **imagined** as being connected straight to the quad at C, so that the second length really becomes a long test lead, with an unbalance of +140 mmfds. The transposition at B changes the sign of the unbalance in the first length, which becomes +150 mmfds., so that the overall for the two lengths taken together in this way is +290 mmfds.

(b) The third length is now added; as this is the one to be made to oppose the others, the connection at C must be such that its unbalance does not summate with the first and second lengths. Regarding the set-up as though the test set is connected straight to the quad at D, the third length becomes the test lead, with an unbalance of +450 mmfds. The combined first and second lengths now have their overall unbalance changed from +290 to —290 mmfds., by transposing at C, so that the overall for the three lengths is +160 mmfds.

(c) Transferring the theoretical test set to E, and connecting straight to the quad there, the fourth length becomes the test lead, with an unbalance of +50 mmfds. The overall of the first three lengths is now changed from +160 to —160 mmfds. by transposing at D, so that the final residual becomes —110 mmfds. With a little practice the calculation can be applied very quickly (including cases where there are eight balancing lengths in the section concerned) and jointing instructions produced without delay for the guidance of the jointer.

Applying the "sign only" method of balancing in this case, the overall residual would build up to a higher value in the following manner:—

On the test results at B, the first and second lengths would be combined without transposition, so that the overall measured at C would be —10 mmfds.

Similarly, the third and fourth lengths combined, with a transposition at D, would display an overall measurement at C of +400 mmfds. Now, the best that could be done at C would be to joint without transposition, to obtain a final residual of +390 mmfds., which is 40 mmfds. over the limit, so that the connection of a condenser to eliminate the residual is necessary.

Capacity Balancing of Minor Trunk Cables: A number of minor trunk cables for voice frequency purposes has been installed in recent years in Victoria and New South Wales to serve routes extending up to 35 miles from the centre of the capital cities. For these cases, 20 lb. local type, star quad, cable, loaded with 88 mH. coils at 6000 ft. intervals, was used. By arrangement with the cable manufacturer, the capacity unbalance characteristics are somewhat better than the normal star quad, local type cable used for junction purposes and covered by the specification limits set out in Table No. 1.

Due to the level differences likely to be involved between circuits transmitted in the cable, conditions not normally met with in junction cables, an overall near-end crosstalk limit of 80 db. was laid down. This limit corresponds to a side to side capacity unbalance of approximately 30 mmfds., which is the figure included in Table 2.

The loading sections, each approximately 2000 yards in length, consisted nominally of sixteen lengths, laid out as shown in Figure 7. The joints A1 to A8 inclusive were jointed "straight," both quads and wires. The four cable sections 1–2, 3–4, 5–6, 7–8, each approximately 250 yards in length, were then treated as a single balancing group (half-loading section), and the jointing at B1, B2 and B3 determined as detailed in the case of the loading section divided into 4 sub-sections and balanced with regard to both magnitude and sign of the side to side condition, so as to reduce the side to side unbalance in each quad to as low a figure as possible. The other half-loading section (9-16) was treated similarly. After the completion of the joints B1 to B6 inclusive, check of tests of side to side unbalance and measurements of side to phantom and side to earth unbalances were made on each quad of each half-loading section. A jointing schedule was prepared, based on these measurements, to reduce the unbalances in the loading section to the required limits, particular attention being given to the side to earth unbalances. This involved selecting quads to be jointed together, as well as transposition of the wires within the quad, to control the unbalances. On completion of joint C a check test was made of the completed loading section to ensure that the side to side, side to phantom and side to earth unbalances were within limits. Tests were made also of pair to pair unbalance, over a large number of pair combinations, to ensure that the unbalance between pairs not in the same quad did not exceed the limit.

Condenser Balancing of Minor Trunk Cables: Due to the great reduction of unbalances called for in using local type, star quad cable for minor trunk purposes, there are a number of cases in which the required limits of capacity unbalance cannot be obtained by the balancing procedure described above. In these cases, however, the excessive unbalances can be reduced by fitting balancing condensers of the type described in connection with the balancing of junction cables. Any one of the five capacity unbalance factors of a quad can be reduced by fitting a condenser between two of the wires of the quad, or (in the case of earth unbalances) between one wire and earth. The latter is undesirable practice, as it involves taking an earth into the joint, and is avoided where possible by attention to earth unbalances at joint C, as mentioned above. If, however, it is necessary to avoid raising the magnitude of the other unbalance factors, then two equal condensers must be connected to the quad in such a way as to neutralise the unbalancing effect on the other factors.

The method of connecting condensers to a quad to neutralise the unbalances is set out in Table 3:—

TABLE No. 3
Balancing of Capacity Unbalance by Means of Condensers

Capacity Unbalance Factor	Sign of Unbalance	Two condensers, each equal to half the unbalance, to be connected between wires:	
S1/Ph	Positive	II. and IIII.	II. and III.
S1/Ph	Negative	I. and IIII.	I. and III.
S2/Ph	Positive	II. and IIII.	I. and IIII.
S2/Ph	Negative	I. and III.	II. and III.
S/S	Positive	I. and IIII.	II. and III.
S/S	Negative	I. and III.	II. and IIII.
		One condenser between wires:	
S1/E	Positive	II. and E	
S1/E	Negative	I. and E	
S2/E	Positive	IIII. and E	
S2/E	Negative	III. and E	

Notes:

(1) Each group of two condensers has no effect on other unbalance factors if component condensers are equal.

(2) A condenser between wire and earth adds half its value to the corresponding phantom to side unbalance, the sign of the change of unbalance being the same.

(3) Where both side to side and side to phantom balancing are necessary, three or all four wires of the quad may require coupling by means of condensers.

The balancing condensers are selected and connected to the respective quads at the time of testing the overall capacity unbalance of the loading section. This is necessary in order to ensure that other unbalance factors are unaffected by the two approximately equal condensers connected to correct a particular unbalance factor. This is especially important in the case of side to side unbalance, due to the small unbalance limits for that factor.

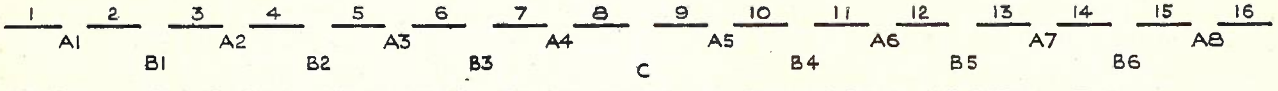


Fig. 7.—Layout of lengths and designation of joints in a 2000-yard loading section of a minor trunk cable.

The condensers are then tabbed to indicate the quad and wire numbers to which they are to be connected, and the final unbalance results for the loading section are recorded, together with details of the condensers required to correct unbalances.

Mutual Capacity Balancing: Although not normally important on this type of cable, during the balancing of the Parramatta-St. Mary's section of the Sydney-Penrith minor trunk cable, a check was made of the variation of mutual capacity among the pairs of a half-loading section. The tests showed that the mutual capacity of the pairs varied over a range of ±8% from the mean value. It was decided, therefore, in balancing the loading section at the "C" joint, to equalise the mutual capacity of the pairs in the loading section to about ± 2% of the mean value.

In making large numbers of tests of capacity unbalance, it is found convenient to house the testing equipment and the operator in a test van, which may require to be some little distance from the end of the cable. Thus, it is necessary to have a test lead approximately 30 ft. in length, by which the four wires of the quad, and the earth lead, may be extended. To avoid the necessity of correcting the test results to allow for the small unbalances of the test leads, a lead balancing unit, consisting of small differential air condensers, is provided. This unit is first adjusted to balance with the test lead free of the cable under test, and the main dials of the test set at zero. The unbalances of the cable under test are then read directly on the dial of the test set.

Each quad was numbered in order of descending mutual capacity of its pairs. In balancing the loading section the lowest numbered (high-

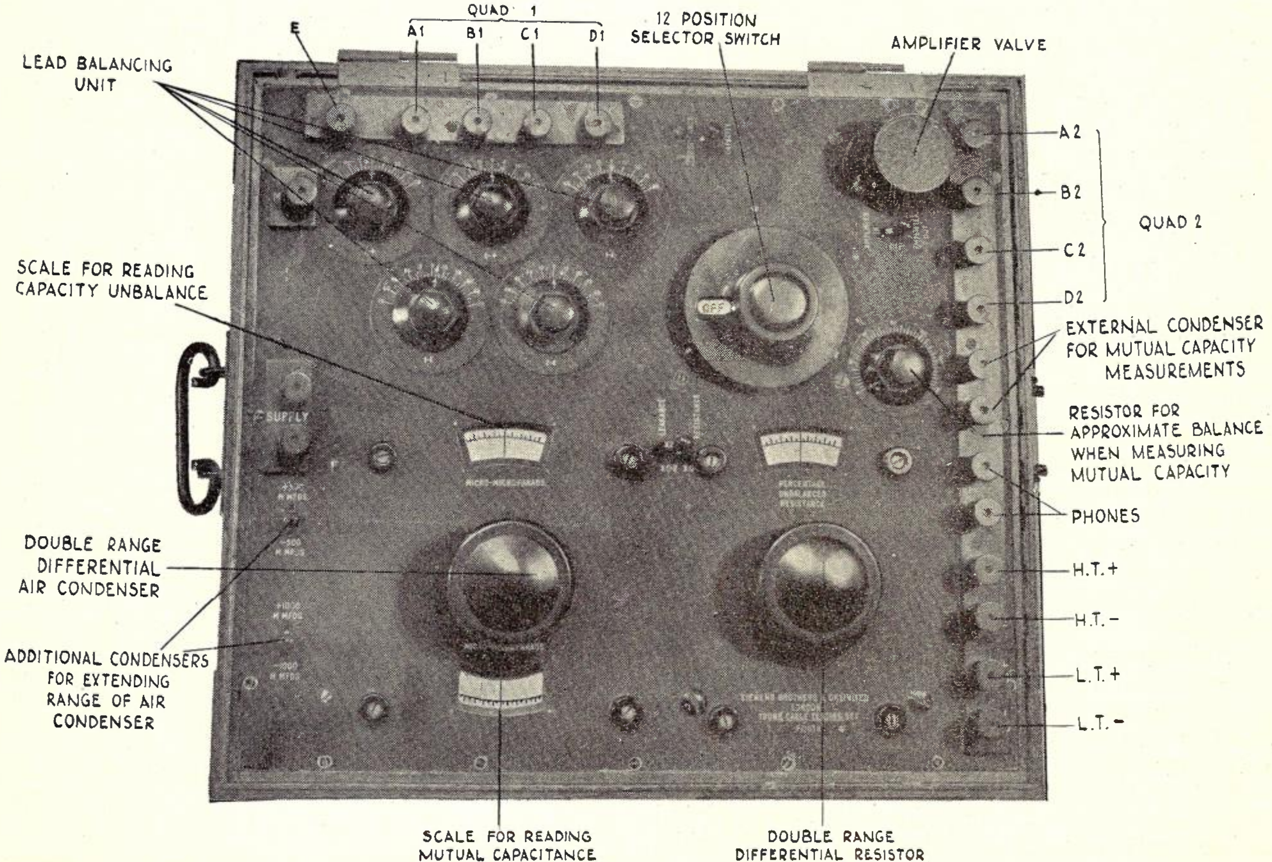


Fig. 8.—Siemens trunk cable testing set.

est capacity) quads in each half-section were connected to the highest numbered quads in the adjacent half-section subject, of course, to the unbalance requirements of the loading section.

In connecting adjacent loading sections together through the loading pots, the quads to be jointed together were selected on the basis of mutual capacity; but in this case the pairs of highest mutual capacity were connected together. In this way, a cable having very smooth and uniform characteristics was obtained, at the expense of a little extra balancing and testing.

The Trunk Test Set shown in Figures 8 and 9 was used to make the mutual capacity measurements. As this set plays an important part in the testing of carrier cables, to be dealt with in Part 2, it is convenient to describe it in detail at this stage.

Figure 8 shows a photo. of the set, which was developed by Siemens Bros., and was described in their Engineering Supplement, No. 165, February, 1939. Figures 9(a) and 9(b) show the schematic circuits used in measuring side to side and side to phantom unbalances respectively. k is the differential air condenser, P is the slide wire potentiometer, A1, B1, C1 and D1 are the four terminals of the bridge, to which the wires of the quad under test are connected. The quad is, of course, left open-circuited at the far end of the test sections. Figure 9(c) shows the circuit used in measuring the mutual electrostatic capacity between the wires of a cable pair. K is a variable condenser having a maximum capacity of approximately 1 microfarad. r is a variable resistance, which provides a coarse balance for leakance of the cable pair, a fine adjustment being made by means of potentiometer P. The trunk test set is fitted with a twelve-position selector switch, which enables the rapid setting up of the circuit conditions for side to side, side to phantom, side to earth or mutual capacity measurements. Four of the positions are required for measurement of capacity unbalance between pairs in adjacent quads. For this purpose, four additional terminals are provided for connecting an additional quad to the trunk test set.

Jointing of Loading Pots and Connection of Balancing Condensers: In jointing the loading sections together through the loading pots, it was decided to connect the balancing condensers to the "country" end of the loading section, which was connected to the loading pot tail with both wires and quads "straight." On the country side of the loading pot the "city" side of the following loading section was connected with wires straight jointed, but the quad order was selected to connect together quads having mutual capacities of similar magnitude, as discussed previously. The final joint of the cable (at the "country" end) is a straightening joint, to make the wires and quads appear straight at each end of the cable.

General: At each stage in the jointing and

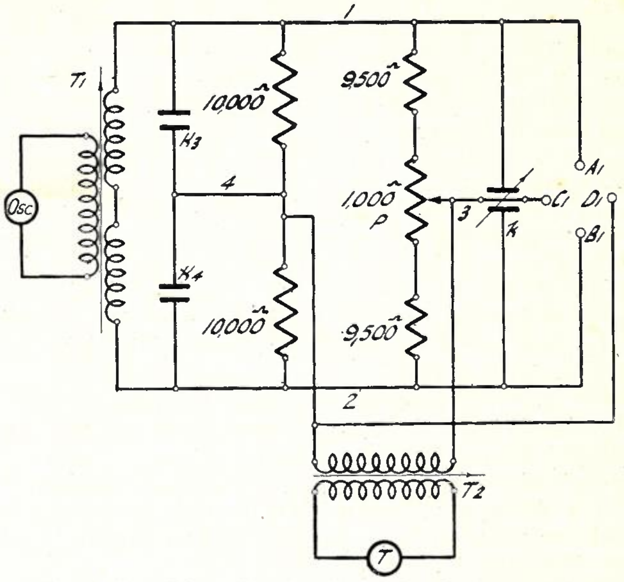


Fig. 9(a).—Schematic circuit of trunk test set in side to side position.

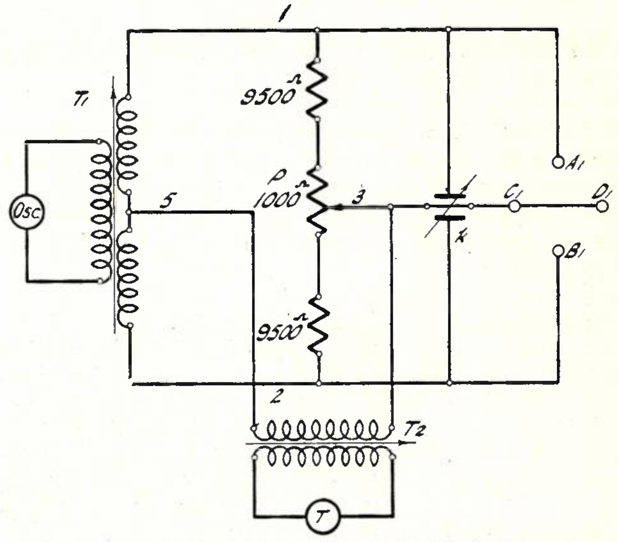


Fig. 9(b).—Schematic circuit of trunk test set in side to phantom position.

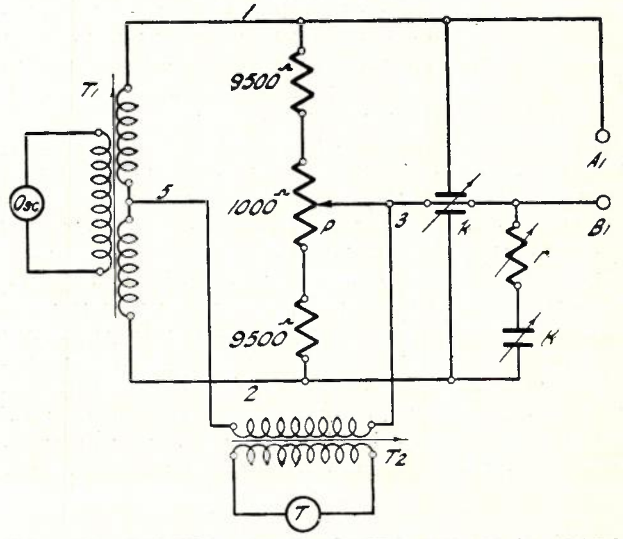


Fig. 9(c).—Schematic circuit of trunk test set in mutual capacitance position.

testing of a cable, the wires are meggered systematically to ensure that there is no undue loss to earth or between wires. It is, of course, of prime importance in all cable balancing operations to ensure by test that:—

(a) Quads are continuous over the length being measured.

(b) That there are no transposals of wires or pairs in quads at intermediate joints between balancing points. It will be appreciated, particularly when applying the progressive calculation method, that, since tests are applied at only two out of the three intermediate jointing points in the case of a four-length section, or four out of seven for an eight-length section, the jointing instructions are based on the assumption that the grouping of wires in the quad is not disturbed throughout the test section.

(c) All wires have a high insulation resistance and are free from contacts. The method of test for this purpose is—

(i) Group No. I. wires of all quads together and measure insulation with a 500 volt Megger against all Nos. II., III. and IIII. wires bunched and earthed. A value of 5000 megohms per mile (10,000 in special cases) should be obtained when the following formula is applied:

Reading in megohms × no. of No. I. wires in bunch × length of cable under test in miles.

(ii) Repeat for each of Nos. II., III. and IIII. wires grouped and tested against the other three groups taken together and earthed.

(iii) Measure each quad (4 wires bunched) against all other quads bunched and earthed. Value of insulation (read directly from Megger) should not be less than 1000 megohms.

Tests (i) and (ii) will reveal any contacts within quads and (iii) between quads.

(To be Continued)

PHONOGRAM SERVICES

C. Cruttenden

The existing arrangements in the larger phonogram installations in the Commonwealth are proving inadequate for handling efficiently the increased volume of traffic now offering, and the replacement with more modern systems has become imperative. A start has been made with the necessary changes.

The first major installation in the replacement programme was that in Brisbane, which was cut over in September, 1944. This installation comprises 36 operators' positions, with associated equipment, including travelling "V" belts for the collection of telegrams. The Sydney replacement, now under construction, will have 136 positions, and that planned for Melbourne will have 102 positions.

As well as automatic aids to minimise operating effort, the new phonogram system includes many new features, the object of which is, first of all, to give an improved grade of service to the users of the phonogram service; and, secondly, to facilitate the maintenance of the better service. Among the former may be mentioned a unique call queueing system and a traffic control desk; and, among the latter, the call timing and speed of answer recorder facilities. In the new Brisbane phonogram system, dials are fitted for making outgoing calls. Operating would have been simplified had it been practicable to fit key-set senders, but time did not permit this improvement. The superiority of senders is well recognised, particularly for phonogram operators, who are all expert typists, and they will be used in other installations whenever circumstances permit. The floor plan layout of the Brisbane installation is shown in Fig. 1.

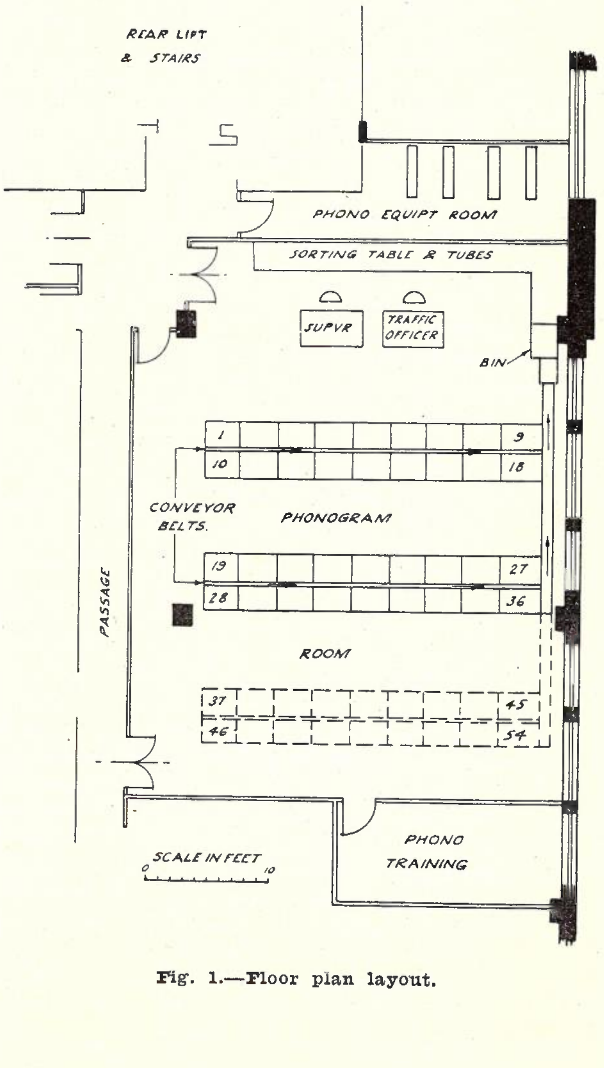


Fig. 1.—Floor plan layout.

Routing Diagram: Fig. 2 shows the route taken by calls or signals through the various items of switching equipment. All the bimotional switches are 2000 type, and are standard line-finder or final-selector mechanisms. These switches were the only ones readily available with sufficient bank capacity to give full availability to all lines; but on other installations it is proposed to use the motor uniselector of the B.P.O. standard type.

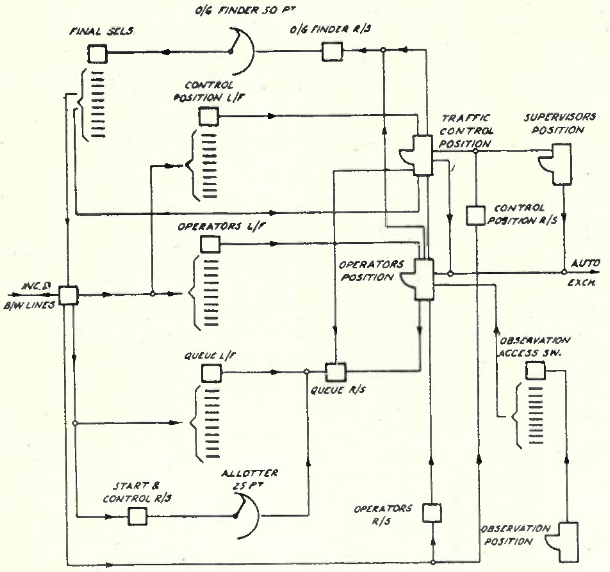


Fig. 2.—Routing diagram.
O/G = Outgoing. R/S = Relay Set. L/F = Linefinder. B/W = Bothway.

Because of the war conditions new switches were not available, and it was necessary to take 2000 type switches already wired to standard circuits, and amend or completely replace the wiring as necessary. Some interesting problems arose in the endeavor to use as much of the existing wiring as possible, and also obtain all the required circuit functions with the existing switch accessories, such as off-normal springs.

Facility Schedule: The following is a list of the facilities provided, together with an associated explanatory note when the statement of a facility is not sufficient:—

(1) Ringing tone is given on all incoming calls until the call is answered.

(2) All incoming calls enter a queue on arrival. The queue caters for 20 calls initially, but can readily be extended to 25 calls if necessary. The queue relay set distinguishes between calls from four different sources, namely: (a) ordinary subscriber (B.075) lines; (b) Post Office (B.076 and trunk) lines; (c) direct Post Office (omnibus 2-party) lines; and, (d) direct subscriber lines. Each type of call is queued separately in a so-called "minor" queue, whilst all types of call are queued in a "major" queue.

(3) A traffic control desk has means for switching any operator's position to enable it to handle any one or more types of incoming call, or outgoing calls only.

(4) A "position staffed" and "position engaged" lamp is mounted on the traffic control desk in line with the position control keys. The former lamp lights when an operator plugs her telephone set into the position, whilst the latter lamp lights only when the position is engaged, and is controlled by the calling or called line.

(5) When an incoming call arrives "waiting call" lamps light on staffed positions only. There is a separate lamp for each type of call, but the lamps light only on the positions which are set to answer them.

(6) Since a position may be answering more than one type of call, a "call answered" lamp lights to indicate the type of call to which the operator is connected. The operator is thus independent of an announcement by the caller, and possible operating errors are avoided.

(7) Each operator's position is connected to a line-finder, which searches for waiting calls when the call answering key is operated. There is only one answering key for all types of call.

(8) A "restore answer key" lamp lights if the line-finder fails to find a calling line for any reason, such as two or more operators attempting to answer a lesser number of waiting calls.

(9) Incoming calls can be held whilst an outgoing call is made, or vice versa. Separate hold keys and lamps are provided for in and out calls.

(10) Operators' positions can be coupled together by a key. This facility allows an incoming call on one position to be held whilst another call is answered on the next. It is intended that alternate positions should be staffed during slack periods.

(11) Incoming calls can be transferred to the control position, which also deals with enquiries. Ringing tone is heard as soon as the transfer is complete. A three-way conversation is possible in order to allow the operator to introduce the caller to the enquiry officer if necessary, but the operator can release from the connection at any stage. If all the transfer circuits to enquiries are engaged when the transfer key is operated, a busy lamp lights to indicate the condition. The call can be extended by the enquiry officer to the supervisor, if necessary.

(12) Outgoing calls are made to subscribers in the Brisbane network by dialling the directory number; and to direct post offices, direct subscribers, the traffic control desk and other miscellaneous services, as required, by dialling a 2-digit number.

(13) Each office on the direct 2-party post office lines is given a separate number in the final selector multiple, so that either office can be called automatically and code ringing is not necessary.

(14) If a direct post office or direct subscriber's line is engaged, an operator dialling

that number can break in on the call, if necessary. This facility permits all outgoing traffic for a particular line to be taken to one operator, who can arrange to take control of the line if necessary to dispose of urgent telegrams.

(15) Any direct both-way line can be assigned to any position via the position line-finder. When an operator requires to work a line for an extended period, the desired line is dialled in the normal way and then the answer key is operated and the outgoing call key restored. This action forces the release of the last party release final selector, whereupon the line loop operates the line relay set and marks the bank of the position line-finder. This facility was included to economise in the number of final selectors required, and was secured by circuit arrangements only and without any additional equipment.

(16) Automatic access, for traffic observation purposes, is given to each operator's telephone circuit by dialling a 2-digit number. The access switch can be stepped to the ten positions in each level by a step-on key, instead of re-dialling. The observation officer is supplied with a list of the staffed positions, but if the access switch is dialled or stepped on to a position which is not staffed, a distinguishing tone is heard.

(17) Three jacked-in, portable phonogram operators' positions are provided in the telegraph operating room for use after the phonogram room staff have ceased duty at 10 p.m. each day. These positions cannot be operated until a night switching key on the traffic control desk is operated.

(18) All incoming calls are timed, and when the first call in the major queue has waited 30 seconds a lamp flashes on the control desk. There is a separate lamp for each type of call, so that the group requiring relief is known.

(19) The number of waiting calls in each queue is indicated by a column of lamps.

(20) The average waiting time, in seconds, of calls in any queue can be checked as required by a speed-of-answer recorder mounted on the control desk.

(21) Automatic routining is included in the circuit of the queue and final selector line-finders.

(22) If any of the queues fail, a key on the traffic control desk diverts all calls to the operators' line-finder banks.

The Call Queueing System

Call queueing is a comparatively recent development in the field of communication engineering, and one which, if published information is any guide, is not yet widely used. Its first use in Australia, so far as the author is aware, was in 1938, in the Melbourne Trunk Exchange. The term "compound queue" has been coined to describe the method of call queueing which was developed for Brisbane, where calls of each particular type are queued, as well as the total calls, in the order of arrival. Using this phraseology, a "simple" queue would be one consisting of calls arranged in the order of arrival only.

The majority of operators will be called upon to work only one type of line, and calls are released from the appropriate minor queue when the call answering key is operated. By operating the relevant keys on the traffic control desk, however, any position can answer two or more types of call, and this facility permits traffic peaks to be absorbed automatically, instead of requiring attention by the traffic control officer.

Calls are only released directly from the major queue by operators who are answering all four types of call, which is normally only during slack periods, and by the three special positions in the telegraph operating room. Calls are indirectly released from the major queue each time a call is released from a minor queue, and vice versa.

When an operator is answering two types of call, say, B.075 and B.076, waiting calls are taken first from the B.075 minor queue, and then, when this is empty, from the B.076 minor queue. There are two reasons for this arrangement; the first is that it simplifies operating procedure (see appendix 1) by enabling an operator to preselect the type of form to be used for typing the message, as she can be reasonably certain that, if the B.075 waiting call lamp is alight, that is the type of call she will be connected to; the second reason is that the circuit for releasing calls from the queues is very much simplified. This arrangement would appear to give a preference to the B.075 calls, but in practice this is not the case, as it is the traffic control operator's duty to balance the traffic among the operators so that the average waiting time is about the same for all types of call. For instance, if the waiting call lamp display shows that B.076 calls are not getting as good attention as others, the operation of a key is all that is necessary to allot another operator exclusively to B.076 calls.

When calls are released from the major queue the operators may be connected first to one type of call, and then another, depending only on the order of arrival. This may slow down operating somewhat, but is necessary because the traffic control desk will not be continuously staffed during slack periods.

Fig. 3 is a close-up view of an operator's position, showing the operator's key-shelf equipment.

Fig. 4 is an explanatory diagram of the operation of the queueing system. When the first call arrives it puts a start condition on the queue line-finder allotter, which seizes a queue position and then starts the line-finder hunting for the calling line. When the calling line is found, it is switched through to the queue position, the allotter releases, and preselects the next queue position. Each line relay set applies a potential over a high or a low resistance to either the positive or negative wire via the line-finder, in order that the queue relay set may distinguish the type of calling line. The queue relay set applies a start condition to the major queueing switch R and the appropriate minor queueing switch RA, RB, etc., depending upon the type of call and, at the same time, marks the banks. The switches drive until the marks are found, and then prepare the release circuit. The major queueing switch searches only for the first call of any type, whilst the minor queueing switches search only for the first call of the type with which they are associated. Calls subsequent to the first only mark the banks as the start condition is disconnected by the finding of the first call. The R switch is an 8-level uniselector, but all the other switches, RE to RH, are 3-level uniselectors.

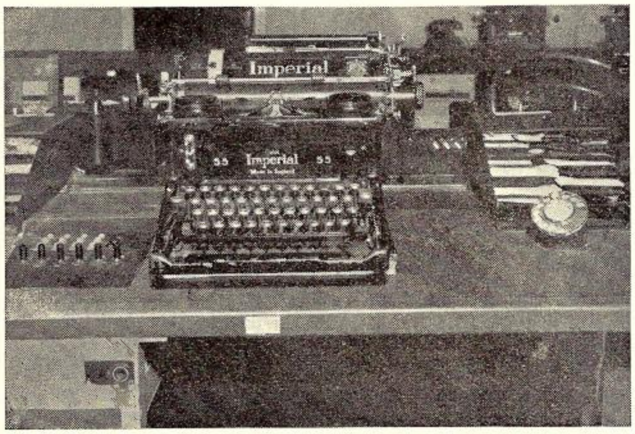


Fig. 3.—Phonogram room. Close-up view of operator's position.

When an operator answers a call a release signal is applied to the release wire of the major queue, or the appropriate minor queue, as the case may be, and when the signal is accepted a positive battery potential is applied to the earthed P wire holding the queue line-finder. This potential operates a relay in the line relay set, which changes the line marking to the operators' line-finder banks and opens the circuit which is holding the call-discriminating relay in the queue relay set. The queue position is now free, and the major queueing switch and the relevant minor queueing switch step onto the bank contact corresponding to the next call.

Abandoned Calls: In all queueing systems it is necessary to arrange in some way that queue positions which were occupied by calls which have been abandoned are not subsequently taken by new calls in incorrect priority. The function of the four switches RE to RH, in Fig. 4, is to take care of abandoned calls. Each of these switches normally keeps in step with an associated minor queue switch, thus switch RA is partnered with switch RE, and RB with RF, and so on. When a call is abandoned a change-over contact removes the marking from, say, the RA switch bank, and transfers it to the RE switch bank.

The holding earth on the P wire is disconnected long enough to release the queue line-finder, and then re-applied. When the line-finder reaches normal, its N springs close the circuit of its HA relay to the P wire earth. Relay HA operates, and busies the queue position on the allotter bank.

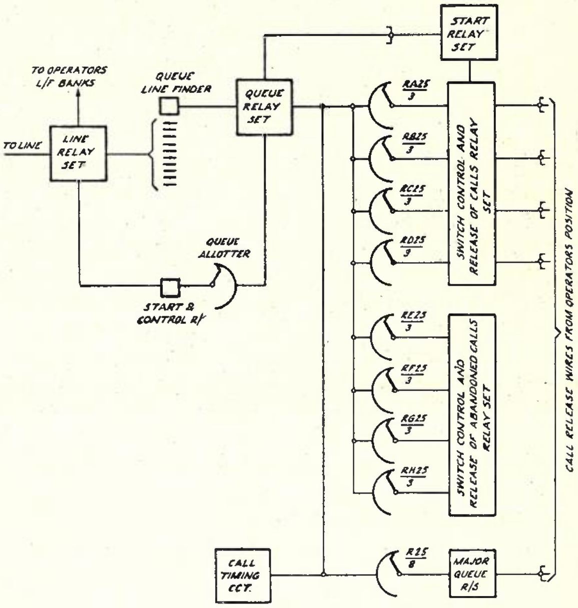


Fig. 4.—Explanatory diagram of queueing system.

When all previous calls have been answered, the RA switch will step over the unmarked contact corresponding to the abandoned call, and will rotate to the next occupied contact. The RE switch attempts to follow, but encounters the marking on its bank and stops long enough to release the holding relay, which removes the P wire earth, which in turn removes the busy condition from the queue allotter bank by releasing the HA relay of the line-finder. Having freed the queue position, the RE switch drives on to catch up with its partner switch, RA, but if there are any other abandoned call markings on the bank contacts separating the two switches, these also will be released.

If the abandoned call had been the last one in the RA switch queue, the queue position may or may not be freed by the RE switch. If further calls do not arrive, the RE switch will have no occasion to step on to the contact occupied by the abandoned call. Under these conditions, the queue position is freed by removal of a common holding earth when the queue system is empty of calls.

Traffic Control Cabinet: Fig. 5 is a photograph of the traffic control cabinet, which is equipped for 36 operators' positions, and has a maximum capacity of 54 positions. The vertical dividing lines between each set of 9 keys correspond to a suite of 9 operators' positions (see Fig. 1). Each position is represented on the cabinet by 4 push-type keys and 2 lamps. There is one key for each type of call, and when a key is pushed in, the associated position can answer that type of call.

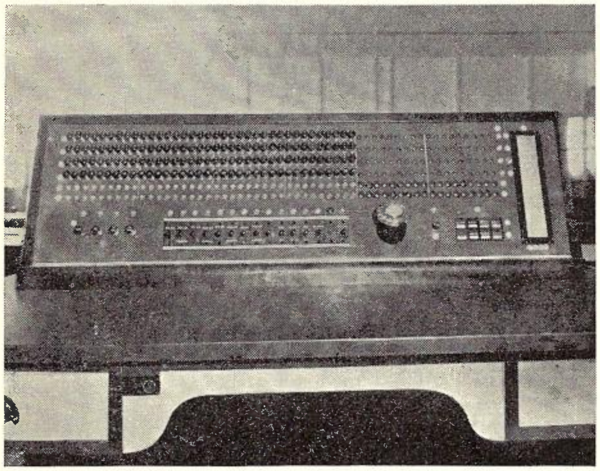


Fig. 5.—Traffic control cabinet phonogram room.

The lamp immediately below the keys is the position staffed lamp. The next lower lamp is the position engaged lamp.

The four push-type keys at the lower left-hand corner are the queue fail keys, there being a separate key for each minor queue. These keys are provided to guard against failure of all or part of the queueing system, and permit it to be taken out of service for maintenance purposes when required. As previously indicated, the operation of any key diverts incoming calls from the normal routing to allow direct marking of the operators' line-finder banks, and the calls are answered in random order.

The row of ordinary switching keys is for answering the 4 enquiry lines provided for calls transferred from the operators' positions. There is an associated hold and transfer key for either holding the call or transferring it to the supervisor. The keys in the next set are for answering other incoming calls or making outgoing calls with the use of the dial. The last key is night alarm on one side and night switching on the other.

The lamp mounted at the right-hand end of each row of position keys is the lamp that flashes when the first call in the associated minor queue has waited 30 seconds.

The rectangular frame holds a ground glass screen, behind which are mounted vertically four strips of 20 lamps, which indicate the number of waiting calls in each minor queue.

Just to the right of the dial are the 8 meters and start-key and lamp associated with the speed-of-answer recorder. The meters are of the ordinary 100A type used on subscriber services. The lamp flashes with each step of the counting switch, and thus indicates correct operation. Two meters are associated with each minor queue. The lower meter, "A," registers the number of calls answered; the upper meter, "B," registers the number of calls in the queue, which are counted every 3 seconds. The speed of answer in seconds is given by the reading of meter "B" multiplied by 3 and divided by the reading of meter "A." To assist the traffic control officer to remember this, as well as cater for changes in staff, the white disc above the meters is engraved with the formula $S = \frac{3B}{A}$.

APPENDIX 1

The information included in this appendix is intended for those who may have more than the average interest in the subject of this article, by virtue, perhaps, of having to design a system themselves or instal one. This information will also provide a clue to the reasons leading to the design of some of the features of the Brisbane system.

Phonogram Traffic

The telegraph traffic dealt with by phonogram operators comprises the following:—

(A) Telegrams telephoned to a telegraph office by a telephone subscriber for onward transmission, or telegrams telephoned to a telephone subscriber from the telegraph office of destination; and
(B) Telegrams telephoned to or received by telephone from a telegraph office.

The traffic under (A) conforms to the official definition of a phonogram; but, strictly speaking, the traffic under (B) consists of telegrams.

Both (A) and (B) include inward and outward traffic; but it may be taken as a general rule that inward traffic comprises about 75 per cent. of the total.

The phonograms under (A) can be subdivided into two groups:—

(1) Subscribers who obtain service through a telephone exchange network; and,
(2) Subscribers who have direct lines to the phonogram section.

The telegrams under (B) can be subdivided into three groups:—

(1) Post offices which obtain connection with the phonogram section through the local telephone exchange network;
(2) Post offices with direct lines to the phonogram section; and,

(3) Post offices which obtain access to the phonogram section over a minor trunk telephone line via a trunk exchange.

Operating Procedure

Phonogram operators working inward traffic type the phonograms as they are being received. Phonograms from telephone subscribers are typed on to a special form having an attached counterfoil which, when completed, bears a carbon copy of the subscriber's name and telephone number, number of words in the message, the name and address of the addressee, and a serial number for reference purposes. The counterfoil is subsequently forwarded to the Accounts Branch.

Telegrams from post offices are typed on the standard telegram form. A counterfoil is not necessary in this case, as the message charge has already been collected at the post office counter.

It simplifies the operating procedure if operators deal with only one type of traffic, because the correct form can be preselected and inserted in the typewriter. Therefore, the practice has been adopted of working the different types of lines as separate groups and, in general, these groups have been available only from different suites of positions. The traffic control desk was provided (in conjunction with full availability equipment) to indicate the incidence of traffic in the various groups and enable it to be directed to staffed positions as necessary. It was previously the practice to move the staff to the positions in accordance with traffic fluctuations. In most cases, all post office traffic is worked as one group; but in Brisbane it was desired that all direct post office lines be treated as a separate group, the reason being that these lines are very heavily loaded and almost continuously occupied during the day, when they are allotted to a separate suite of positions.

Staffing Arrangements: Phonogram positions are staffed in accordance with the average expectancy of traffic during any given period. The traffic is counted in message units (M.U.), a message unit consisting of 5 words. Various empirical loading coefficients allow in M.U. for waiting times, repetition of messages, etc. An operator's load is calculated on an average output of 300 message units per hour.

The Department endeavors to arrange that no call will await an answer longer than 30 seconds. If unexpected and prolonged traffic peaks occur, the calling subscribers' numbers are taken and the calls reverted similarly to delay trunk working.

Hitherto calls have necessarily been answered in chance order, and only the average waiting time could be obtained with a stop watch.

The introduction of call queueing and automatic timing greatly simplifies the staffing problem, as well as serving its prime purpose of providing a better and uniform grade of service to all.

Future Development: The Brisbane installation provides for a 50 per cent. increase in size. It appears, however, that the introduction of facsimile telegraph apparatus into post offices is a probable development in the not-too-distant future. Such apparatus may also be attractive to those subscribers who rent direct lines to the phonogram section. In such an event, phonogram traffic would be reduced to that from ordinary telephone subscribers, and the present phonogram room in Brisbane would probably meet future requirements for many years. Even at its present stage of development, the space requirements of facsimile telegraph apparatus are small compared with phonogram operators' positions, and the traffic capacity of a line is considerably better. A phonogram operator handles only 20 phonograms per hour on the average, and there are varying delays at the originating end from the time the message is handed in at a post office counter until it is transmitted by telephone. On the other hand, a message form received and checked by the counter clerk can be inserted immediately into a slot in a facsimile transmitter and be transmitted practically instantaneously, and without error, to the central telegraph office.

S.T.C.'s 50th ANNIVERSARY

Those associated with telecommunications in this country will be interested to learn or to recall that Standard Telephones & Cables Pty. Ltd. has recently reached the 50th anniversary of the firm's establishment in Australia. In that period the Company has supplied equipment for various services provided by the Department. This Society is happy to record the anniversary, particularly for the information of our many members who have had personal association with the Company's staff.

To celebrate the event the Company held a dinner recently in Melbourne, at which were present the Postmaster-General, the Director-General, the Assistant Director-General, the Chief Engineer, members of his staff and others associated with telecommunications in this country. Sir Louis Beale, speaking for the Company, stressed the tremendous development that had taken place in Australia's communication services over the last half-century, referring to the Department's achievements in this regard and the part the Company had played in contributing to the progress.

RELAY SET REPEATERS

O. C. Ryan

In the automatic switching of telephone calls the subscriber selects the number required by operating a dial associated with his telephone. Generally, for a local call, a selected bi-motional switch from each rank of switches receives a train of impulses in turn direct from the subscriber's dial, the impulsing line relay of a particular rank being switched from the circuit when the call is advanced to the switch ahead. When the final selector is reached, however, the impulsing relay, after operating the switch to select the required number, provides a battery bridge for the calling subscriber. In addition, an earth is placed on the private wire (P) to hold operated all ranks of switches in the call set-up, until the loop is removed from the calling subscriber's line. Under these conditions, the problem of operating the various selectors is a comparatively simple one. If the call is routed via one or more automatic exchanges in the network, however, provision must be made for the repetition of impulses over two-wire junctions at each stage, and for battery supply for the calling subscriber, or for signalling purposes, etc. To meet these requirements, a repeater relay set is provided at the outgoing end of each junction line.

With the introduction of the repeater relay set, additional problems have arisen due to relays being connected permanently across the speaking and impulsing circuit and the use of condensers to isolate the various sections of the circuit for direct current signalling purposes. The inductance of the relays and the capacity of the condensers tend to cause impulse distortion and initial and subsequent "pick-up" troubles. These troubles are increased with the number of repeaters connected in tandem for a particular call.

In the following, the functions and circuits of typical earlier and more modern types of repeater are described, and the modifications and additions to the circuits to reduce to a minimum the various defects disclosed are discussed.

The general functions of a repeater are as follow:—

(a) Connects guarding and holding earth to the release trunk or private (P) wire to hold preceding switches operated and to permit the use of two-wire circuits between exchanges.

(b) Repeats impulses over the junction to the distant exchange (auto-auto repeaters).

(c) Provides a transmission bridge to feed current to the calling subscriber.

(d) When the called subscriber answers, the repeater reverses battery to the calling subscriber for metering, in reverse battery metering exchanges, and for public telephones. In booster battery or positive battery metering exchanges, the repeater provides a positive battery impulse for metering.

Various types of repeaters are in use; and in some exchanges there are a number of different circuits for working to or from automatic exchanges under different conditions, including junctions to C.B. manual and magneto exchanges.

Fig. 1 shows the elements of a typical con-

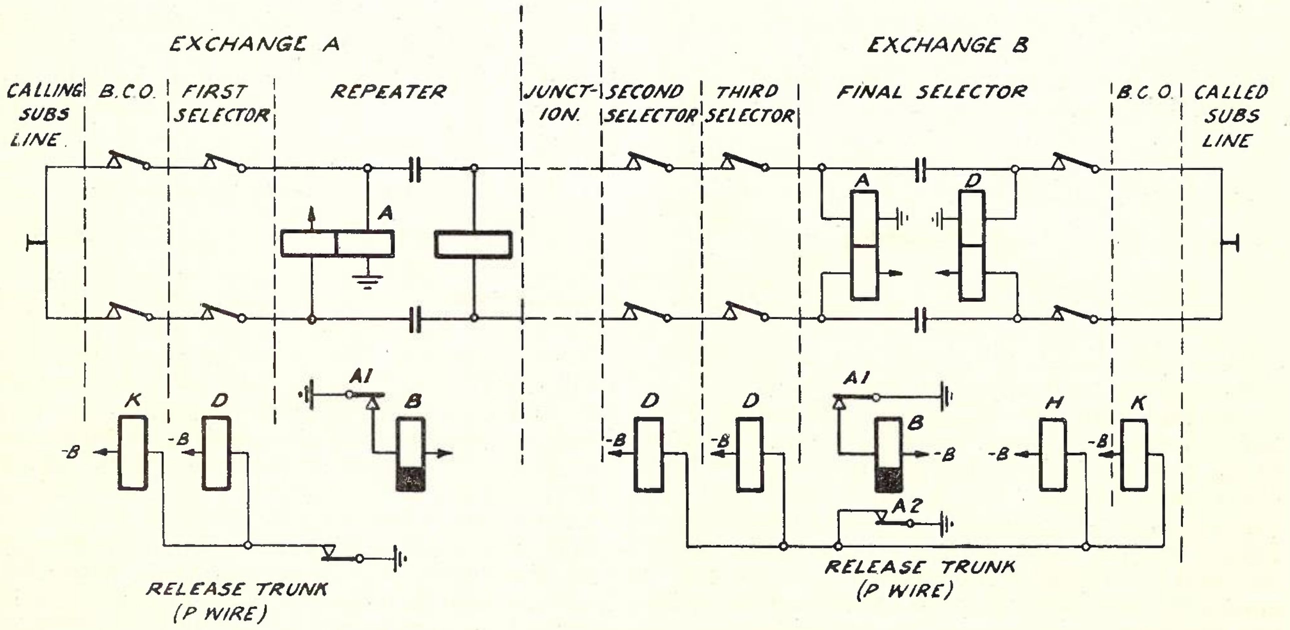


Fig. 1.—Typical connections of call between Exchanges.

nection between two subscribers in different automatic exchanges, including a repeater and junction, and shows the method of eliminating the third wire between exchanges. The relay contacts are shown in the operated position.

Automatic to Automatic Relay Set (Repeater) —Booster Battery Metering: A typical automatic to automatic repeater circuit, convertible automatic to manual, with booster battery metering and using Strowger type relays, is given in Fig. 2. The operation of the auto-auto repeater, disregarding dotted lines, is as follows: When a repeater is seized, relay A operates from negative battery, 200 ohm winding of A, D1, subscriber's loop, D2, 200 ohm winding of A to earth. A operates, A1 closes circuit for B, and A2 prepares the loop for the switch ahead. B operates, B1 earths the P (release) wire via H1 to hold the preceding switches and busy the repeater. B2 closes the junction line circuit from negative line, B2, C1, 60 ohm winding of relay F, D3, E250, A2 to positive line. B3 closes relay G and the 1900 ohm polarizing winding of F, whilst B4 prepares the circuit of relay C.

The electro-polarized relay F will not operate with the current in its 60 ohm winding flowing in the direction indicated in the circuit, nor will it operate with a current in one winding only. It will operate, however, when the current in the 60 ohm winding is reversed to that shown, due to a reversal of current in the junction line from the final selector.

Relay E operates, and E1 closes one link of the chain relay circuit associated with a group of repeaters, for traffic distribution studies, or for metering of simultaneous connections in a group, if required. E2 is associated with the auto-manual circuit.

G operates, and G1 prepares the booster battery circuit whilst G2 maintains the chain relay link when E restores during dialling. The circuit is now ready to receive impulses, and A impulses according to the digits dialled. On the first impulse being received from the subscriber's dial A restores, but slow-release relay B remains operated, due to its release lag of 300 mS (approx.). A1 normal closes the circuit of relay C, and A2 opens the loop to the distant exchange and causes the bi-motional switch to step. C operates and, being slow to release, remains operated during the impulse train. C1 short-circuits the 60 ohm winding of F and the 250 ohm winding of E, to reduce the impedance of the circuit for the distant A relay during the remaining impulses of the train. The 2000 ohm N.I. resistance YA., connected across the back contacts of C1, maintains the loop to the

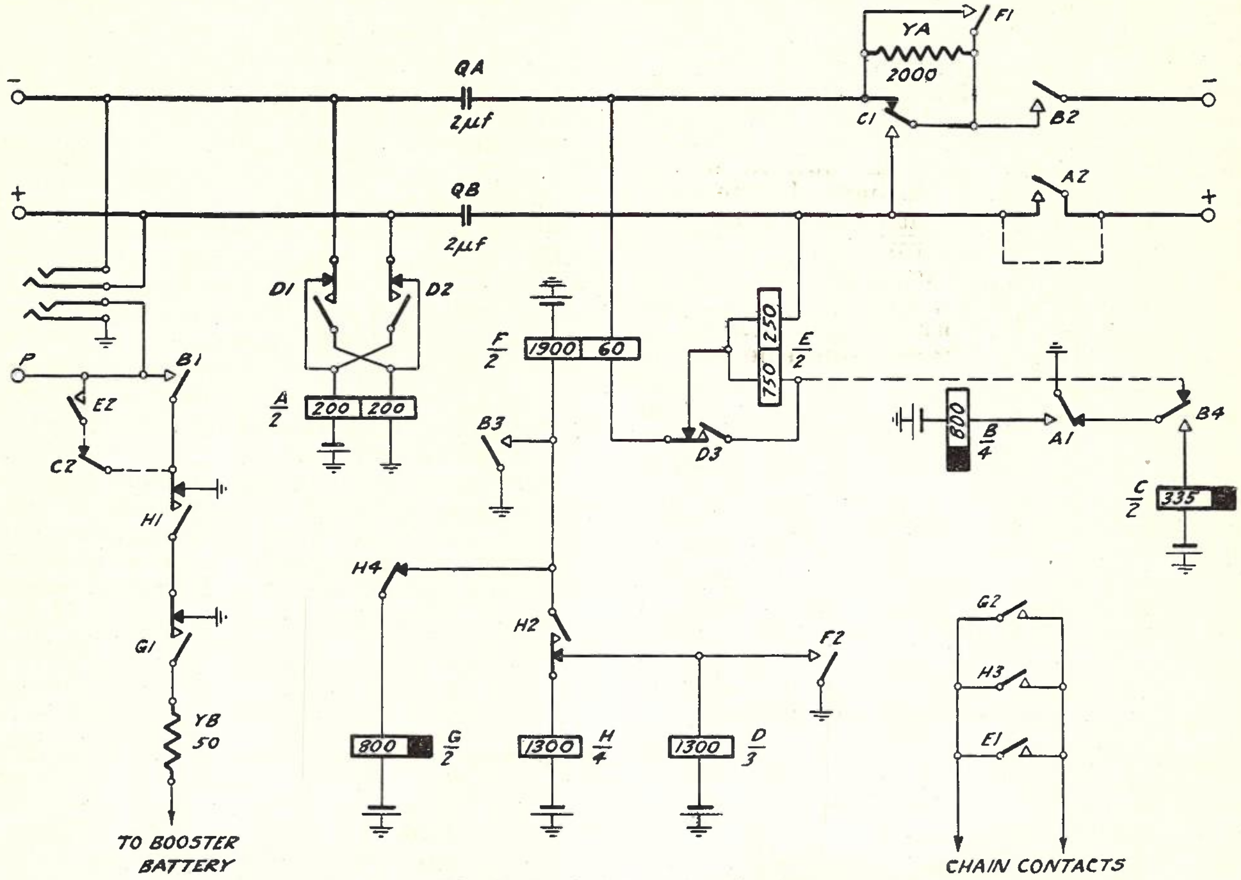


Fig. 2.—Typical Repeater Circuit.

switch ahead during the transit period of the lever spring, and prevents the possibility of a false impulse. Subsequent impulse trains are repeated as described above. Relay C operates during the first impulse of each train.

When the called subscriber answers, the final selector in the distant exchange reverses the current flowing in the junction. Relay F in the repeater operates, and F1 provides an additional short-circuit on the 2000 ohm resistance YA, whilst F2 closes the circuits of relays D and H.

D operates, D1 and D2 reverse battery to the calling subscriber, D3 increases the impedance across the junction by including the 750 ohm winding of E, to reduce transmission losses.

H operates, H1 connects the 50 volt booster battery in series with the exchange battery, thus applying 100 volts to the subscriber's meter for a period of approximately 300 mS. H2 closes its locking circuit to earth at B3; H3 maintains the chain contacts when G restores, H4 opens the circuit of G.

G, after its slow-release period, approximately 300 mS, restores, G1 disconnects booster battery and re-connects earth to the P wire.

When the calling subscriber restores, relay A releases, and A1 opens the circuit of B, A2 opens the loop to the switches ahead, which restore.

B restores after its slow-release period, covering the release of switches in the distant exchange. B1 removes the holding earth from the P wire and allows the preceding switches to restore, whilst B3 and B4 release the remaining repeater relays.

The 50 ohm resistance YB, connected in series with the 50 volt booster battery lead, limits the current to a repeater so that a short-circuit occurring in one repeater will not impose undue drain on the booster battery.

Auto-C.B. Manual Repeaters: In an automatic to automatic connection, the calling end and the outgoing end of the circuit up to the final selector (last party release), are released simultaneously when the calling subscriber restores. In an automatic to manual connection, the calling end only is released when the calling subscriber restores; the incoming manual end remains in circuit until the junction is cleared by the telephonist at the manual exchange. Special circuit arrangements are necessary, therefore, to ensure that the auto-manual repeater tests busy so long as the incoming end is held in the manual exchange.

In addition to the general functions indicated under automatic to automatic repeaters, the auto-manual repeater must perform the following:—

(a) Light a calling lamp in the distant manual exchange.
(b) Light the cord circuit supervisory lamp at the manual exchange when the calling subscriber restores.

The automatic-automatic repeater circuit shown in Fig. 2 may be converted for auto-manual working by making the following alterations, shown by dotted lines:—

(a) Bridge the impulse repetition contacts A2.
(b) Connect the 750 ohm winding of relay E to a back contact of B4.
(c) Connect the P wire to H1 via make contacts of E2 and break contacts of C2 in series.

The circuit description of the auto-auto repeater, Fig. 2, applies in general to the auto-manual repeater. The main differences are as follow:—

The loop is extended to the manual exchange by B2 (A2 is bridged; see dotted lines), the line relay in the manual exchange operates and lights the line lamp.

The telephonist switches the calling subscriber to the called subscriber, and the line lamp is extinguished. (Auto A cord circuit). When the called subscriber answers, the repeater relays F, D and H operate, and the conditions are similar to those for the auto-auto repeater until release occurs.

When the calling or automatic subscriber restores first, A releases, opens the circuit of B and closes the circuit of C for the slow-release period of B. C operates but, when B releases, its circuit is opened at B4. A circuit is now provided from earth, A1, B4 normal, dotted section of circuit, two windings of E in series, positive side of junction and thence to manual exchange, tip conductor of cord to battery via the cord circuit relay. Relay E remains operated.

B2 opens the loop to the manual exchange, giving the cord circuit clearing signal to the telephonist. F restores.

On the P wire, at the moment that B1 removes the earth, C is energised, and the P wire is open at B1 and C2; but after its slow-release period C2 restores and re-connects earth to the P wire, which has been open for the release period of relay C (approximately 100 mS), E2 being operated.

During this open period the preceding switches have released and the repeater and junction have been in danger of seizure by a selector hunting for a disengaged trunk. The restoration of the earth to the private guards the repeater from further intrusion until the switching plugs at the manual end are withdrawn. Battery is then removed from the positive side of the junction, E restores and removes earth from the private wire.

When the manual subscriber clears the call first, relay E (repeater) releases; but A and the relays dependent upon it are held until the calling subscriber releases.

Auto-Magneto Repeaters: An auto-manual repeater of the type shown in Fig. 2 (including dotted lines) is suitable for working to a magneto exchange. As a loop is placed on the junction to indicate a call, it is necessary to feed out battery from the magneto exchange and arrange the circuit to provide a battery reversal over the junction when the operator completes the call. A circuit has been developed for use at magneto exchanges to handle calls incoming from standard auto-auto repeaters. The circuit provides for switch-hook supervision for the called subscriber, and reverses battery back to the auto-auto repeater when the call is answered.

(a) Relays G and H, used principally for the application of the booster battery pulse to the private wire, are not required; the number of relays being reduced to 6. The chain contacts G2 and H3 are replaced by C2.

(b) The private wire is earthed at B1 in lieu of H1 or G1.

Automatic-Manual Repeater Convertible to Automatic to Automatic—Booster Battery Type: Fig. 3 is typical of the more modern booster battery type repeaters, equipped with a barretter (ballast resistor) and relays of the 3000 type. A large number of these repeaters is in service.

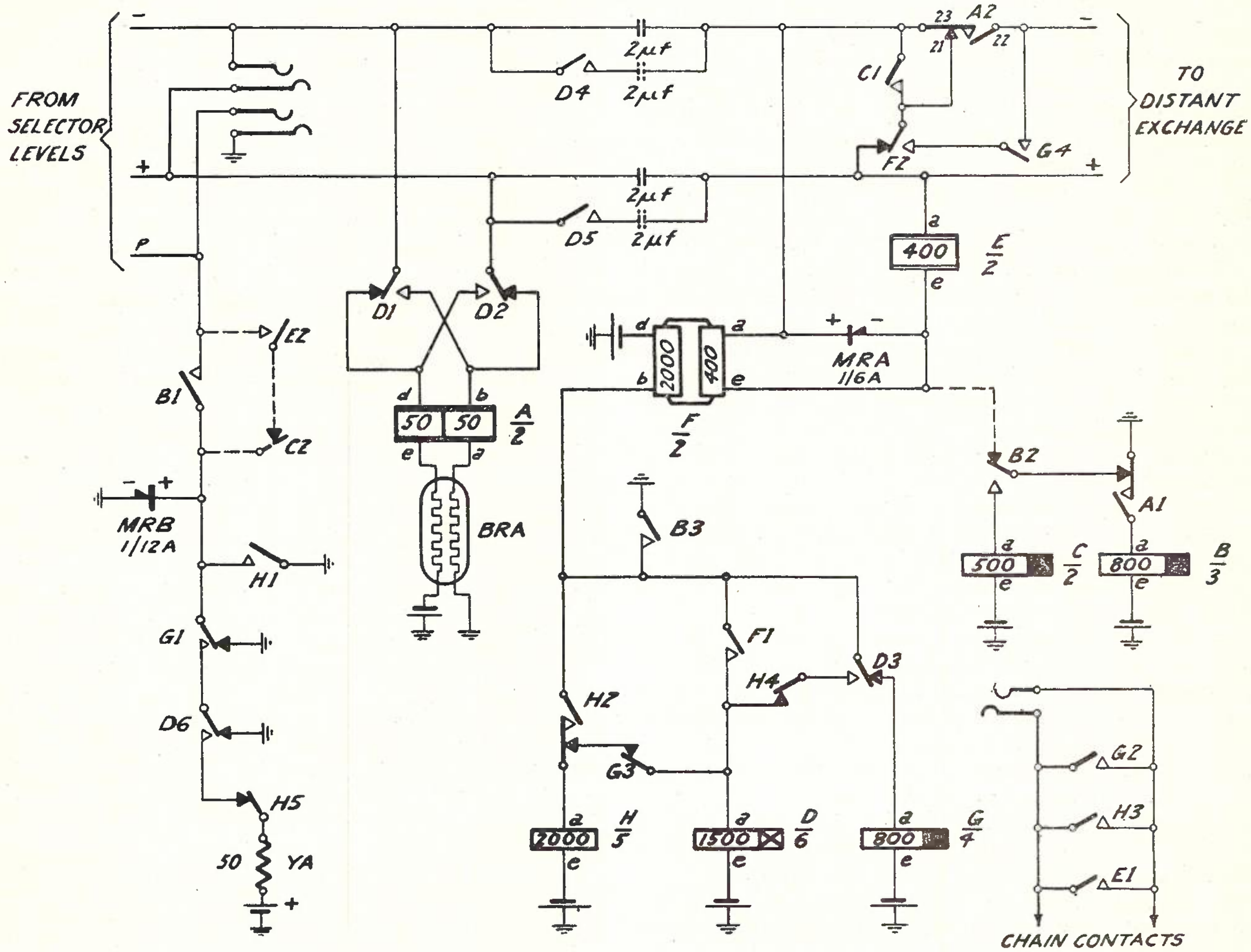


Fig. 3.—Modern Booster Battery Repeater.

Automatic-Automatic Relay Set (Repeater)—Reverse Battery Type: Before the introduction of booster battery metering, in addition to its function of supervision and public telephone operation, the reversal of battery on the calling subscriber's line was employed to control relays which, in turn, closed the subscriber's meter circuit when the called subscriber answered.

One type of reverse battery auto-auto repeater in general use is similar to Fig. 2, with the following modifications:—

The operation of the auto-auto repeater, disregarding the dotted lines, is as follows:—

When the repeater is seized, relay A operates from negative battery, BRA, 50 ohm winding of A, D1, subs. loop, D2, 50 ohm winding of A to earth via BRA. A operates and A1 closes the circuit for B, whilst A2 closes the circuit to the switch ahead, from negative line 400 ohm winding of the shunt field relay (bridged by MRA), 400 ohm winding of E to positive line. B operates and B1 extends earth to P wire via

G1, B2 prepares the circuit of C, B3 closes the circuits for G and 2000 ohm winding of F, but the latter does not operate at this stage. E operates and E1 closes a link of the chain relay circuit, whilst the function of E2 relates to the auto-manual repeater. G operates and G1 prepares the booster battery metering circuit, G2 bridges E1 to maintain the chain relay link when E restores during dialling, G3 opens the operating circuit for H relay, whilst a short-circuit is prepared for A2 at G4.

When impulsing occurs, relay A impulses according to the digits dialled. On the first impulse being received from the subscriber's dial, A restores, A1 normal closes the circuit for relay C via B2. C operates and, being slow to release, remains operated during the impulse train.

C1 short-circuits the 400 ohm windings of relays E and F, whilst the function of C2 refers to the auto-manual circuit.

Subsequent impulse trains are repeated as indicated above.

When the called subscriber answers, current is reversed over the junction, and F operates. F1 closes the circuit for D, F2 completes a parallel circuit to A2, via break contact of A2 and G4, to prevent an impulse being sent to line should A relay restore momentarily during battery reversal to the calling line at D1 and D2.

D operates, D1 and D2 reverse the current to the calling subscriber's line, D3 opens the circuit of G and closes a parallel circuit for D, via H4; D4 and D5 increase the capacity of the transmission condensers when specified. D6 connects 50 volt booster battery from earthed negative battery, YA50, H5, D6, G1, B1, P wire, to exchange battery at subscriber's meter, thus applying 100 volts approximately to the circuit for the release time-lag of G relay. Relay D is slow-operating, to cover the "flick" operation of F, due to line surges, etc.

G, after its slow-release period, restores, and G1 disconnects the booster battery pulse and reconnects earth to the P wire, G3 closes the operating circuit of H, via F1 and B3, and G4 opens the short-circuit across A2.

H operates, H1 earths the P wire, H2 closes its locking circuit to earth at B3, H3 closes a parallel chain relay link, H4 opens the parallel circuit of D, H5 opens the booster battery circuit.

When the calling subscriber restores, A releases and A1 opens the circuit of B, A2 opens the loop to the distant exchange and allows the switches to restore. B, after its slow-release period of approximately 300 milli-seconds, restores, B1 opens the guarding earth from P, B2 and B3 open the circuit of the remaining relays. Earth through MRB is applied to the P wire between B1 and H1, to cover the transit period of G1 and D6 lever springs from their associated break to make springs. This method replaces the make-before-break springs previously used which, during operation, momentarily short-circuited the meter battery. MRB also maintains an earth on the P wire to prevent the associated switches restoring, should the fuse operate and disconnect the earthed booster battery.

When a relay set wired to Fig. 3 is used as an auto-manual repeater, the portions of the circuit indicated by dotted lines are included. The additional functions of the circuit are similar to those described for Fig. 2.

Automatic to Automatic Relay Set (Repeater), with Ballast Resistor and Auto-Routining Feature: Fig. 4 is typical of the most modern auto-auto relay set, and embodies a number of new features, some of which are not yet included in repeaters in service. The operation of relay sets wired to Fig. 4 is:—

On seizure from the preceding switch, A operates and A1 closes the circuit for B, whilst the loop to the switch ahead is prepared at A2. B operates and, at B1, extends earth to the P wire, via G5. B2 prepares a circuit for C, whilst B3 closes a circuit for G and prepares a parallel circuit for B, via E2. B4 closes a circuit for HA. G operates, and at G1 closes the chain relay link, G2 provides an alternative holding circuit for C, G3 opens the operating circuit of H, G4 prepares a local loop to hold A operated, and G5 transfers the P wire earth to D4.

Relay HA operates from battery, HA3000 N.I., HA winding, B4, B1, to earth at D4. The loop to the switch ahead is closed from negative side of junction, HA1, A2, 2 limbs of MRB in parallel, 400 ohm winding of E, HA3 to positive side. HA2 closes its holding circuit. Relay F connected in parallel with MRB does not operate through its associated rectifier MRC at this stage, due to the comparatively low forward resistance of MRB, which is in series with E and allows the latter to operate, shunted by 800 N.I. resistance G.

Relay E operates, and E1 removes the N.I. resistance G connected in parallel with it. E2 closes a parallel circuit for B, via B3, and renders the release of B dependent upon the release of E, thereby increasing the guarding period of the repeater from 300 mS to 550 mS, approximately. When the subscriber dials, relay A impulses and, on receipt of the first impulse, A retores and A1 closes the circuit for C, via B2, while A2 opens the loop to the distant exchange. C operates and, due to its slow release, remains operated during the remainder of the train of impulses. C1 short-circuits MRB and relay E. The function of C2 is described under the release of repeater.

When the called party answers, the battery is reversed over the junction, and the comparatively low forward resistance of MRC allows relays F and E to operate in series. MRB, due to its high back resistance, no longer shunts F.

The local loop for relay A is closed by F1, via G4, and the circuit for D is closed at F2.

Relay D is slow-operating to cover the "flick" operation of F, due to line surges, etc. On operation, D1 and D2 reverse battery to the calling subscriber's line, D3 opens the circuit of G and closes its locking circuit via H5 and B3, while D4 closes the positive battery metering circuit from earthed negative battery, YA50, H4, D4, G5, B1 to P wire, thence to exchange battery via the subscriber's meter, where booster battery is used, or earth via the meter where positive battery is employed. After its release-lag period, 300 mS approximately, G restores and G3 closes the circuit for H via H2, F2, to earth via B3. G4 opens the loop across relay A.

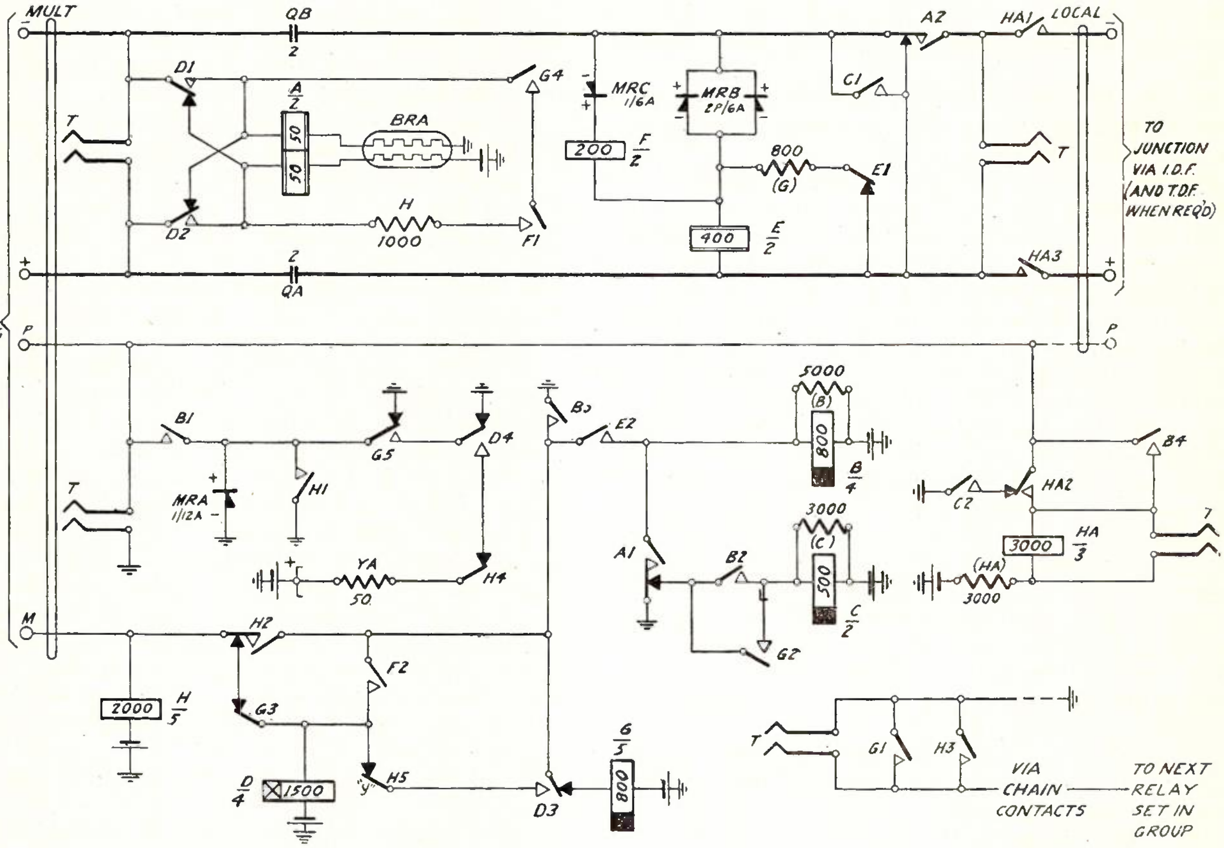


Fig. 4.—Modern Auto.-Auto. Relay Set Repeater.

H operates, and H1 connects a parallel earth to the P wire. H2 completes a locking circuit for itself, while H3 maintains the link for the chain relay. H4 opens the metering circuit and H5 opens the temporary locking circuit for D.

Earth is extended also to the M wire for metering. This is required only on auto-auto working in branch exchanges, where the repeater is connected directly to a primary uniselector designed for fourth wire metering. The circuit is from earth, B3, H2, M wire, uniselector bank contact, to negative battery via the subscriber's meter. Earth through MR is applied to the P wire between B1 and H1 for the reasons given in the circuit description of Fig. 3.

When the calling subscriber restores first, A releases, followed by F, E, D, B and H. During the release period C re-operates via A1 normal, and B2 operated, and earth on C2 guards the P wire until all relays have restored. If the called subscriber restores first, relays F and D restore.

It will be seen that the shunt field relay F (Fig. 3) has been replaced by a standard 3000 type relay connected in series with a rectifier, MRC, and shunted by rectifiers, MRB. This arrangement is more reliable in operation, as the shunt field relay has a tendency to "flick" up when the circuit of the polarizing winding is closed at the first operation of B; and, in addition there is no need for a special relay.

Components of the Circuit (Refer to Figs. 3 & 4)

Following the introduction of the 3000 type relay, various alterations were made to the repeater relay sets for general use, and it will be of interest to consider the steps taken to render the components of the circuit as efficient as possible.

Impulsing Relay A: The impulsing relay (A), having two coils, each of 50 ohms resistance, is connected in series with a ballast resistor, BRA, to provide a feeding bridge to the calling subscriber. This arrangement limits the current on short lines to 100 milliamps., thus preventing damage by excessive current to the transmitter and feeding coils; while, on long lines, an increase of current over that provided by the use of 200/200 ohm windings, is obtained.

The relay coil is sandwich-wound, i.e., half of the first winding is placed on the core, the second winding is then wound on, followed by the second half of the first winding. The two halves of the first winding are then connected in series. By this method the two windings are balanced, approximately, with respect to the number of turns, ohmic resistance, impedance and operating current.

Three nickel iron sleeves are placed over the soft iron core of the relay, to increase the impedance to voice frequency currents, without affecting unduly the direct current characteristics of the relay. The A.C. flux due to speech currents penetrates only a comparatively short distance into the core; and by making this portion of high permeability magnetic material a high impedance is obtained, without increasing the D.C. characteristic.

Isthmus Armature: In order to repeat impulses undistorted, the operate and release times of the relay armature must be equal. It is very difficult to do this with a standard 3000 type relay, having a plain armature. A special armature, therefore, is used on "A" relays of these repeaters, and consists of an armature of ordinary shape, portion of which is cut away to form a narrow "neck" or isthmus, from which it derives its name. The effect of the isthmus armature is to produce magnetic saturation at low current value so that the flux is constant approximately over the exchange voltage range, and on short and long lines. Consequently, the release-lag is shortened and is stabilised.

For fast-operating relays a short armature travel is necessary. In the 3000 type impulsing relay, the travel is approximately 25 mils, in place of the standard armature travel of 31 mils.

"A" Relay Shield: The isthmus armature, due to its imperfect magnetic circuit, permits a large leakage flux; and relays having this type of armature are therefore susceptible to magnetic interference or crossfire from adjacent relays. Relays fitted with ordinary armatures are not so subject to this defect. Tests indicate that if repeater B and C relays are permanently operated during impulsing, the operate and release currents of the impulsing relay are increased considerably over the values obtained when the B and C relays are de-energised. Under normal impulsing conditions, however, as the B and C relay fluxes are impulsing, the effect is reduced somewhat.

To minimise the interference effects due to magnetic crossfire, 3-sided 19 mil mild steel shields are now fitted to all 3000 type repeater impulsing relays. The shield has been designed so that it can be slipped into position readily over the impulsing relay, with its open side next to the yoke. The shield reduces the operate and release currents, also the impedance, of the impulsing relay, without affecting unduly the transmission efficiency of the circuit over long junctions.

"K" Spring Units in Lieu of "C" Spring Units: One reason for using a make-before-break (K) contact unit in place of a changeover (C) unit for operating the B and C relays is to avoid the transit or changeover time interval which is lost when a C unit lever spring moves from its associated break-to-make contact. This time is added to both the make and break periods in the K unit. As an example, assume that the transit time of a lever spring is 4 mS when an A relay is impulsing at the rate of 10 impulses per second, with 33 per cent. make and 67 per cent. break periods, approximately. The B relay circuit will be closed for 31 mS with the C contact unit, and for 35 mS with a K unit, while the C relay circuit will be closed for 65 and 69 mS respectively. The use of a K unit, therefore, increases the time available for saturating the B and C relays and, as a result, the tendency for the relays to restore under adverse conditions is reduced.

Sparking and Pitting at "A" Relay Contacts: Sparking and pitting of the A relay K unit controlling the B and C relays at contacts A1, occurs during impulsing with varying degrees of severity. Measurements disclose that the peak voltages developed across the B relay contacts, in some instances, exceed 1000 and, for the C relay contacts, 850 volts. Various methods of quenching the spark were tried, including a standard condenser resistor unit, silicon carbide discs, and shunting the relays with a non-inductive resistance. Of the methods tried out to quench the spark, the shunting of the coils by connecting a metallised resistor of 5000 ohms across the coil of the B relay, and one of 3000 ohms across the C relay, appeared to be the most satisfactory (see Fig. 4). In addition to reducing the peak voltage to 340 for the B, and 330 for the C relays, the resistors had the advantage of being cheap and readily applied, being connected directly across the relay coil terminals and occupying but little space. The operating efficiency of the C relay is not reduced by connecting a 3000 ohm resistor across its coil but, on the contrary, this arrangement tends to reduce the contact bounce.

The resistances are being connected across B and C relay coil tags in all instances where excessive sparking and contact wear are occurring.

Relay B: In order to ensure satisfactory impulsing performance from B relays, a special test is conducted by the manufacturer. This comprises an impulse or dynamic test. The relay is connected in series with one of its own make contacts, an interrupter, and a 46 volt battery. After saturation with 46 volts, the relay must hold in on an infinite train of impulses at a speed of 12 impulses per second and a make ratio of 20.4 per cent., i.e., on a make period of 17 mS. If necessary, the manufacturers adjust the residual screw until the release lag of the relay complies with the above conditions, other relevant adjustments being within the tolerances allowed. The minimum residual gap existing is then marked on the relay cheek. This explains the different residual values marked on B relays which are apparently similar. In maintenance, the relay is re-adjusted within the tolerances specified for the marked residual. The usual method of testing the release-lag by saturating a relay and timing the release of the armature from the opening of the circuit, is termed the static method.

Ballast Resistors: The failure of ballast resistors in service, as a result of subscribers' lines contacting with power wires, has been reduced considerably by the following amendments to the repeater circuit. The failures occur principally on branch exchanges, where the outgoing junctions are routed direct through repeaters and not via selector levels.

As the ballast resistor is not used for transmission, generally, until the called subscriber answers, and a battery reversal takes place on the calling line, a 150 ohm N.I. resistance is connected in series with each 50 ohm winding of the A relay, via the break contacts of the battery reversing spring units of relay D, the ballast resistor filaments being connected to the respective make contacts of the units.

As each 50 ohm winding of the A relay is connected normally in series with a 150 ohm N.I. resistance, the ballast resistor filaments are protected from overload as a result of intermittent contact with power circuits until battery reversal has taken place on the line.

Where 150 ohm N.I. resistances are fitted and a ballast resistor filament fails in service, the call will proceed until the called subscriber answers and the battery reversing relay operates and switches A relay circuit from the resistances to the filaments. As the filament is open, the A relay restores and releases the connection, the called subscriber does not hear the caller.

To overcome this difficulty, a 1000 ohm resistor is connected across each ballast resistor filament to maintain the circuit on reversal, should the filament be open, and permit the conversation to proceed, although the transmission efficiency is reduced somewhat. The reduced speech volume can be detected readily during tests.

The alterations to the ballast resistor circuit are being made on all repeaters and switching selector repeaters used as first selector equivalents. In making the alteration it is necessary that the current through the A relay be maintained in one direction. A reversal of current through A tends to produce false impulses. The circuit alterations are indicated in Fig. 5.

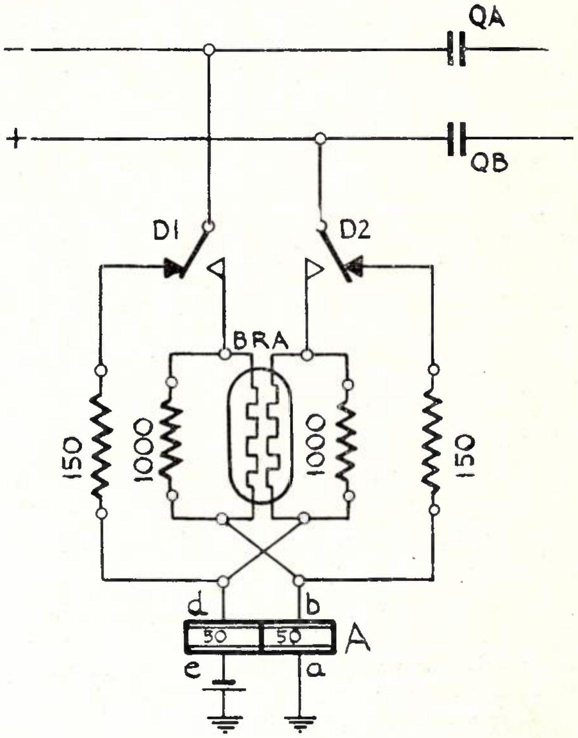


Fig. 5.

Long Line Conditions: When a junction is seized the repeater and distant selector A relays are operated, and the circuit is prepared to receive the train of impulses which follow; this is termed the "initial pick-up." Where two or more repeaters are connected in tandem, and the junction line resistance is high, even if the A relays operate fully, the long line, together with the inductance of the repeater E and F relays, cause the A relays to operate slowly, and the make-before-break contact unit controlling the B and C relays may be bunched together for an appreciable length of time, allowing these relays to operate momentarily. When the associated B and C relays release on the complete operation of the A relay, a surge may be set up in the junction, tending to de-energise the selector A relay, and a premature impulse may result. The bunching time of K contacts has been reduced by the use of stiff back springs, now standard, in place of the flexible ones used formerly.

During a train of impulses, the C relay associated with each repeater is operated, and the E and F relays are short-circuited by C relay contacts. At the end of the train of impulses C, after its release-lag period, restores, and the E and F relays are again included in the loop to the switch ahead. This is termed the subsequent pick-up. At the instant this takes place, the current in each half of the selector A relay winding, due to the effect of the inductance and capacity, does not immediately fall to the direct current value, but is in the form of a damped oscillation or surge, which is of a complex nature, and may cause the relay to release momentarily, in which case the selector may receive an extra impulse. Whether the extra impulse appears as an extra vertical step or a premature rotary step, in the case of a final selector, depends upon the relative values of the repeater and selector C relay release-lags. If the repeater C relay release-lag is small as compared with the selector C relay release-lag, the selector relays will not have had sufficient time to change from the vertical to the rotary movement before the momentary release of the A relay, so that an extra vertical step will result. If, however, the final selector relays have connected the rotary magnet before the release of A, then the premature rotary step will result. The release of the selector A relay may occur, however, during the time that the selector is changing from the vertical to the rotary movement, in which case false stepping of the selector will not occur so readily. The worst form of subsequent pick-up trouble results when two or more repeaters are connected in tandem. In this instance, the repeater A relay armature may flick, in addition to the selector A relay. Incidentally, some types of bi-motional switch operate more easily on the first than on subsequent impulses, thus assisting premature impules to this extent. The leverage ratio of the off-normal spring operating arm of these switches is such as to assist the switch to step on the first impulse.

The maximum permissible resistance of a junction between repeaters or repeater and selector, so that no false impulses occur on the initial or subsequent pick-up, has been increased considerably by connecting a 1/6A rectifier across the 400 ohm winding of relay F, Fig. 3, and a 2P/6A rectifier for relay F, Fig. 4. This is due to the fact that the final value of the current in the A relay circuit is increased when the C relay releases, the effective inductance of E and F relays is reduced also, so that the oscillations set up through the A relay winding are smaller, and the tendency for the A relay to release is reduced. The rectifier is connected so as to shunt the relay with the current flowing in the normal direction in the junction. When the called subscriber answers, the polarity of the junction is reversed, and the F relay operates in the normal manner. The forward resistance of a 1/6A rectifier with 100 mA flowing is 42 ohms, approximately, while the reverse resistance is 9000 ohms.

Generally, subsequent pick-up troubles do not occur on single junctions, having a resistance of less than 1800 ohms, approximately, when the rectifier is connected; but when two or more junctions are connected in tandem, the limiting resistance is much lower and, under certain conditions, the rectifier does not completely eliminate the trouble.

Since relays in service are adjusted mechanically or electrically within specified tolerances, and not to specific values, to cover the variations in adjustments within the tolerances set, the limits under which a relay is permitted to operate are determined with the relevant tolerances acting adversely in the circuits.

To further reduce pick-up troubles, the latest repeater circuit, Fig. 4, in addition to having the rectifier connected across the F relay, has an 800 ohm resistor connected across E relay and controlled by E1 contacts. As previously stated, at the end of a train of impulses (subsequent pick-up), the C relay restores, and at that instant the current in the A relay ahead momentarily falls to zero because of the inductance of the F and E relays being re-introduced into the circuit. With the 800 ohm resistor connected in parallel with the E relay, the current from the A relay ahead is transferred momentarily to the 800 ohm resistor until the inductive effects of E have been overcome and the current rises sufficiently to cause the relay to operate and disconnect the 800 ohm resistor. The loop current is therefore maintained, and false impulses are eliminated.

In one modern repeater circuit, an additional slow-release relay, CA, controlled by relay C, is provided. The CA contacts are connected in series with an 800 ohm resistor, the whole being connected in parallel with the C contacts, which short-circuit E and F relays. At the end of the train of impulses, C restores, followed by CA, after its slow-release period, the 800 ohm resistor maintaining the loop to the A relays ahead until the inductive effects of E and F relays have been overcome. On restoring, CA removes the 800 ohm resistor from the circuit.

Resistance Across "A" Relay: One of the principal factors limiting the maximum junction resistance for inter-repeater working, is the re-operation of the repeater A relay, via E and F relays, should it restore during the reversal of current on the junction line. To prevent A restoring under these conditions, a 1000 ohm N.I. resistance is being connected across the A relay at the D reversing springs, Fig. 4. The circuit will be closed on existing repeaters by F2 contacts, and opened on the release of G4 contacts, a period of approximately 160 mS. Contacts G4 and F2, Fig. 3, are used at present to short-circuit the A repetition contacts to guard against an extra impulse should A restore. This amendment to the circuit increased considerably the maximum junction resistance over which the repeater will operate, and is being made on all repeaters associated with junctions exceeding 1200 ohms resistance.

Short Line Conditions: On short lines, especially with low insulation resistance, or where additional condensers are in circuit, the A (impulsing) relay break period tends to become of small duration, and heavily adjusted selector magnets sometimes fail to respond to the dialled impulses. There is also a tendency for the C relay to fail at low dial speeds if the make ratio of the A relay break contact is low. Amongst the worst conditions for dialling is the Extension Switch No. 1 when in the exchange-to-extension position while dialling proceeds from the main telephone. Short-circuited turns on the impulsing A relay may cause short line impulsing failure, due to the increase in release-lag and, in addition, may increase transmission loss due to reduction in relay impedance.

Short First Impulse: In some earlier types of repeater, not equipped with K impulse repetition contacts, when a train of impulses is repeated via one or more auto-auto repeaters, the first impulse of a train received by the selector is shorter than the remainder, and the break contacts of the selector A relay, controlling the vertical and rotary magnets, are made for a shorter period than for subsequent impulses.

It is of interest to consider such a repeater, equipped with a 3000 type A relay, impulsing under short line low insulation conditions. Consider first a circuit consisting of a short subscriber's line, an auto-auto repeater with the transmission condensers disconnected, and a low resistance junction line. On the initial "pick-up" the circuit for the selector A relay is closed, via the repeater impulsing contacts and relays E and F; but on the operation of relay C, during the first impulse, E and F relays are short-circuited, and the current through the selector A relay is increased, resulting in increased release-lag, the first break of the selector A relay is therefore actually longer than subsequent breaks.

On connecting the transmission condensers in the above repeater, however, oscillograms of the impulsing in the circuit disclose that the subscriber's instrument and the transmission condensers cause a building-up of the make ratio of the repeater A relay contacts, in the first instance, due to oscillations. The building-up is to some extent offset by the reduction in the release-lag. This is explained by the surges which occur in the repeater A relay winding on the break of the repetition contacts, being in a magnetising and de-magnetising direction in the battery and earth-connected windings respectively. Similarly, when the repetition contacts re-make, surges are again in evidence in the relay winding, but in the opposite direction to those which occur when the contacts break.

It is found, therefore, that, on connecting the transmission condensers, the length of the first break of the repeater repetition contacts of a single repeater is about the same as subsequent impulses in the train, but the selector A relay break contact make period is now shorter than the remaining impulses.

A further consideration of oscillograms of impulsing in the circuit when two or more repeaters are connected in tandem, discloses that, for the second and subsequent repeaters, the rate of decay of the A relay current for the first break is less than for subsequent breaks; and, as a result, the length of the first break of the repetition contacts is less than for subsequent impulses in the train. Under limiting conditions this is as much as 3 mS less for each repeater. It appears that the first short impulse on all repeaters, other than the first repeater, is due to the inclusion of the E and F relays in the circuit on the first impulse. This causes the current in the A relays to decay at a reduced rate in the form of a more highly damped oscillation through the associated E and F relays. Since the first repeater A relay is not looped via the E and F relays, the first short impulse trouble is not in evidence.

If the C relay of the first repeater be held operated during a train of impulses, the length of the breaks of the second A relay repetition contacts will all be the same.

In modern repeaters equipped with 50+50 A relays and ballast resistors, to reduce the difference in the length between the first and subsequent impulses, a make-before-break (K) unit is used, instead of a make unit for the repetition contacts. The break spring of the K unit is connected to the positive side of the junction line, thus simulating the action of the C relay in short-circuiting the E and F relays for the first impulse and allowing the oscillations to be damped to the same degree for all impulses of the train. See A2, Figs. 3 and 4.

To reduce impulse distortion in some instances where the junction lines are very short, such as semi-automatic sender junctions or direct dialling lines from a manual position impulsing into an automatic exchange in close proximity, it has been found necessary to include a resistance of approximately 200 ohms in series with the repetition contacts during impulsing. Further, in P.A.B.X.'s equipped with selector repeaters or final selector repeaters, the lines connected with the automatic exchange are usually of low resistance and, to reduce impulse distortion, therefore, a resistance has been included in the switch circuit during impulsing in each case.

Relay C: When impulsing on lines having additional capacity, and where two or more repeaters were employed in a call set-up, it was found that if the A relay tended to operate during the break period, due to the oscillations referred to previously, the lever spring of the unit controlling the B and G relays would tend to open C relay circuit. The result was that, as the C relay was not being sufficiently fluxed, it released towards the end of the next make period, and the E and F relays were re-introduced into the junction loop, the result being that the conditions for the A relay ahead were similar to or worse than those of the first short impulse. The above results depended upon the characteristic of the C relays concerned, the chatter being worse on a heavily adjusted relay and less on a relay having a high release-lag, and the trouble occurred generally on the second or subsequent repeaters. To overcome this defect, the C relay release-lag has been limited to 150-225 mS, and 12 mil springs have been used. A heavy adjustment is one in which the spring tensions, armature travel and residual gap are all at the maximum tolerance allowed for a particular relay, so that the operate lag is increased and the release lag reduced.

Adjustments of Impulse Repetition K Unit: The make contact clearance, i.e., the clearance between springs 22 and 23, Figs. 3 and 4, with the armature released, of the repeater repetition contacts has a considerable effect upon the maximum permissible junction resistance when two or more repeaters are connected in tandem. For a particular make contact clearance, the break contact clearance will depend upon the amount of flexing of the lever spring. Small make contact clearance is detrimental to short line, low insulation conditions, as the smaller the make contact clearance the smaller will be the make time of the A relay break contacts operating the selector magnets. On the other hand, a large make contact clearance limits the permissible long line impulsing conditions by decreasing the make contact closed period. This causes B relay failure. To meet general conditions and to limit extremes of contact clearance, the following rule has been made for maintenance purposes:—

(a) On an impulsing A relay having a K spring unit, measure the armature travel; if this is more than 25 mils, adjust the make contact clearance to be about equal to the break contact clearance, as judged by the eye. If the travel is 25 mils or less, adjust the make contact clearance by eye to be slightly greater than the break contact clearance. After adjustment it should be checked that the break contact clearance is not less than about 10 mils; if it is, then the make contact clearance should be reduced slightly so that this condition is met. Where two K units are included in a spring set, they should make and break respectively as near as practicable at the same time.

(b) Where the relay carries an M spring unit, in addition to a K unit, adjust its contact clearance by eye to be about the same as that of the K spring unit make contact clearance.

The above rule ensures that lightly adjusted relays will have large make contact clearances, and the more heavily adjusted relays will have smaller make contact clearances.

The dial speed also has a bearing on the permissible dialling limits. In the standard speed of 10 impulses per second the make period is 33 mS, while the break period is 67 mS. If the dial speed be increased to 12 impulses per second, the make period is reduced to 28 mS and the break period to 56, approximately. The operating tolerances are thereby reduced.

References: B.P.O. Research Reports, Nos. 8409, 9406 and 10076. P.M.G. Research Laboratories Test Report, No. 1682.

UNIVERSAL TELEPHONE, TYPE 300

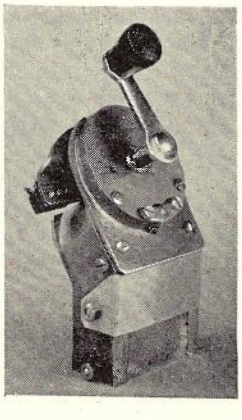


Fig. 1.—Laboratory Model of re-designed Generating Unit.

In view of the interest created by the description of the Universal Telephone, Type 300, appearing on pages 298-302 of the October issue of the "Journal," readers may be interested in two further illustrations associated with the development of this telephone.

In addition to ensuring provision for either wall or table mounting, an essential factor in the achievement of a universal type of telephone was a fundamental re-design of the generator unit, and it was to this aspect that a considerable proportion of the activities of the Circuit Laboratory, Chief Engineer's Branch, were directed during the development work.

The laboratory model of the re-designed generator unit is shown in Fig. 1, whilst Fig. 2 illustrates, by means of a transparent telephone model, the disposition of this unit in relation to the other equipment in the Type 300 telephone. As referred to in the article, the subsequent development of the generator from the workshop production aspect will be published in a subsequent issue of the "Journal."

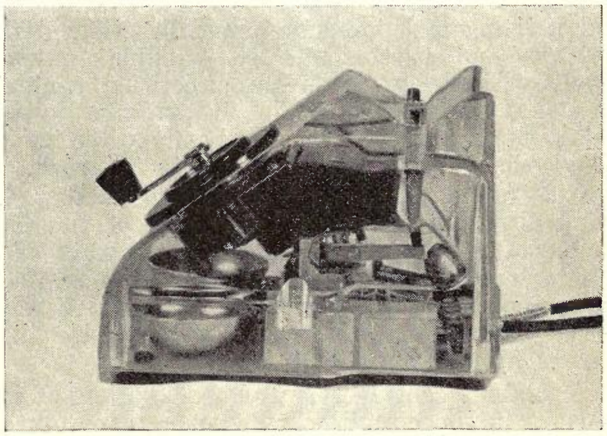


Fig. 2.—Generator fitted to transparent Telephone Model.

THE DESIGN AND CONSTRUCTION OF UNDERGROUND CONDUITS FOR TELEPHONE CABLES

A. N. Hoggart, B.Sc.

PART VII.: BURIED JOINT CONSTRUCTION PRECAST JOINTING PITS AND MANHOLES.

General: A conduit run must necessarily be intercepted at frequent points along its length for the purpose of drawing-in cable; the length of the section of cable which can be drawn-in in one operation being strictly limited. This necessitates the making of a joint in the cable at these points. It is also necessary to provide for branch cables to join the main cable in accordance with the cable distribution scheme for the area; and, in some cases, particularly trunk and junction cables, to joint loading coils into the cable. The construction at such jointing points is a vital part of the whole conduit system, and it is of special importance that close attention be paid to the design and workmanship at these points. In particular, the only part of the system in which the cable is not continually supported is in the manholes or equivalent structure. Experience has shown that, unless special care is taken in arranging proper supports for the cable, an excessive number of faults due to failure of the cable sheath, etc., will occur. The facilities offered for drawing-in cable, jointing or repairing cable, are also of prime importance.

The following classes of construction will be considered:—

(a) Buried joint construction.
(b) Jointing pits, including small, precast joint boxes for the smaller cables.
(c) Manholes or jointing chambers.

Buried Joint Construction: Buried joints may be accommodated in either of the following:—

(i) Split pipes or couplings.
(ii) Buried jointing chambers, such as illustrated in Fig. 45.

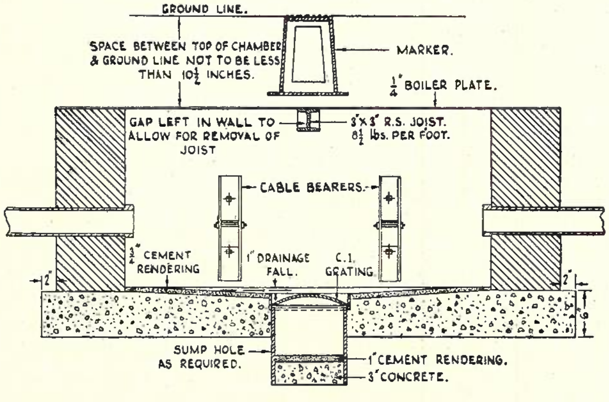


Fig. 45.—Buried Jointing Chamber.

These, although much less costly than manholes in initial outlay, suffer from the following disadvantages:—

(1) It is necessary to open up the ground by means of pick and shovel on each occasion work is required to be carried out.
(2) On account of (1), they are unsuitable for use under paved surfaces. If, subsequent to their installation, the surface is paved, the construction of a manhole becomes necessary.
(3) Accurate records of the location of such buried jointing points is necessary, and surface markers should be used. Much time can be expended in locating them when work is to be carried out if records are inaccurate or markers become displaced.
(4) Special precautions are necessary to prevent infiltration of silt, etc., which in turn tends to block the ducts.
(5) Split pipes and couplings do not make provision for grading and drainage of the conduits, which is necessary to reduce the liability of the cable to corrosion troubles.

In spite of these objections, there was considered to be justification for the use of buried joint construction, mainly on single-pipe runs under unpaved surfaces, where re-opening of joints was anticipated only at rare intervals. This consideration applied prior to the introduction of small precast jointing pits, as the only alternative available was a built-in situ jointing chamber or manhole, at considerable additional cost.

Jointing Pits: These provide an inexpensive and satisfactory means of housing joints in small cables, are easily installed and, being light in weight, are readily transported to the job. Precast jointing pits have rendered buried joint construction obsolete. They are made in seven different sizes, to meet varying sizes of cable. Fig. 46 illustrates the single-cover types (sizes Nos. 0 to 4), which are generally used in conjunction with small diameter iron pipes; sizes Nos. 3 and 4 are deep pits for use where pipes are laid at extra depth, such as road crossings. Fig. 47 shows the double-cover types (sizes Nos. 5 and 6), which are designed for use with one or two 4 in. pipes respectively. The body of the pit is constructed of laminated asbestos cement sheet; although, in the smaller sizes, fairly extensive use has been made of concrete, consisting of asbestos fibre, sand and cement, in which case the thickness of the material is ¾ in., in lieu of ⅜ in. The cover is of reinforced concrete. Table 3 gives a guide to the maximum size of cable which each size of pit can house satisfactorily. The cable is looped around the pit so that the jointing can be carried out above ground, and the joint is supported on clips against one wall, just below the lid, or on the bearers shown, in the case of sizes Nos. 5 and 6.

TABLE 3
Cable Jointing Pits

Size No.	Internal Dimensions (inches) Length	Width	Depth	Maximum Cable Size	Location, etc.
0	12	9	9	5 pr. 10 lb. twin	Final lead-in to subscriber's premises, or in footpath.
1	18	9	9	28 pr. 10 lb. S.Q. 14 pr. 20 lb. S.Q.	Footpath, where iron pipe is laid at shallow depth.
2	24	12	12	74 pr. 10 lb. S.Q. 38 pr. 20 lb. S.Q.	As for No. 1, but for larger cables.
3	18	9	18	28 pr. 10 lb. S.Q. 14 pr. 20 lb. S.Q.	As for No. 1, but where pipe is at greater depth, e.g., at road crossings.
4	24	12	24	74 pr. 10 lb. S.Q. 38 pr. 20 lb. S.Q.	As for No. 3, but for larger cables or greater depth of pipe. Can also be used with 4 in. E.W. or concrete pipe with small cables.
5	48	12	24	500 pr. 6½ lb. S.Q. 400 pr. 10 lb. S.Q. 200 pr. 20 lb. S.Q.	With single 4 in. E.W. or concrete pipes, where a manhole is not justified.
6	48	16	24	Two cables as for Size No. 5.	With two 4 in. E.W. or concrete pipes, where a manhole is not justified.

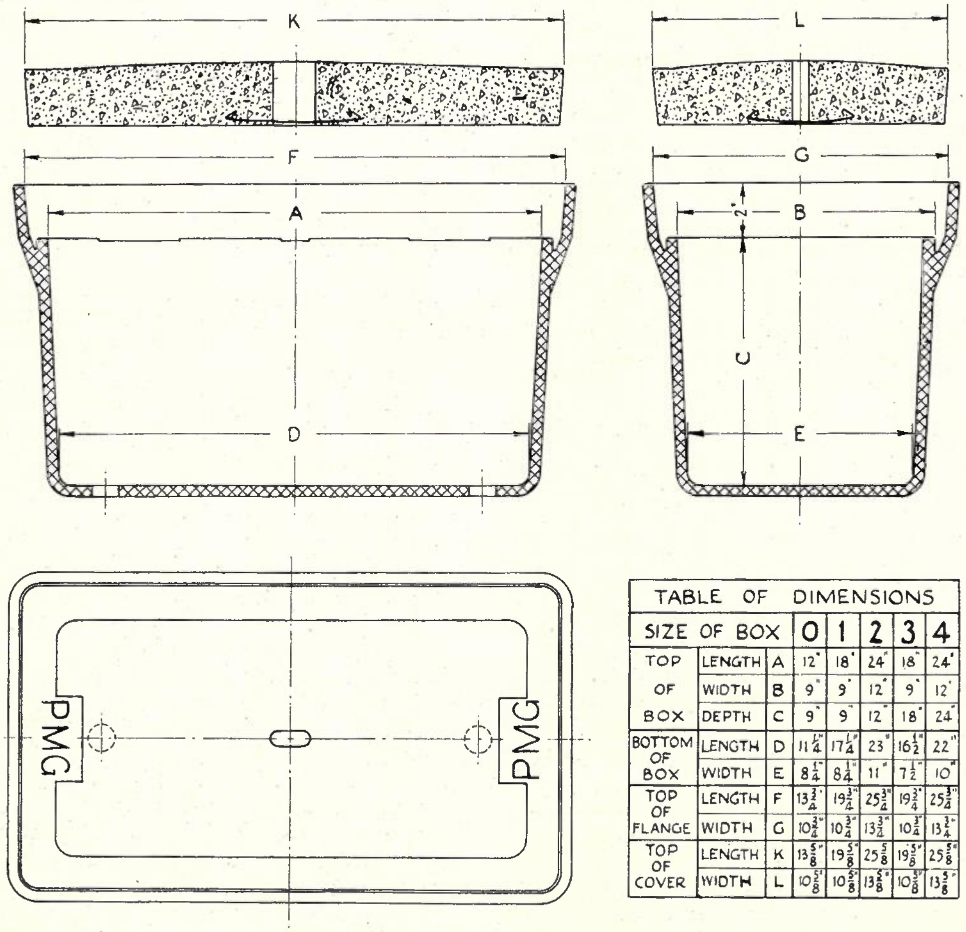


TABLE OF DIMENSIONS							
SIZE OF BOX			0	1	2	3	4
TOP OF BOX	LENGTH	A	12"	18"	24"	18"	24"
	WIDTH	B	9"	9"	12"	9"	12"
	DEPTH	C	9"	9"	12"	18"	24"
BOTTOM OF BOX	LENGTH	D	11¼"	17¼"	23"	16½"	22"
	WIDTH	E	8¼"	8¼"	11"	7½"	10"
TOP OF FLANGE	LENGTH	F	13¾"	19¾"	25¾"	19¾"	25¾"
	WIDTH	G	10¾"	10¾"	13¾"	10¾"	13¾"
TOP OF COVER	LENGTH	K	13⅝"	19⅝"	25⅝	19⅝"	25⅝"
	WIDTH	L	10⅝"	10⅝"	13⅝"	10⅝"	13⅝"

Fig. 46.—Precast Jointing Pits, Sizes Nos. 0-4.

Jointing pits are normally designed for installation in footways; but on occasions the need arises for the provision of a jointing pit in a location where it might be subjected to isolated road traffic, such as in drive entrances, right-of-ways, along unmade roads, etc. For such cases the concrete cover is insufficiently strong, and is replaced by a steel cover of the type shown in Fig. 48. On account, however, of the extra cost, it is advisable to consider the practicability of choosing an alternative location for the pit before a steel cover is provided. Tests show that jointing pits fitted with steel covers can safely carry all loads in the nature of light road traffic; but it is advisable to reinforce the sides of the pit by means of a concrete surround approximately 4 in. wide by 4 in. deep.

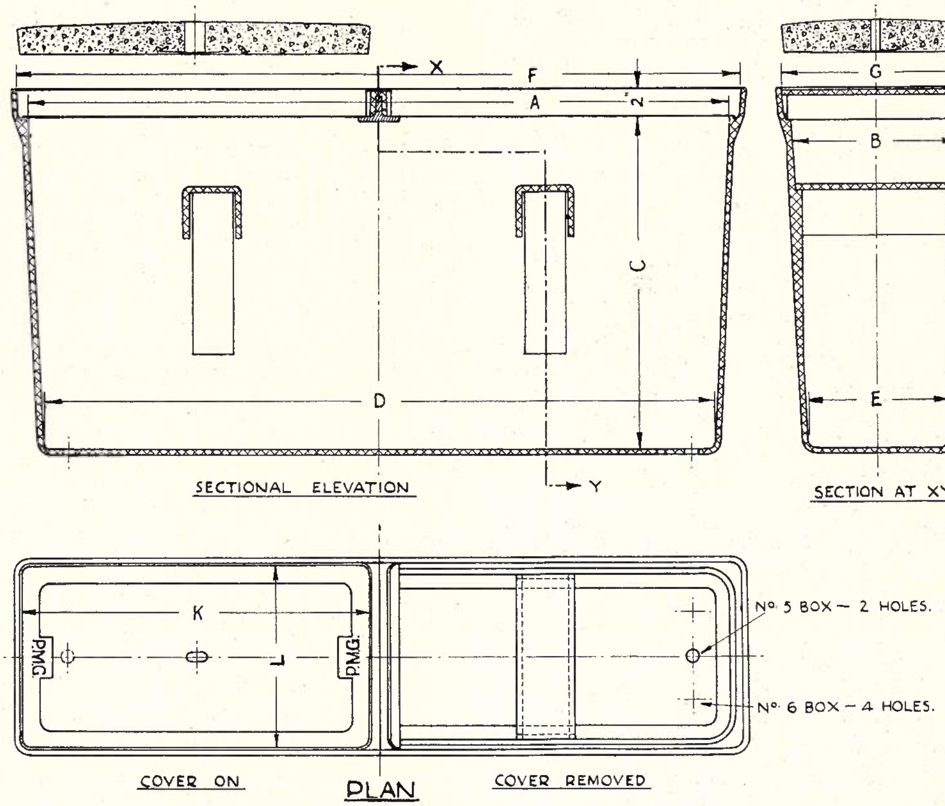


TABLE OF DIMENSIONS				
SIZE OF BOX			5	6
TOP OF BOX	LENGTH	A	4'-3"	4'-3"
	WIDTH	B	1'-0"	1'-6"
	DEPTH	C	2'-0"	2'-0"
BOTTOM OF BOX	LENGTH	D	4'-0¾"	4'-0¾"
	WIDTH	E	10"	1'-4"
TOP OF FLANGE	LENGTH	F	4'-4⅝"	4'-4⅝"
	WIDTH	G	1'-1¾"	1-7¾"
TOP OF COVER	LENGTH	K	2'-1⅝"	2-1⅝"
	WIDTH	L	1'-1⅝"	1-7⅝"

Fig. 47.—Precast Jointing Pits, Sizes Nos. 5 and 6.

Careful consideration of the location of jointing pits is necessary, particularly where more than two pipes will enter the pit either immediately or ultimately. Where pits are provided for subscribers' underground reticulation purposes, it will generally be satisfactory to place pits at alternate property alignments, so that two premises can be served from one pit. The locations of iron pipe entries into jointing pits have a bearing on the manner in which pits are positioned, in that they affect the manner in which the cables are subsequently arranged and jointed. In order to avoid objectionable "S" bends in the cable, and to ensure straight-through joints, the pipe entries should be arranged so that the iron pipes enter near a corner and not in the middle of a wall of the pit, and are disposed in the pit in the manner illustrated in Fig. 49. If, for example, a pipe entering one side of the pit is placed at the opposite end to that shown, it will not be practicable to arrange the cable in the desired manner. Care in the location of the pit during installation is necessary to ensure that present and future pit entries conform thereto.

Where a pit is to be installed in other than sandy soil or loose loam, it is advisable to have on hand a small quantity (about 1 cubic foot) of sand for bedding and filling around the pit when set in the ground. The use of sand for filling around the pit reduces the amount of ramming necessary, and enables a firm job to be achieved with minimum excavation.

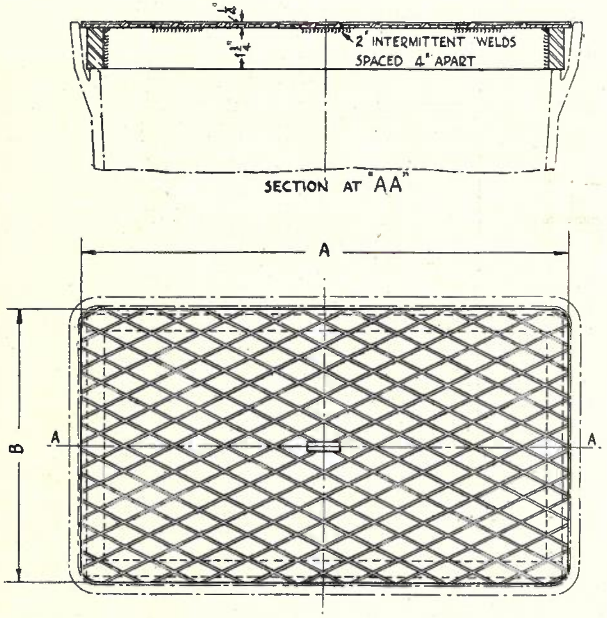
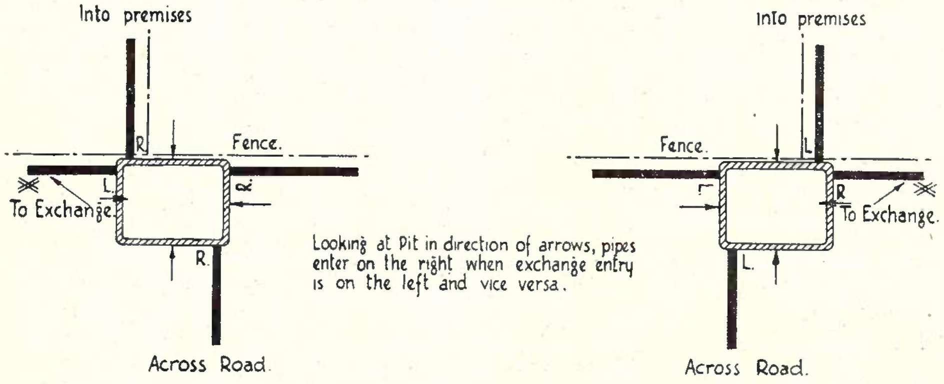


TABLE OF DIMENSIONS.

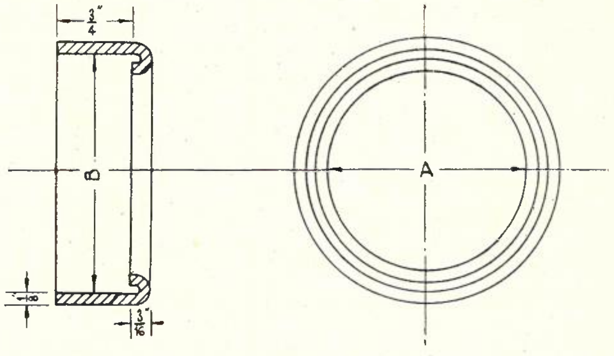
SIZE OF BOX		0	1	2	3	4
LENGTH	A	$13\frac{11}{16}$"	$19\frac{11}{16}$"	$25\frac{11}{16}$"	$19\frac{11}{16}$"	$25\frac{11}{16}$"
WIDTH	B	$10\frac{11}{16}$"	$10\frac{11}{16}$"	$13\frac{11}{16}$"	$10\frac{11}{16}$"	$13\frac{11}{16}$"

Fig. 48.—Steel Covers for Jointing Pits.



Looking at Pit in direction of arrows, pipes enter on the right when exchange entry is on the left and vice versa.

Fig. 49.—Position of suitable Pipe Entrances to Jointing Pits in relation to Exchange.



LEAD PATTERN. MANUFACTURED FROM 7lb. LEAD.(0·018" THICK.)

USED WITH	A	B
$\frac{3}{8}$" PIPE	$\frac{11}{32}$"	$\frac{45}{64}$"
$\frac{1}{2}$" "	$\frac{15}{32}$"	$\frac{55}{64}$"
$\frac{3}{4}$" "	$\frac{23}{32}$"	$1\frac{5}{64}$"
1" "	$\frac{31}{32}$"	$1\frac{23}{64}$"
$1\frac{1}{4}$" "	$1\frac{7}{32}$"	$1\frac{45}{64}$"
$1\frac{1}{2}$" "	$1\frac{15}{32}$"	$1\frac{59}{64}$"
2" "	$1\frac{31}{32}$"	$2\frac{25}{64}$"

Fig. 50.—Ferrules for use with Iron Pipes in Jointing Pits.

Before setting the pit, it is necessary to make holes in the side of the pit for pipe entries. The location of these should be marked by measurement on the outside of the pit, and the holes made by means of an old auger or brace and old bit; the hole can be finished off with a rasp so that the pipe is a neat fit. When the pit is in position, the iron pipes should project 1 in. inside the pit, and any roughness at the edge of the hole patched with mortar, so as to provide a neat, finished appearance. To protect the cable against damage during the pulling-in process, and subsequently, metal ferrules (usually lead) are fitted over the ends of the pipe. The ferrules are illustrated in Fig. 50, and the method of fitting is shown in Fig. 51. It is important that the ferrules fit firmly on the pipe, the end of the pipe being expanded slightly with a drift pin to ensure this. They should also be pushed on the pipe to the fullest extent.

The larger sizes of jointing pit are most frequently used in conjunction with 4 in. earthenware or concrete pipes, pit No. 6 being of sufficient width for use on a 2-way run. For terminating single 4 in. pipes in jointing pits, the use of pipe bushes, illustrated in Fig. 52, permits a gradual entry of the cable into the pit and enables the cable to be manipulated more

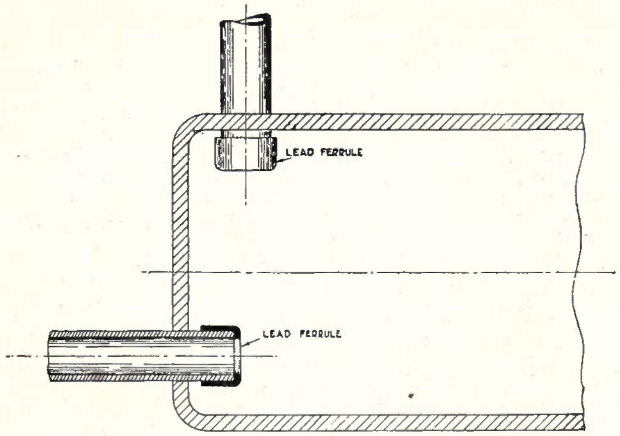


Fig. 51.—Method of use of Ferrules.

easily for jointing purposes. These bushes are made of asbestos cement, similar to the jointing pits. The method of use is shown in Fig. 53. Failing the use of these bushes, or where two pipes are to be brought into the pit, a concrete "bell-mouth" should be fitted, so as to provide ample room for installing and bending the cable into position. This is illustrated in Fig. 54, which also shows an arrangement that has been used where two ducts are used to accommodate an important (e.g., trunk) and a minor (e.g., subscribers') cable. The duct for the minor cable is set at a lower level, so that the important cable duct is, as far as possible, kept dry. Fig. 55 shows a No. 6 pit installed, the concrete surround being used in this case to reduce risk of damage by cattle.

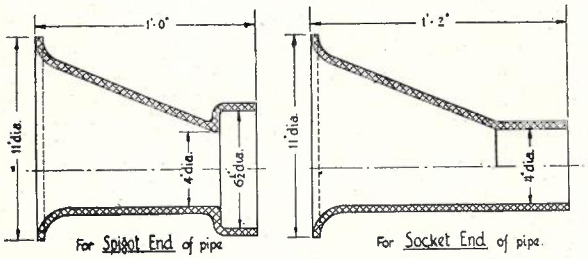


Fig. 52.—4" Pipe Bushes for use with 4" E.W. and Concrete Pipes.

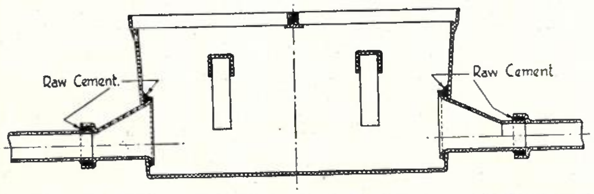


Fig. 53.—Method of using 4" Pipe Bushes in Jointing Pits.

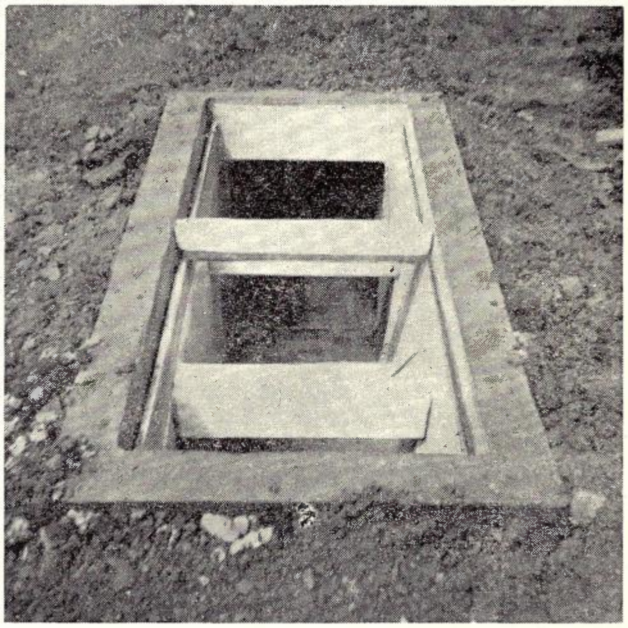


Fig. 55.—No. 6 Pit installed (covers removed).

When the pipes have been fitted into the pit and the pit firmly bedded down so that the lip is flush with the surrounding ground, the earth and sand should be rammed down so that the pit is firmly held, and the surface re-instated.

It will be noted from Figs. 46 and 47 that two or four 1-in. diameter holes are provided in the bottom of each pit. These are drainage holes to permit water, which may otherwise collect in the pit, to soak away into the soil. If, however, the soil is likely to become waterlogged for extended periods, water will tend to flow back into the pit through the holes, in which case it is advisable to seal the holes with concrete. In exceptional circumstances the provision of a pipe to drain the pit to a gutter or underground drain may be justified.

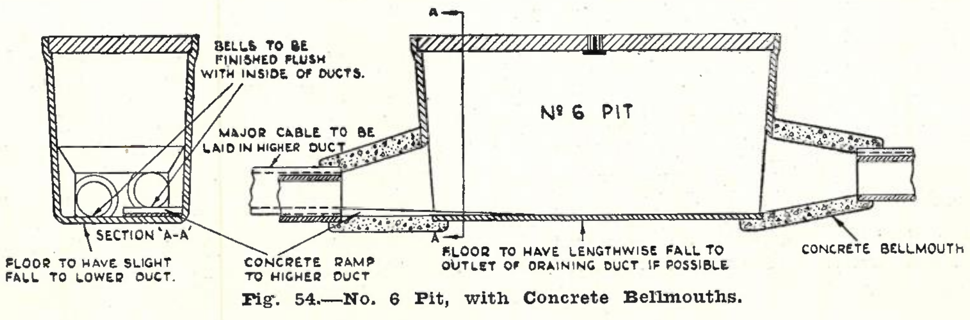


Fig. 54.—No. 6 Pit, with Concrete Bellmouths.

APPLICATION OF QUICK-RUPTURING FUSES IN POWER DISTRIBUTING CIRCUITS

K. W. Macdonald, B.Sc.

In power distribution for large automatic telephone exchanges it is customary to provide on each floor an overload circuit breaker, whose function is to react to any accidental short circuit or overload placed upon the main busbars, and so protect the equipment from damage, and the staff from the danger likely to be incurred thereby.

Standard practice is then to distribute the load over sub-sections, each sub-section being fed through its own individual fuse. The purpose of the sub-section fuse is, of course, to limit any fault within its own suite, and it is therefore essential that the fuse should have characteristics which ensure that it will operate in advance of the main circuit breaker, thus avoiding a major dislocation being caused by an accidental earth applied within one sub-section only. To provide a margin between the fuse and circuit breaker operate times, accepted power practice provides that the circuit breaker is given a definite timing lag, but this heightens the risk of severe damage occurring due to an overload or accidental short circuit on the main busbars.

The sub-section fuse used is generally of the cartridge type. In a typical fuse of this type, the actual fuse comprises a flat zinc element, joined by short lengths of copper wire which are sweated into each end of the brass caps of the cartridge mounting. The red fibre cartridge is packed with asbestos fibre and chalk dust, which act as the quenching medium. Various ratings are available to provide for varying equipment conditions, but the more commonly used sizes cater for normal section currents of 150 amps or 75 amps.

It appears that such fuses possess inherent disadvantages which are due to the materials used. In order to obtain a low resistance fuse using copper and/or zinc, the dimensions of the fusing element need to be comparatively large. Consequently, the time of operation of the fuse is increased. Furthermore, although the overload circuit may be broken by the fuse, there is a great tendency for an arc to occur, and this arc is readily maintained between the copper or zinc elements.

On two occasions at the Melbourne Trunk Exchange, accidental earths applied to the suite busbars failed to operate the sub-section fuses before the main circuit breaker tripper.

Tests made with the standard type of fuse then confirmed that such a fuse rated at 150 amps would hold while the circuit breaker, set at 1000 amps or even at 2000 amps, was operated.

Since the circuit breaker carries the normal load of 500 amps as well as the overload current, this would indicate that an overload current of 500 amps in a sub-section would operate the main circuit breaker before the sub-section fuse could isolate the faulty section. Since the provision of a timing lag on the circuit breaker is not favoured, from considerations of staff safety, quicker operation of the sub-section fuses was sought.

Further tests were then made, using special quick-rupturing fuses which had become available. With these fuses it was found that the circuit breaker setting could be reduced to 1000 amps (twice normal peak load), and 100/160-amp fuses would consistently rupture before the circuit breaker could operate. Accordingly, fuses of this type were installed throughout the exchange. Since then, one case of an accidental earth on a sub-section busbar has occurred, and the sub-section fuse carried out its function and prevented the circuit breaker from operating.

Some details of the quick-rupturing type of fuse may be of interest. The assembly is in a cartridge type mounting of conventional design, but the dimensions are much smaller than the normal copper type. The actual fuse comprises pure silver wire fabricated elements built into a heavy steatite cylinder with plated copper end caps and tags. Under short circuit conditions, the current volatilizes the metal in the central chamber, which is packed with fine quartz powder. The intense heat and turbulence of the resulting arc cause a thermo-chemical reaction to take place between the volatilized metal and the quartz filling. The resultant material forms a solid non-conducting core having a break-down value of about 5000 volts per inch.

The use of pure silver and the fabricated element construction ensure correct operation of the fuse after it has carried its correct nominal current for an indefinitely long period. Troubles experienced with copper wire fuses, chiefly due to fatigue or oxidisation, are avoided.

The fuses have an extremely high speed of rupture, and it is claimed that the largest ratings will interrupt a full capacity short circuit in less than 10 milliseconds. The current rating of the fuses is expressed as a range, e.g., 100/160 amps, and the speed of operation is satisfactory at the lower end of the range, though naturally increased at the higher current value.

ANSWERS TO EXAMINATION PAPERS

The answers to examination papers are not claimed to be thoroughly exhaustive and complete. They are, however, accurate so far as they go and as such might be given by any student capable of securing high marks.

EXAMINATION No. 2586.—SENIOR TECHNICIAN, TELEPHONE—SECTION (b) TELEPHONY

C. Cruttenden

Q. 1.—(a) If requested by a subscriber to erect a telephone on a glazed tile wall, how would you proceed?

(b) If the lead-in wires of an exposed line are left unconnected pending the installation of apparatus, state briefly what precautions should be taken regarding them.

(c) In installing a P.B.X. in a subscriber's premises which method of cabling would you prefer:—

(i) Overhead.

(ii) Under the floor or under the floor coverings.

assuming that either was suitable and practicable.

(d) How would you test the insulation resistance of a newly-installed P.B.X. of the C.B. cord type? What precautions are necessary regarding the 10 u.f. condenser?

(e) What factors should be considered in determining the location of a distributing frame in a large building?

(f) A subscriber having an automatic handset telephone receives a loud click in his receiver when the switch-hook is pressed or released. Assuming that the trouble is in the telephone, what is the likely cause of the fault, and how is it remedied?

(g) Why are a 2 u.f. condenser and a non-inductive resistance of 100 ohms connected in series across a dial associated with a switchboard?

(h) In cabling an exchange what precautions would you take regarding the runway when a "block" of cables is passed through to a lower level?

A.—(a) The subscriber's attention should be drawn to the liability of damage being done to the wall and, before the work is commenced, the subscriber should be requested to sign the form relieving the Department of the responsibility for any damage, other than that due to carelessness, which may be caused. Locate the positions of the holes with extreme care. Use a "twist" drill and a holder for use with standard screw anchors and apply the hammer lightly until the drill has passed through the tile.

(b) Connect both leads to earth.

(c) Under the floor.

(d) (i) Operate all plug seat switches, if any; remove the common earth from contacts of supervisory and also AX relays (if AX relays are fitted).
Connect a 500 volt megger to the direct current power lead terminals.

(ii) Disconnect the 10 u.f. condenser prior to connecting the megger to the power lead terminals.

(e) (i) Reasonable proximity to the distribution centre of the area which it is to supply, and also to an available cable run.

(ii) Availability of reasonable natural or artificial light.

(iii) Freedom from dampness or excessive dust.

(iv) Selection of a permanent wall.

(v) Accessibility. Except when associated with a P.B.X. as a main distributing point, the box should be in the public portion of the building.

(vi) Wherever possible, the height of the uppermost terminal of the box should be within the reach of a technician of average height standing on the floor.

(vii) The distance between the distribution box and a power or lighting switchboard should preferably exceed 6 feet.

(f) (i) The fault is due to the switch-hook springs being out of adjustment, so that the receiver circuit opens later or closes earlier than the transmitter circuit.

(ii) Re-adjust the switch-hook springs and ensure the tip of No. 4 outer tension spring has approximately 20 mils additional set inward.

(g) To dissipate the inductive energy developed in the line during dialling by the line relay in the exchange.

(h) Cover the runway slat over which the cables turn with wood or leather.

Q. 2.—(a) How would you busy a selector associated with an incoming junction if it were necessary to adjust the switch on the shelf?

(b) How is a trunk associated with an auto-auto relay set (repeater) in a 2000 type exchange busied when the relay set is removed from the shelf?

(c) List the tests you would make from a standard test desk to a new automatic subscriber's service.

(d) What is the standard dial speed and impulse ratio?

(e) A final selector is being replaced in service in an automatic exchange. State what tests you would apply to ensure that—

(i) the wiper spring tension;

(ii) position of the wipers on the bank contacts;

(iii) cut in,

are correct.

(f) List the alarms in an automatic exchange which require—

(i) urgent attention;

(ii) non-urgent attention.

(g) What cord test facilities are provided on a standard magneto floor-pattern switchboard at a subscriber's premises?

A.—(a) Arrange for the junction to be busied at the outgoing end.

(b) When the relay set is removed from the shelf, the shelf jack springs 9 and 11 make contact and thus automatically busy the associated trunk.

(c) (i) Line loop resistance to instrument terminals.

(ii) Loop resistance, including instrument, or hold coil.

(iii) Condenser kick.

(iv) Insulation resistance between wires and between each wire and earth.

(v) Transmission, with the 25 db. and 40 db. artificial lines in circuit.

(vi) Protector earth.
(vii) Bells.
(viii) Dial speed, ratio and impulse count.
(ix) Exchange equipment.

(d) The standard dial speed is 10 impulses per second and the standard impulse ratio break to make is 2 to 1.

(e) **Final Selector, 2000 type—**
(i) Check that the wiper tip gap is between 12 and 20 mils when the wipers are off the bank.
(ii) Check that the wipers rest ⅓ to ½ way on contact 6 of the first and tenth levels.
(iii) Check that each wiper spring is clear of the separating insulator when the wiper tips are resting on any bank contact on any level.

Final Selector, pre-2000 type—
(i) Check that when either spring of a pair is deflected the other will follow approximately ⅛″ in the case of line wipers and 1/16″ in the case of private wipers. (Alternatively, check by tension gauge applied at angular tip of each wiper spring that line wipers have between 30-40 grammes tension and private wipers between 25-35 grammes).
(ii) Check that the wipers rest approximately centrally on the first and last contact of the first and tenth levels.
(iii) Check that the wipers enter the bank levels without having appreciable rise or fall.

(f) (i) Fuse, Release, Ring Fail, Voltage, Charge, Line Finder Supervisory.
(ii) Permanent loop (P.G.), called subscriber held (C.S.H.), N.U. tone supervisory, N.U. tone overload, Ringer (if automatic change-over provided).

(g) Test jack with 6 volt battery and 30 ohm non-inductive resistance connected across tip and ring.

Q. 3.—(a) Why is a copper slug placed on the armature end of a line relay associated with a Keith type uniselector?

(b) In a primary finder circuit provision is made for relay "H.B." to operate before relay "H.A." when testing corresponding bank contacts on M.1 and M.2 banks, which are marked simultaneously. State briefly how this is arranged.

(c) What is the maximum number of springs provided on a—
(i) 3000 type relay;
(ii) 600 type relay?
What would be the effect of removing the residual screw from an impulsing relay associated with an auto-auto relay set (repeater)?

(d) A 3000 type relay is required to have very fast operation. What are the necessary requirements—
(i) in the relay design;
(ii) In the circuit?

(e) Show by means of a rough sketch how a 3000 type relay should be associated with a copper oxide rectifier when connected across a 230 volt A.C. supply in a "no voltage" alarm circuit.

(f) For what purpose is an interception circuit used, and how is it associated with other circuits?

(g) (i) What provision is made in an automatic exchange for giving temporary service on faulty subscribers' lines?
(ii) On what class of faults can the temporary service be given?

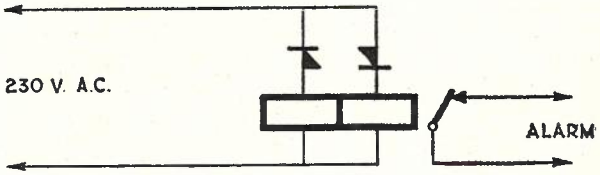
A.—(a) To delay the operation of the relay until it is fully saturated and thus obtain sufficient release-lag to prevent chattering of the line-switch.

(b) The circuits of relays HA and HB include copper oxide rectifiers in series, but two rectifiers are connected in parallel in the HB relay circuit in order to reduce the series resistance and increase the operating current. The increased current results in relay HB operating before relay HA.

(c) (i) 18.
(ii) 12.
(iii) The release-lag of the relay would be affected and, consequently, impulses from the repeater would be distorted.

(d) (i) The relay should have low inductance so that the operating current will rise rapidly, and the relay core should be of nickel iron to reduce eddy currents and their effects. The springset load should be limited to one contact unit, if possible.
(ii) The circuit external to the relay should not include inductance or capacitance. The operating current should be limited by a relatively high series non-inductive resistance, and not by relay winding resistance.

(e)



Q. 3, Fig. 1.

(f) (i) To intercept incoming calls to a subscriber's line.
(ii) The interception circuit is generally associated with a subscriber's line circuit at the M.D.F.

(g) (i) A "Special Service to Faulty Lines" (also known as "Hospital") circuit is used.
(ii) Temporary service can be given on looped lines or lines which are earthed or open on one leg.

Q. 4.—(a) In a local call the group selectors restore when the called party answers. Name the most likely point in the circuit for the fault.

(b) The wiper assembly of a 2000 type selector associated with an incoming junction, after release from the bank level, fails to return to normal from the horizontal position. List the possible causes of the fault.

(c) What effect will the failure of a 2000 type switch to restore from the horizontal position have on the junction with which it is associated?

(d) What would be likely to happen to a group selector, in an automatic exchange, if the speed of impulses from a dial from which it was receiving impulses were below standard?

(e) How would you locate an earth fault on a selector bank multiple in an automatic exchange?

(f) What method of bank marking is used for the finding action on the following:—
(i) Primary allotter;
(ii) Primary line finder during vertical search, in an automatic exchange (2000 type)?

(g) When providing restricted access facilities on a P.A.B.X. what alterations are necessary to—
- **(i) uniselector;**
- **(ii) line finder bank,**

for the extension line prohibited exchange access?

(h) What is a "tie line"?

A.—(a) Final selector line reversing relay contacts open circuit, or an open circuit on the "P" wire during the metering period.

(b) Selector shaft dry from lack of oil or weak tension of restore spring.

(c) If an incoming selector fails to restore completely from the horizontal position, the junction with which it is associated will be inoperative, but may be seized at the outgoing end because an off-normal switch does not cause a junction to test busy.

(d) The design of the group selector includes a factor of safety against impulses differing from the standard of 10 per second, but if the received impulses are too slow for the switch to function correctly, failure occurs through premature release of relays B or C. Premature release of relay B causes the call to drop out, whilst the release of relay C may cause the switch to cut in on a wrong level.

(e) By the "drop of potential" method of testing. A low potential is applied to the faulty wire, and the drop checked from bank to bank with a head receiver.

(f) (i) and (ii) battery via a 150 ohm resistance.

(g) (i) On the uniselector type of P.A.B.X., connect a 500 ohm resistance across the winding of the B.C.O. relay in the line circuit.
- (ii) On the line finder type of P.A.B.X., connect battery, via a 500 ohm resistance, to the appropriate bank contact. Alternatively, on a later type of P.A.B.X. line finder circuit, connect direct earth to the bank contact.

(h) A line between two P.B.X.'s or P.A.B.X.'s.

Q. 5.—(a) A row of 10 selectors is observed at regular intervals for an hour. The number of selectors engaged at successive periods is as follows—

5.5.5.4.0.4.5.5.4.5.9.9.5.8.4.5.2.0,8,8.

Find the traffic units carried by the selectors in that hour.

(b) State when the following methods of trunk distribution are used:—
- **(i) Interconnecting;**
- **(ii) Grading.**

(c) Explain the difference between "demand" and "delayed" trunk line working.

(d) Explain briefly why voice frequency signalling is necessary in modern trunk line operating procedure.

(e) What is meant by the following terms appearing on relay adjustment charts?
- **(i) Saturate current;**
- **(ii) Hold current.**

(f) List the routine tests applied to a straight line final selector, using "Routine Test Set No. 1."

(g) State briefly the reason for connecting a non-inductive resistance in series with a spark quench condenser associated with a bi-motional switch.

(h) What is meant by the term "self-protecting" as applied to electro-magnets associated with bi-motional switches and uniselectors?

A.—(a) The number of observations = 20. The number of engaged circuits observed = 100. The average number of simultaneous connections during the hour $= \frac{100}{20} = 5 = 5$ T.U.

(b) (i) When trunking from non-homing type switches.
- (ii) When trunking from homing type switches.

(c) When trunk calls are completed either immediately or with only a short delay by the telephonist who initiates and completes the call docket the term "demand" trunk working applies. When trunk calls are booked only by a telephonist and the call completed later, perhaps by another telephonist, by reverting the call to the subscriber, the term "delay" trunk working applies.

(d) Voice frequency signalling is necessary because it is independent of the type of transmission circuit provided and, theoretically at least, signalling is possible over any circuit which is suitable for speech purposes.

(e) (i) The minimum current that is to be applied before operate current tests, etc., are made.
- (ii) The minimum current which will retain the relay armature in its operated position when the current is reduced in one step to this value from the saturate value.

(f) (i) Operation of relays A and B and holding earth on the release trunk.
- (ii) Impulsing long line and busy test.
- (iii) Release.
- (iv) Impulsing short line and ringing.
- (v) Ring trip, battery reversal, metering and wiper cord reversal.
- (vi) Transmission.
- (vii) Last party release.

(g) The non-inductive resistance slows down the rate of discharge from the spark quench condenser and thus prevents heavy discharge currents causing damage to contacts controlling the operation of the switch magnets.

(h) An electro-magnet is said to be self-protecting when a continuously applied current of normal value will not cause damage through overheating.

EXAMINATION No. 2473.—ENGINEER—TELEPHONE EQUIPMENT

K. B. Smith, B.Sc.

Q. 8.—Plate II. is the schematic diagram of a switch. Say what switch it is and explain the precise function of each of the following relays included in the diagram E, F, H, J and WS. What modifications would require to be made to the circuit if the rectifier MRA were removed?

A.—Plate II. is the circuit of a 2000 type 200 line regular final selector.

Functions of the E relay:
- (i) Changes over the impulsing circuit from the vertical to the rotary magnet after the completion of the vertical train of impulses.
- (ii) Connects metering battery to the private after the called sub. answers.

Functions of the F relay:

The F relay operates when the called subscriber lifts the receiver.
- (i) It disconnects ringing current from the called subscriber's line.
- (ii) It disconnects ringing tone from the calling subscriber's line.

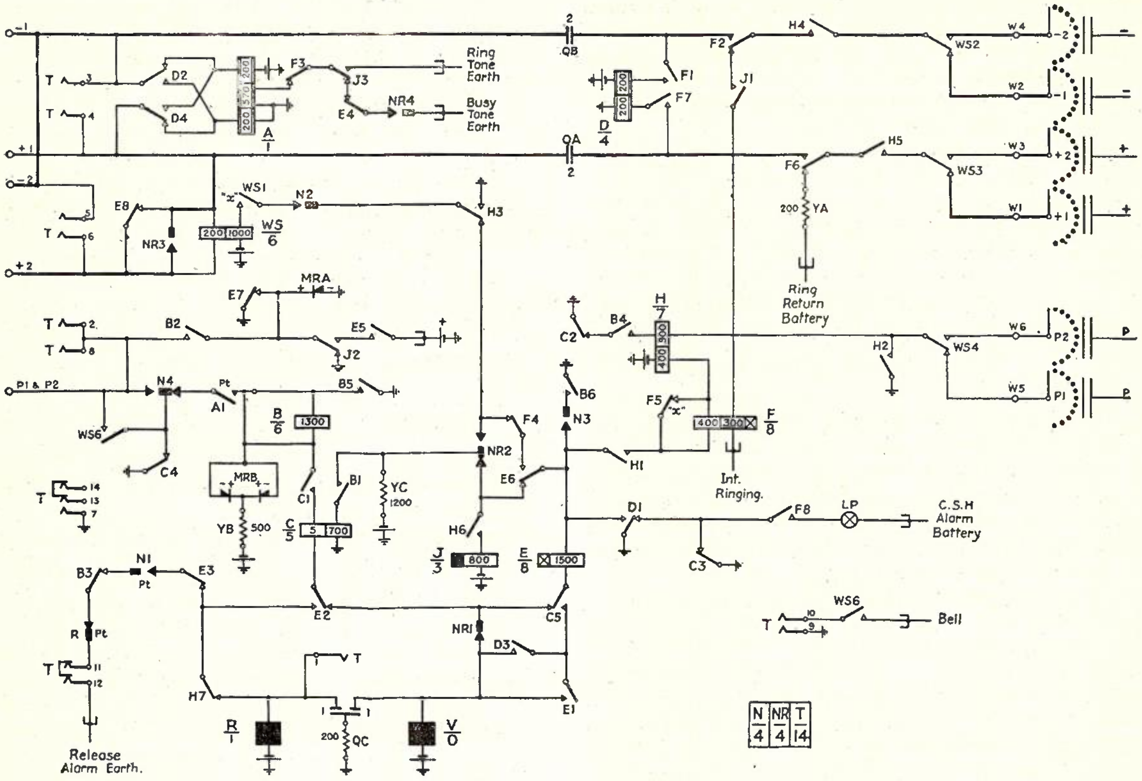


PLATE II.

Q. 8, Fig. 1.

(iii) It feeds battery via the D relay to the called subscriber.

Functions of the H relay:

The H relay is the testing relay.

(i) The H relay operates if the called subscriber is disengaged, but does not operate if the called subscriber is engaged.

(ii) It guards the line against intrusion by another final selector.

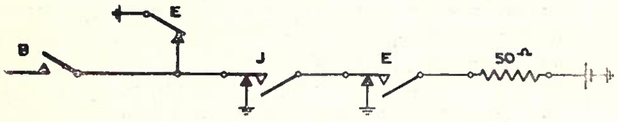
(iii) Initiates the condition for the transmission of ringing current to the called subscriber.

Function of the J relay:

The J relay is operated when the H relay operates.

(i) It connects ringing current to the called subscriber's line.

(ii) It prepares the metering circuit. The meter pulse is applied to the private during the time J releases when its hold circuit is opened by E.



Q. 8, Fig. 2.

Functions of the WS relay:

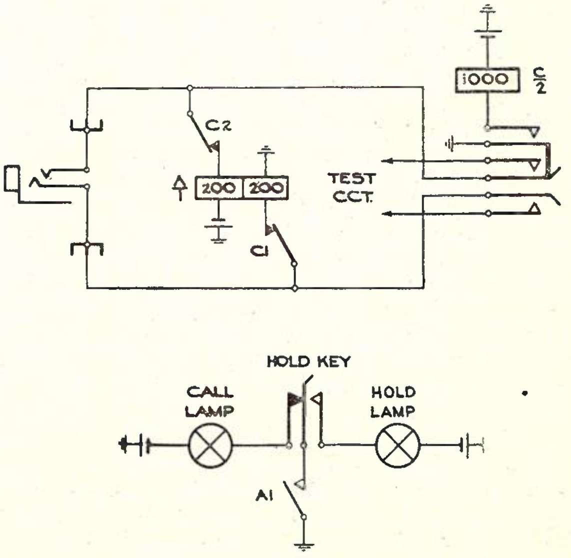
This is the wiper switching relay.

(i) The WS relay changes the wipers from the first to the second set of bank contacts.

(ii) The WS is controlled by the penultimate selectors and only operates if the call is originated from an even level on the banks of these selectors.

The rectifier MRA maintains a holding earth on the private during the operation of the relay E and the release of relay J. The rectifier does not short circuit the positive battery metering pulse. The replacement of the E and J contacts in the metering circuit by make-before-break contacts, and the addition of a 50-ohms resistance in series with the metering battery would be necessary if MRA was removed. The required circuit is shown in Figure 2.

Q. 9.—(a) At a continuously attended automatic exchange, how are faulty subscribers' circuits kept under supervision when it is so desired? Give a sketch of the circuit arrangements.



Q. 9, Fig. 1.

(b) Describe a method of measuring the conductor resistance of a subscriber's loop, using the apparatus provided for the purpose at an automatic exchange test desk. Indicate by a schematic sketch the essential circuit elements of the equipment used on the test desk itself when such a test is made.

A.—(a) Faulty subscribers' circuits are kept under supervision by means of the circuit shown in Figure 1. The circuits are wired to jacks on the line side of the M.D.F. The subscriber's line under supervision is connected to the plugging-up circuit by means of a cord and clips. When the subscriber's line is looped, relay A operates and lights the call lamp. The test desk operator associates the subscriber's line with the test circuit by operating the answer key, which also disconnects the A relay from the line.

(b) See answer to Question 1 (b), Examination No. 2425, Volume 4, No. 4, Page 250, and Volume 4, No. 5, Page 316.

POSTAL ELECTRICAL SOCIETY OF VICTORIA

Items of Interest Extracted from the Annual Report for 1945

The Committee once again decided that it was advisable to suspend the pre-war lecture programme for this year. However, two special meetings were arranged. The first was held on the 9th July in Kelvin Hall, when Mr. T. Skillman, M.A., M.I.E.E., gave a very interesting lecture on "Current and Future Developments in Long Distance Telephony" before a well-attended meeting. By courtesy of the Superintending Engineer, Melbourne, and members of his Staff, inspections of City West Trunk Exchange were made on 21st and 29th August. It is desired to thank those officers who arranged these inspections and conducted the various parties through the Exchange. On 29th October a lecture and demonstration was arranged by courtesy of the Department of Labour and National Service on "Colour and Lighting in Industry," and was presented by Messrs. Ashmore and Alexander of that Department in the Lecture Theatre of the State Electricity Commission.

During the year, overseas interest in the "Telecommunication Journal" has grown and the following are among the new subscribers:—

Postmaster-General, Burma Posts & Telegraphs, Rangoon.

Chief Engineer, Iraq Posts & Telegraphs, Bagdad.

Postmaster-General, Palestine Posts & Telegraphs, Jerusalem.

United States Naval Research Laboratories.

The number of members and subscribers as at December, 1944 and 1945, is:—

	1944	1945
Members	1,052	1,085
Subscribers	1,544	1,369
	2,596	2,454

The Annual General Meeting was held in the Radio Theatre, Melbourne Technical College, on 10th December, 1945, when a most interesting address was given by Mr. D. McVey, A.M.I.E.(Aust.), Director-General, on "Commonwealth and Empire External Telecommunications."

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[*No. 1, June, 1944, pp. 1-64. No. 3, Feb., 1945, pp. 125-188. No. 5, Oct., 1945, pp. 253-316.*
No. 2, Oct., 1944, pp. 65-124. No. 4, June, 1945, pp. 189-252. No. 6, Feb., 1946, pp. 317-380.]

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