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Telecommunication Journal of Australia

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EXPANSION OF LONG-DISTANCE V.F. DIALLING IN AUSTRALIA — PART 1

F. P. O'Grady

In line with the world trend towards the ideal of having only one operator involved in a long distance trunk call, considerable progress has been made in this respect in Australia during recent months.

Long distance dialling had already been expanded considerably in Australia prior to 1944, particularly in Victoria, South Australia and, to a lesser extent, in New South Wales. Fig. 1 shows the layout of some long circuits. In some cases, the long distance dialling equipment enabled the country town to dial direct into the capital city. In the reverse direction, ring-down manual working was generally in use, as very few of the country towns were equipped for automatic working. With a few exceptions, the trunk groups in Australia are comparatively

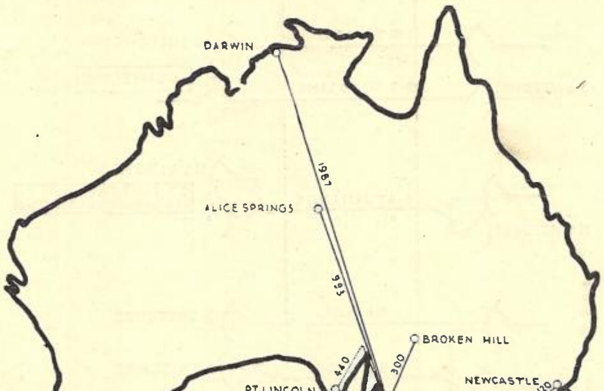


Fig. 1.—Map of Australia showing long dialling routes.

small, and, in order to retain the best possible efficiency, it is desirable to use the trunk circuits on a both-way basis. For example, where only ten circuits exist between a capital city and a country town, it is generally uneconomical to divide these into two groups of five for one-way working only, a much better arrangement being to use them as a group of ten both-way circuits if switchboard and equipment facilities permit this to be done. Figs. 2, 3, 4 and 5 illustrate this point.

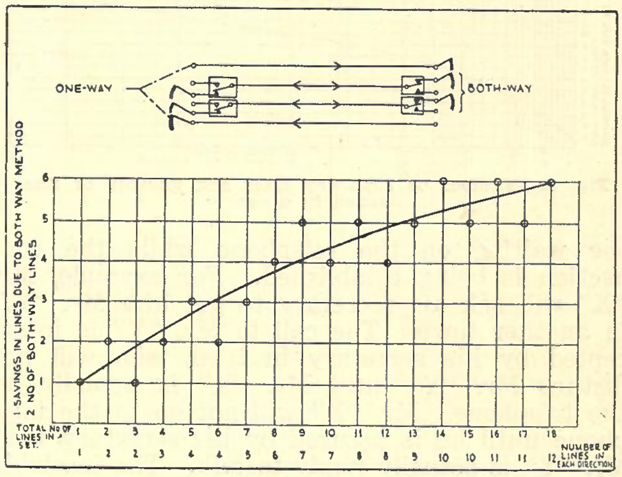


Fig. 2.—Number of both-way lines saved in a set of lines.

Beneficial effect of V.F. Dialling on Trunk Operating: The introduction of long distance dialling between country centres and capital cities has proved to be of considerable benefit to the operating staff in speeding up the handling of dockets and preventing delays due to phonetic errors and similar difficulties which inevitably occur when telephonists have to repeat details of dockets by telephone to other telephonists. One of the principal advantages of automatic working is the practically instantaneous release of the trunk circuit as soon as the originating operator releases the circuit. This is in marked contrast to conditions when manual ring-down working is employed.

Some Features of Long Distance Traffic: One of the principal causes of delay in establishing a trunk connection between two particular persons is the difficulty found in obtaining the wanted person at the telephone exactly when the call matures. Persons frequently book trunk line calls asking for a particular party at the distant end, and if the call can be completed on demand or within a reasonably short period, the calling party usually is available at once for the trunk connection. When delay working is in use, however, and the period of delay becomes excessive, it is quite common for the calling party to leave the vicinity of his telephone for other duties, with the result that difficulty is experienced in getting him to the telephone when the connection finally becomes available. Difficulty is similarly experienced in getting the called party to the telephone at times. This is particularly the case where the individual required is a very busy man whose duties require him to be at any one of a number of points throughout a large factory, for example. A further complication, in this connection, is the habit formed by certain executives who insist on their secretary doing all

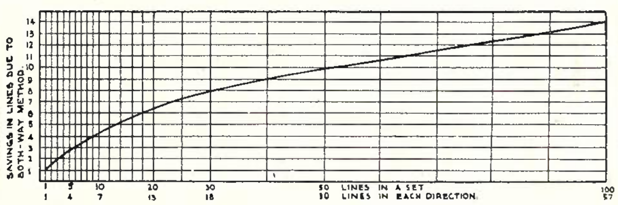


Fig. 3.—Number of both-way lines and number of lines saved in a set.

the waiting on the telephone while the connection is being established. For example, Mr. "X" will ask his secretary to get him Mr. "Y," in another town. The call to Mr. "Y" is intercepted by his secretary in turn, who will not disturb Mr. "Y" until Mr. "X" is actually on the telephone. Mr. "X" will not go to the telephone until he is assured by his secretary that Mr. "Y" is actually ready to talk. The insoluble problem thus presented is the cause of a great deal of distress to telephonists, and accounts for a lot of wasted line time on trunk calls. As it is obvious that one or the other party must be prepared to do a certain amount of waiting, it would appear to be a simple case of courtesy for the person who originates the call to do the waiting, rather than the person who is being called. It is thoughtlessness on the part of these executives which undoubtedly gives rise to this difficulty, and it could possibly be removed if the public were aware of the difficulties which it causes to trunk line telephonists. On interstate calls between capital cities, where the tariff for the call is generally higher than for trunk calls within the State, the proportion of "personal calls" or "particular person" or "party to party" calls—as they are variously described—is much higher than with trunk calls over moderate distances. Obviously, a subscriber is not willing to pay the interstate trunk line tariff for a call to a particular number only and run the risk of finding his particular party not available. The above and similar difficulties in handling "person to person" calls were believed, by the traffic staff, to be so formidable that direct dialling over interstate lines could never compete with manual ring-down methods of operation. For this reason, the introduction of long distance dialling on the inter-capital circuits was delayed for several years, until experience had been obtained on the circuits over more moderate distances. In an attempt to expedite handling of traffic on interstate circuits, a teleprinter order wire system was tried between Melbourne and Sydney and between Melbourne and Adelaide. The procedure, using this system, was as follows:—

(a) The subscriber booking the interstate call was answered by the appropriate recording operator.

(b) The docket was passed to the teleprinter operator, who forwarded particulars of the docket to the teleprinter operator at the distant end.

(c) The teleprinter operator at the distant end passed the dockets to a special telephonist, who called the wanted number and advised that a trunk line call from "X" would be maturing shortly. "Would Mr. 'Y' be available in so many minutes?"

(d) The advice that Mr. "Y" would be available at such and such a time was then passed back to the originating end by the teleprinter.

(e) The docket was passed to the line operator who was working a group of circuits to the distant end on a delay basis.

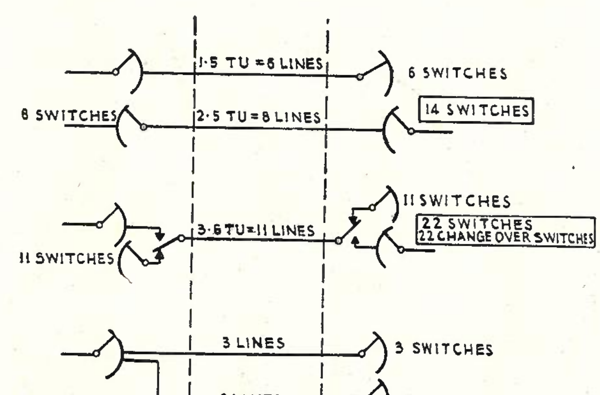


Fig. 4.—Saving with both-way lines.

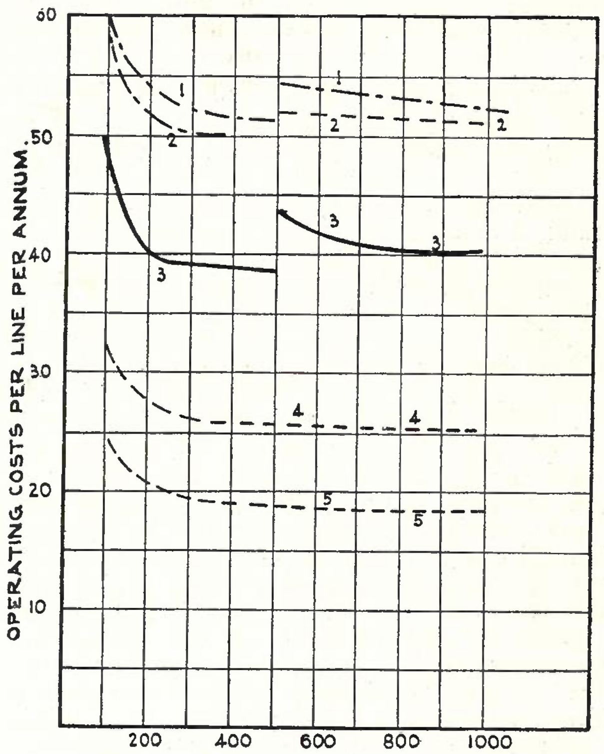
(f) The telephonist usually arranged that while one pair of subscribers was conversing, she had one of the next pair of subscribers waiting at the telephone for the first conversation to finish, and was making preliminary arrangements for the third pair of subscribers.

If all trunk conversations were of equal length, this system would work fairly well; but if the first pair of subscribers decide to extend their call to unusual length, it is obvious that the next pair of subscribers destined to use that same line will be kept waiting for inordinate periods. This in turn undoubtedly increases the tendency of busy executives to delegate the waiting to their secretaries, with the inevitable result that confusion occurs in attempting to establish the second call when the first one finally ends.

First V.F. Dialling Circuits on Interstate Routes: On the assumption that advance warning by teleprinter would ensure the wanted party being within reasonable distance of the telephone, a decision was made in 1945 to try direct dialling from Melbourne to Adelaide and Adelaide to Melbourne on the interstate route between Victoria and South Australia. Siemens' 2 V.F. equipment was installed for the purpose; but, when the trials were first conducted, there were only seven circuits in use. It was decided to equip two circuits for dialling one way from Melbourne into Adelaide, two circuits for dialling one way from Adelaide into Melbourne, and three circuits were left on a manual both-way basis. It was not possible with the equipment available to utilize the circuits on a both-way dialling basis, and there were certain difficulties associated with the existing trunk line switchboards which made it desirable to operate the circuits on a one-way basis in spite of the advantage of both-way working from a traffic efficiency point of view. The system of operating adopted was as follows:—

(a) A subscriber booking the trunk line call is answered by a recording operator.
(b) The docket is passed to the teleprinter operator.
(c) The teleprinter operator furnishes details to the distant city.
(d) The teleprinter operator at that city calls the subscriber and asks whether Mr. "Y" will be available at such and such a time, approximately.
(e) Suitable advice is forwarded back by teleprinter to the originating end.
(f) The docket is endorsed with the necessary particulars, such as W.T. 10 a.m., indicating that the particular person required "will talk" at that time.
(g) The docket is passed to the line operator, who assembles it with other dockets in order of priority, etc.
(h) The line operator dials the distant number required when she is ready, and then establishes the necessary connection back to the calling party.

Advantages of V.F. Dialling on Interstate Circuits: It was found almost at once that the advantages of direct dialling were very considerable. The practically instantaneous release of the circuit considerably reduced lost line time, and phonetic errors were practically eliminated. The originating telephonists soon discovered many short-cut methods they could take when handling particular problems, as, for example, the Melbourne telephonist would dial into Adelaide and be answered by a P.B.X. attendant at a factory. Melbourne would say, "Is Mr. Jones available?" and P.B.X. might reply, "I think Mr. Jones is in the factory somewhere. I will try and find him for you." Melbourne would reply, "It is Melbourne calling. Please tell Mr. Jones I will call him again in a few minutes." Melbourne would then release the



1. Manual service with 15 years' life and night traffic, 1920.
2. Manual service with 20 years' life, night traffic, 1920.
3. Manual service with 20 years' life without night traffic, 1920.
4. Automatic service with 20 years' life and night traffic, 1920.
5. Automatic service with 20 years' life and night traffic, 1935.

Fig. 5.—Operating Cost for 100-1000 lines, excluding the line network. (Typical German costs in R.M.)

circuit and go on with one or two other dockets. She would then call the number again and almost invariably find that Mr. Jones was ready to talk. The fact that the originating telephonist could talk right through to the factory attendant and was not dependent on advice being relayed back to her second- or third-hand made a tremendous difference to the smooth working of the system. As a result of these and many similar advantages arising from the direct dialling system, the amount of traffic handled per circuit on the interstate groups increased considerably over that handled by manual methods. Because of the fears that had been entertained regarding difficulties with particular persons, etc., on interstate routes, the proponents of the direct dialling system were somewhat cautious in their expectations, and would have been quite content if the direct dialling method had furnished the same traffic handling capacity per circuit as the manual method, since it would at least have eliminated the incoming operator and the attendant annual expenses.

Effect on Switchboard Provision: This was a particularly important point, because of the congestion on operating positions and difficulties in obtaining relief by the provision of new positions.

Results of Trial of V.F. Dialling, as Regards Traffic Handling: The opponents of the direct dialling method were pessimistic about the results likely to be obtained, as they felt that additional lost time on the valuable interstate circuits would be inevitable due to "particular person" difficulties. Those who had had extensive experience with the advantages of dialling on the trunk networks (within a State) were reasonably certain that the dialling method would ultimately prove to be better than the manual method. During the first few days' operation of the system, extensive checks were made on the respective merits of dialling and manual methods. In assessing the amount of traffic carried by an interstate line, various methods are employed to obtain the required information, depending on the angle from which the problem is approached. From the accountancy point of view, the amount of paid time per hour is an important matter. From the engineering point of view, the occupancy of the trunk line with effective traffic is important. From the operating point of view, the number of calls which can be disposed of is important. From both the subscribers' and operating point of view, the delays which occur in disposing of the traffic are important. The paid time per hour is assessed simply by adding up the money value of the dockets disposed of in any particular hour under investigation. With this system, it is possible to get 60 or even 70 minutes' paid time in an hour, simply because subscribers occasionally end their conversation at odd fractions of the 3-minute units which are employed for timing purposes on interstate calls. A subscriber who actually speaks for five minutes will be debited for six minutes on the docket. This method of assessing traffic capacity of a circuit is obviously of little interest to an engineer, except to show comparisons between different methods of operating, etc. In line with standard methods of measuring traffic in local automatic networks, it was decided at Adelaide to endeavour to measure the occupied time of the trunk circuit. The switchboards both at Melbourne and at Adelaide are of the modern cordless type, with coupling circuits which enable the interstate circuit to be coupled through to the local network (or another trunk line) by the operation of a key. The normal operating procedure is such that the circuits are not coupled until the two particular persons are ready to talk. The operation of the coupling key at Adelaide, for example, indicates that so far as can be determined the actual trunk line conversation is about to begin. Similarly, the circuits are not de-coupled until the conversation has ended. Relay contacts were available on the Adelaide switchboard which indicated by their operation the time during which the interstate circuit was coupled or uncoupled. A recording voltmeter, with a chart travelling at a suitable speed, was modified so that the pointer deflection indicated the time when the circuit was coupled or uncoupled. This recording meter was kept in operation at Adelaide, for several days in succession, both on the dialling circuits and on the manual circuits, and tests were repeated at various intervals in order to obtain samples as representative as possible. It was found that the direct dialling method gave substantial increases in the amount of effective occupied time on the interstate circuit. There were variations due to varying efficiency of telephonists and due also to many well-known factors which are encountered in traffic studies in any telephone network. For example, a particular hour on a Wednesday might be taken with three calls each of 20 minutes, while the same hour on the following day might be made up largely of three-minute calls. Taking the business hours of the day from 9 a.m. to 5 p.m., and averaging the results, there appears to be little doubt that the direct dialling method gave improvements of at least 20% over the same circuits used on a manual basis. This is a very substantial gain, since it amounts to adding one new trunk circuit to every five existing. The capital costs and annual charges on these interstate routes, 480 miles long, are obviously such that a gain of 20% in traffic handling is a very important one. In addition, of course, the incoming operator is completely eliminated, and this not only reduces the staffing costs considerably, but is reflected in the reduced capital costs and annual charges on the operating positions which are necessary for manual methods. The improvement to the originating operator brought about by the reduction of phonetic errors and the reduction of waiting time by the subscriber is difficult to assess in money terms, but is undoubtedly an important factor tending towards smoother operation of the telephone system.

At Melbourne also a special study was made of the traffic handling of the automatic and of the manual circuits. This trial was made for 34 days successively on the traffic flowing from Melbourne to Adelaide. This study was made to determine the paid time by noting carefully the particulars on every docket handled during the trial period. The following results were obtained for the 34 days:—

Manual—

32.95 minutes per hour paid time (average).
41.5 minutes per hour paid time (maximum).
26.9 minutes per hour paid time (minimum).

Automatic—

49.4 minutes per hour paid time (average).
53.3 minutes per hour paid time (maximum).
44 minutes per hour paid time (minimum).

Permanent Installation on Interstate Routes—Adelaide-Melbourne: The advantages of the direct dialling method were so clearly established that it was decided to adopt the direct dialling method exclusively on the Melbourne-Adelaide route. Concurrently with a 12-channel type "J" carrier telephone system being put into use, V.F. dialling equipment was installed at Melbourne and Adelaide. There are at present (September, 1946) 13 circuits in use between Melbourne and Adelaide, all of which are equipped with direct dialling apparatus. Normally, five circuits are used for dialling from Melbourne to Adelaide, five circuits are used for dialling from Adelaide into Melbourne, and three circuits are equipped for both-way dialling and are utilized from time to time in either direction, as determined by the traffic officers. This meets changing conditions in the amount of traffic flowing from either capital city. The first two circuits for dialling from Melbourne into Adelaide were cut into service on 28.7.45. Two circuits in the reverse direction from Adelaide into Melbourne were cut over a week later, 4.8.45. The group of circuits was increased from four to 13 and cut over completely to automatic working on 15.3.46. Fig. 6 illustrates the arrangement.

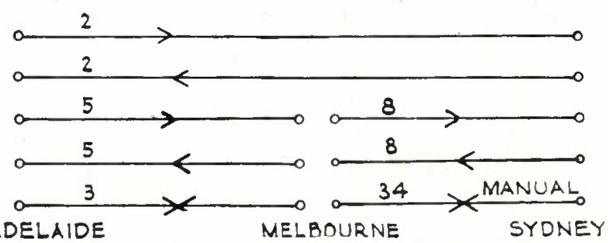


Fig. 6.—Circuit layout, Adelaide-Melbourne-Sydney (September, 1946).

Extension to Melbourne-Sydney Route: The direct dialling method was extended to the Melbourne-Sydney route on 26.3.46. Of a total group of 50 circuits, 18 have been working on a direct dialling basis since 26.3.46. The dialling circuits are used in two groups, one for dialling from Melbourne into Sydney and another group for dialling from Sydney into Melbourne. As equipment becomes available, the dialling system will be extended to the remaining manual circuits. (The Melbourne-Sydney route distance is 575 miles.)

Some Very Long Dialling Circuits in Australia: With carrier methods of working, where the overall transmission equivalent can be kept to very low figures irrespective of distance, there is no particular technical difficulty in dialling over any distance. From the traffic point of view, however, the long distances present special difficulties. The tariff naturally increases with the distance involved, and consequently the proportion of persons who require their calls to be on a "particular person" basis increases rapidly with the distance. For this reason, the conditions associated with direct dialling on very long distance trunk circuits are of particular interest. From this point of view, there are now some very long distance direct dialling circuits in Australia; and, so far as can be judged from published information, these distances are very much in excess of those used in other parts of the world. For seven years, long distance direct dialling has been in use from Port Lincoln to Adelaide, a distance of 440 miles. From 6.3.42 direct dialling has been used from Alice Springs, in the Central part of Australia, into Adelaide, a distance of 993 miles. From May, 1946, direct dialling has been in use from Darwin, the capital of the Northern Territory, into Adelaide, a distance of 1987 miles. Even to those who have been closely associated with the development of the trunk line network in Australia, and particularly the use of automatic methods of working, there is still a very real fascination in watching the operation of a selector picking out a particular telephone in Adelaide, when one realizes that the selector is stepping accurately under the control of a simple dial nearly 2000 miles away!

Extension to Adelaide-Sydney Route: Direct dialling was inaugurated on the Adelaide-Sydney route on the 28th June, 1946, a total distance of 1035 miles.

There is at present no direct trunk route from Sydney to Adelaide, but channels are provided between the two cities by joining Adelaide-Melbourne circuits to Melbourne-Sydney circuits at Melbourne. Four such direct circuits are in use at the present time, and these are arranged to provide two circuits dialling from Sydney into Adelaide and two for dialling from Adelaide into Sydney. The circuits are joined through permanently at Melbourne on a four-wire tail-eating basis.

General Results of Interstate Dialling: Experience obtained to date in Australia has shown that the direct dialling method of handling traffic over these exceptionally long distances is quite satisfactory, and there appears to be little doubt that future plant installed in Australia will be based on the use of the direct dialling method exclusively.

Present Position of Australian Trunk Network and General Trends: In Australia at present a considerable proportion of the population of each State is concentrated in the capital cities. This has had the effect of expediting the conversion of the city areas to automatic telephone working, but has correspondingly delayed the introduction of automatic exchanges in country towns. The country towns in Australia, speaking in very general terms, are rather on the small side, and consequently there has not developed any urgent need for conversion to automatic working (except in a few cases). On the other hand, there are in Australia comparatively large numbers of exchanges having only a few subscribers each. The number of subscribers is so small, in fact, in many of these cases, that it is uneconomical to provide a continuous 24-hour service for the subscribers on a manual basis. The obvious need for continuous service to satisfy the subscribers' legitimate demands is such that intensive efforts have been made to convert these small exchanges to automatic working for local subscribers' service. These small exchanges, known as R.A.X.'s (Rural Automatic Exchanges), have to be arranged to handle their trunk traffic in and out through a nearby larger exchange, which is still operating manually, and which is known as a parent exchange for one or more R.A.X.'s. Australia, at present, therefore, has a network in which the large regional centres are already converted to automatic working, as well as numbers of the very small exchanges, but the various intermediate size country exchanges are still working manually both for local subscribers' service and for trunk traffic. It seems that, with the gradual growth in numbers of R.A.X.'s, there will soon arise a pressing need for the capital city operators to be able to dial direct into the R.A.X. It may be difficult to dispense with operators for handling trunk traffic at the parent exchanges serving R.A.X.'s, so far as outward traffic from the R.A.X. subscribers is concerned. The principal difficulty, of course, is the fact that the elimination of the manual operator at the parent exchange will require the installation of multi-metering devices or toll ticketing machines. The multi-metering method of registering trunk line calls has the very substantial advantage of using only simple and well-tested mechanisms. It has the disadvantage that the subscriber cannot be furnished with any separate account for trunk line calls, since there is no way of distinguishing between a trunk line call at, say, fourpence or four local calls at a penny each. There is, however, some doubt regarding the real need for the subscriber having a separate account. It is understood that although totalized trunk charges are shown separately from local calls on subscribers' accounts at present, it is only rarely that the subscriber requests a detailed list of the trunk line calls; in fact, such a detailed list is furnished only on payment of an extra fee. There is reason to believe, therefore, that subscribers would raise little objection to an account which merely gave the total debit for all telephone calls. However, in England at present, the multi-metering system is used only for trunk line calls not exceeding the equivalent of four local calls, i.e., fourpence. For calls beyond that distance, a manual parent exchange must be used to obtain the trunk line service and the ordinary docket method is employed. In Europe, however, it is understood that the multi-metering system was highly developed and was used up to 60 multiples of the local fee. The average trunk line distance in England is, of course, very small, and even in parts of Europe it is considerably below the distances which exist in Australia. It is by no means certain, therefore, that the multi-metering system used alone would suffice to meet Australian requirements. The Toll Ticketing Machine method is free of the disadvantage of the multi-metering system, but is obviously of a much more costly character so far as equipment charges are concerned, and it may be difficult to justify its use in Australia in the smaller telephone areas. For the above reasons it is quite possible that manual methods of handling trunk traffic at selected parent exchanges or group centres will be retained in Australia for some time. These manual operators will handle outgoing trunk traffic from the group of smaller exchanges in the area and will utilize existing docket methods of accountancy. These group centre operators will, of course, be furnished with direct dialling facilities to the capital cities. This process has already been carried out on a large scale in Victoria, South Australia and, to a lesser extent, in New South Wales, and will undoubtedly be extended to the other centres as soon as possible.

While the manual operator may still be necessary to handle outward traffic from the R.A.X. subscribers in order to overcome difficulties of multi-metering, etc., there appears to be no reason why the operator should be retained for incoming traffic to the R.A.X.'s. The next step, therefore, in developing the automatic trunk line network would appear to be the provision of equipment to enable the capital city operator to dial through the group centre to the R.A.X. subscriber. The city operator will seize a circuit to the group centre and dial a preliminary digit, or digits, which will select a circuit to the R.A.X., and then dial the subscriber's number. In the event of congestion on the route between the group centre and the

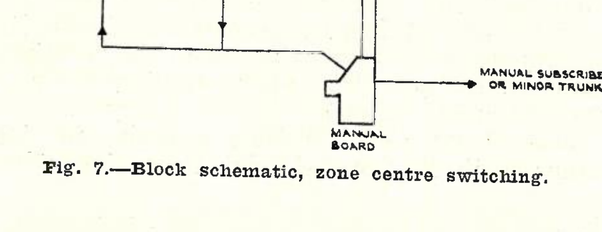


Fig. 7.—Block schematic, zone centre switching.

R.A.X., it would be desirable for the switching equipment at the group centre to automatically route the call to the manual operator at the group centre. This is illustrated in Fig. 7. The operator will then take particulars of the call on a "through" docket and revert the call when a circuit becomes available to the R.A.X. In addition to facilities for the capital city operator to dial through the group centre to the R.A.X., facilities would also be provided to enable other group centre operators to dial through the group centre to the R.A.X. At present in Australia the trunk line network is built up largely on a Mesh system, in which direct circuits are provided between each group centre and all other group centres in the adjoining territory. The Star type of network is used only in taking traffic from one large area of country to another large area, generally on the other side of the capital city. See Fig. 8.

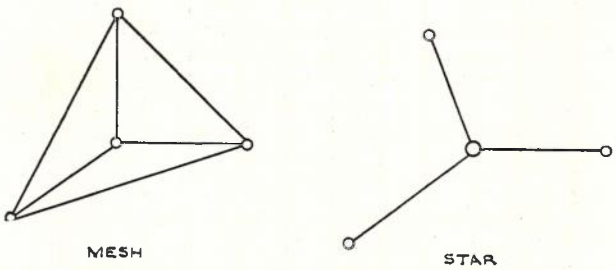


Fig. 8.—Mesh and star layouts of trunk centres.

The actual network differs considerably in detail from one locality to another, but is best described as a combination Mesh and Star system. With completely manual methods of trunk handling it is practically essential to eliminate tandem methods of operation as far as possible. With a true Star System it would be necessary to have five or more operators involved in tandem in setting-up a through connection from one group centre to another, even though the distance between them were not very great. The delays and the difficulties due to phonetic errors, etc., are such that tandem working is viewed with disfavour as long as a manual method is employed. For this reason, in most parts of Australia the tendency has existed to provide direct circuits between one town and any other town in the vicinity as soon as the traffic is sufficient to warrant at least one circuit on a nearly full-time basis. See Fig. 9. While this network exists, there will be no difficulty in providing equipment for one group centre to dial through an adjoining one to reach the R.A.X. subscriber. This will eliminate the incoming operator on each trunk call and will assist in speeding-up the handling of traffic and eliminating phonetic errors, etc. The group centre exchanges at present are connected also to large towns known as Zone Centres. The zone centres in turn have direct circuits to the capital city. The group centre exchanges therefore depend in many instances on the zone centres for traffic flowing to the capital city or to other zone centres. In

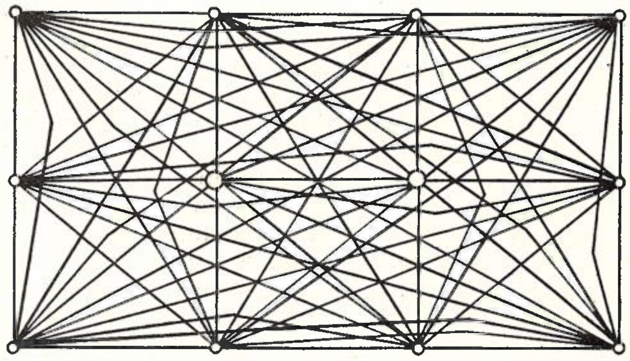
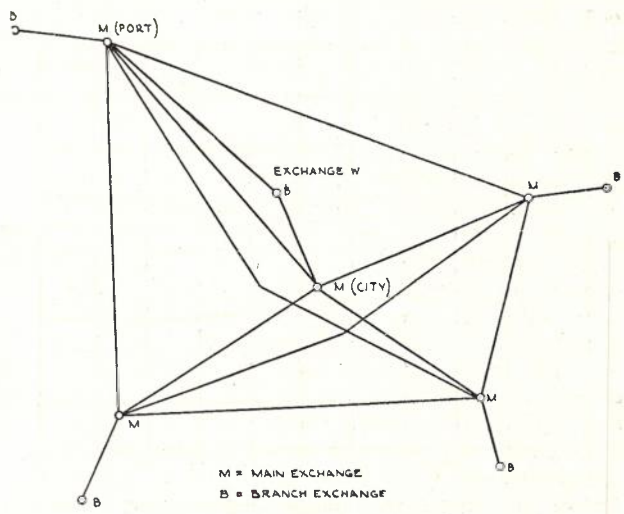


Fig. 9.—Interconnecting the main exchanges of a rural area by means of trunk lines.

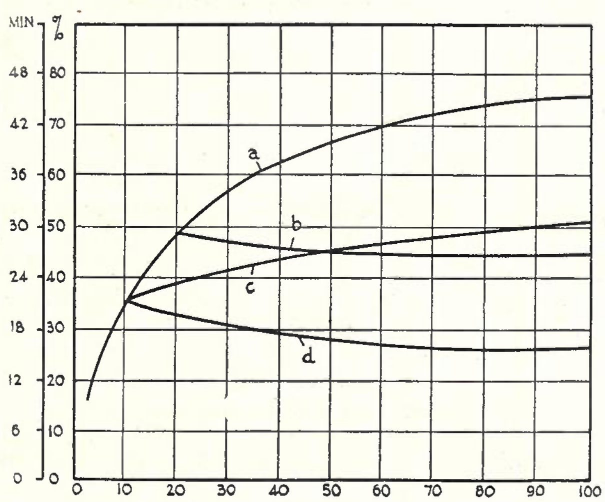
this respect, the network has some of the features of the Star System. There are, however, large numbers of exceptions, in the area close to the capital cities, for example, where the group centres have direct circuits to the city. There are also many cases where group centres in one zone have direct circuits to group centres in adjoining zones and are not dependent on the zone centres for handling traffic over these routes. This latter exception is quite commonly used in such circumstances, e.g., in a capital city local network shown in Fig. 10,



Note: Exchange W is a branch of main City exchange, but because of unusual community of interest it has also junctions to main exchange, Port.

Fig. 10.—Capital city junctions (typical).

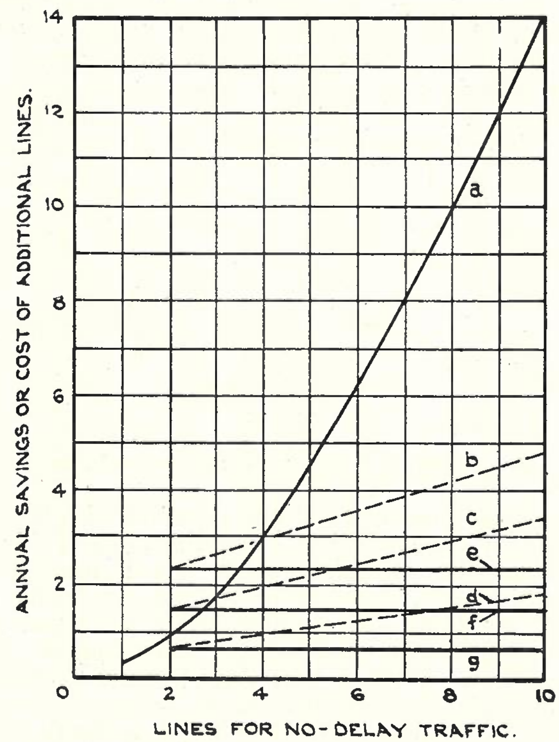
where a particular branch exchange may have sufficient traffic to warrant direct circuits to a main exchange other than its own, or even to another branch exchange. Where the group centres are connected direct to the city, the provision of direct dialling facilities from the city through the group centre to reach the R.A.X. will, no doubt, be undertaken as above. Where the capital city can reach the group centres only through zone centres, however, consideration will have to be given to the provision of automatic switching equipment at the zone centres to enable the capital city to dial through the zone centre to reach any group centre and thence any R.A.X. The introduction of switching equipment at the zone centres may well be justified even in advance of the conversion of the smaller exchanges to R.A.X. working, and even before the introduction of switching equipment at the group centres. If a fundamental switching plan is drawn up, embracing the capital city and the zone centres on a Star type of network, it is possible to arrange for substantial improvements in the method of handling traffic to and from the capital city and the zone centres. At present, because of the difficulties with manual tandem switching, many comparatively small group centres have been provided with direct circuits to the capital city. These circuits pass through towns which would certainly be zone centres on an automatic basis. The result is that radiating from the capital cities, there are large numbers of separate trunk groups, many of which have only one, two, three or four circuits each. These groups of circuits provide very inefficient means of handling trunk traffic even on a manual basis.



a. Complete line groups.
b. Simple 20 line groups, ungraded and unmixed.
c. Incomplete line groups, 10 line groups graded and mixed.
d. Simple 10 line groups, ungraded and unmixed.

Fig. 11.—Occupancy of the lines in various line groups, with a grade of service of 1 in 1000 during the busy hour.

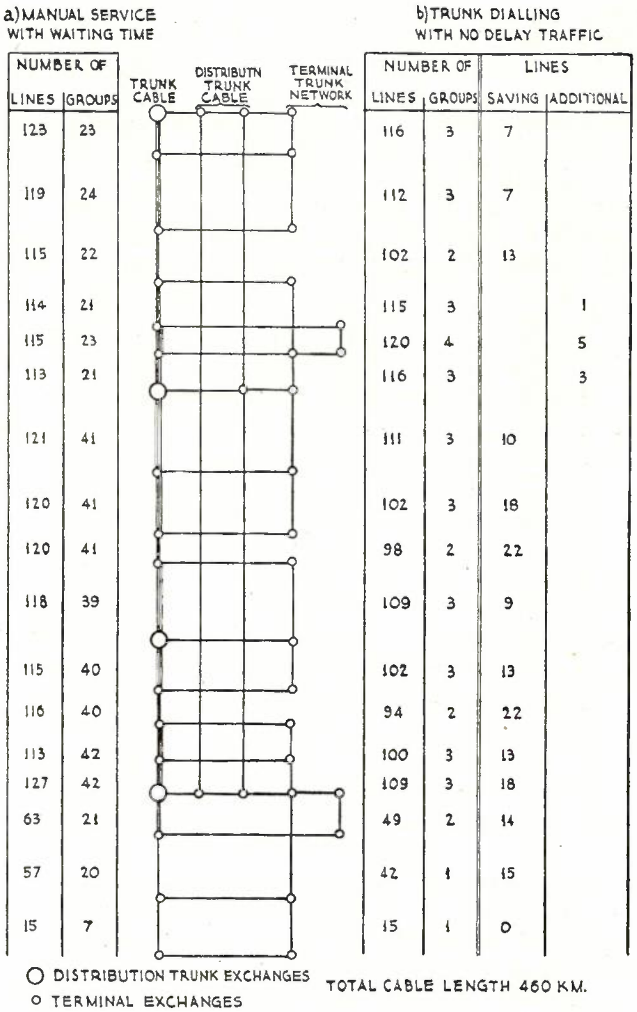
On an automatic basis, they leave much to be desired from the point of view of total annual charges. The distances involved in Australia are comparatively great, and the cost of trunk channels is correspondingly very high, so the economies to be obtained by the better utilization of trunk channels assume unusual importance. The conditions in Australia are no doubt radically different in this respect from most other countries. In England, for example, the distances are comparatively very small and the density of traffic is very great, since most of the towns concerned are large. It is a well-known fact that by combining numbers of trunk channels into larger groups the traffic efficiency of each circuit is increased. Fig. 11 illustrates. The curve relating the traffic capacity of each circuit in a group to the number of circuits in the group is not a straight line, however, but begins to bend over as the



a = savings with no-delay traffic.
b = 30 km.; c = 20 km.; d = 10 km.—Occupancy of the trunk lines, 45 min.
e = 30 km.; f = 20 km.; g = 10 km.—Occupancy of the trunk lines, 35 min.

Fig. 12.—Annual savings effected by no-delay traffic and the cost of the additional lines required for this purpose.

number of trunk circuits increases above a certain point. Thus, when the number of circuits in the group is about 100, there is nothing to be gained by making the number in the group much larger. In England the number of circuits in each group, in many cases, is very great, and nothing would be gained in this respect by changing from a Mesh network to a Star network. With very large groups of circuits over short distances, the cost per channel mile is low, and any increased demand for circuits can be met readily by increasing the amount of line plant or carrier equipment in use. This is particularly the case where multi-channel carrier systems are used on underground cable routes, and is especially so in the case of coaxial cable installations, where most of the cost is in the initial installation and where additional channels can be provided cheaply from time to time by adding additional blocks of carrier equipment. In countries where this condition exists, it is usually found that it is cheaper to provide sufficient additional



a) Number of Lines	a) Number of Groups	b) Number of Lines	b) Number of Groups	Lines Saving	Lines Additional
123	23	116	3	7	
119	24	112	3	7	
115	22	102	2	13	
114	21	115	3		1
115	23	120	4		5
113	21	116	3		3
121	41	111	3	10	
120	41	102	3	18	
120	41	98	2	22	
118	39	109	3	9	
115	40	102	3	13	
116	40	94	2	22	
113	42	100	3	13	
127	42	109	3	18	
63	21	49	2	14	
57	20	42	1	15	
15	7	15	1	0	

Fig. 13.—Distribution of a trunk cable into line-groups.

channels to guarantee a no-delay basis (just as is done in local automatic areas) rather than instal special operating positions to handle traffic on a delay basis even for part of the day. The extra operating charges involved in establishing delay positions may well be in excess of the additional channel provision costs. See Fig. 12. In Australia, however, the conditions are different in many respects, and there are at present no trunk groups which can be regarded as really large. There are therefore many advantages to be gained by combining the numerous small groups into large groups. See Fig. 13. This arrangement is scarcely practicable while manual methods at zone centres are necessary, and consequently the importance of establishing automatic trunk switching at zone centres assumes unusual proportions.

Effect of V.F. Dialling on Carrier System Design and Layout: In considering the introduction of automatic trunk switching methods, including the provision of a Star type network as the ultimate plan, many problems are encountered in Australia because of the unusually long distances and the comparatively small population outside of the capital cities. At first sight, it would appear possible to instal through switching equipment at the selected zone centres and group centres and simply rearrange the existing circuits to form as far as possible a Star type network (with the normal exceptions mentioned earlier). This is indicated in Fig. 14. In practice, however,

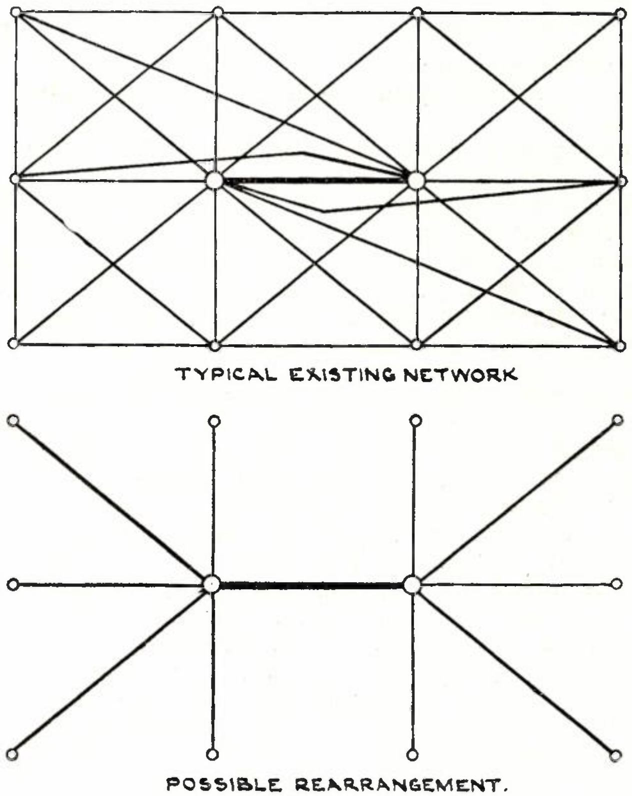


Fig. 14.—Simplification of the trunk-line network. Trunk-line network planned on the principles laid down for suitable network layouts.

the problem is not nearly as easy as this. In Australia, where the distances are great and where the majority of the facilities are still provided by overhead open wire construction, it is natural that extensive use should be made of open wire carrier systems, including a large number of three-channel and an increasing number of twelve-channel systems. The practice adopted for many years has been to instal the carrier systems over as long a distance as possible. The carrier system inherently is a device which gives the same transmission loss from end to end independently of distance, and in this respect differs markedly from physical line working. For this reason, when traffic relief was required between points "A" and "B" it was usually decided to instal the carrier system between points "A" and "C," as shown in Fig. 15. The carrier

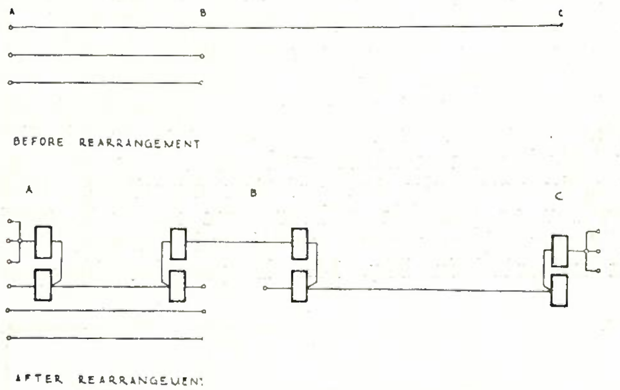


Fig. 15.—Typical use of carrier systems.

system was then used to throw free physical lines from "A" to "C," and these were then cut back to provide additional physical channels "A" to "B" and, without additional expense, spare circuits were obtained from "B" to "C" and so on. This procedure gave the traffic staff the required number of channels, and it assured best use of the carrier system by stretching it out as far as possible. This brought the long distance towns into the capital cities with very satisfactory transmission equivalents, and as the physical circuits were cut up more and more into short lengths they fitted very well into the trunk network scheme. Refer to Fig. 16. Because of the disadvantages of manual tandem working and because of the facility with which carrier systems could be pushed out to the extremities of the trunk route, the practice has grown up of providing a large percentage of the medium and small towns with direct circuits to the regional centre at the city. The pole routes serving these smaller towns in many cases pass through much larger centres which would be favourably situated for use as zone centres in an automatic switching scheme. The practice is equivalent to having direct automatic junction circuits from the city automatic exchange passing through a suburban main exchange direct to a particular small exchange which would normally be a branch of the main exchange. In local automatic networks such a practice would be frowned on, for many obvious reasons. In local networks direct circuits between branch exchanges are provided only where the two exchanges are relatively close together and there is unusual community of interest between them. When the city areas were manually operated some years ago, direct circuits were provided between practically all pairs of exchanges in order to avoid the difficulties of manual tandem working; but with the advent of automatic working, these direct junction routes were rearranged and the city areas were converted to a combination of Mesh and Star type systems (with the few special exceptions referred to). If the trunk line network were composed entirely of physical lines there is little doubt that the system would be changed over to a Star system concurrently with the introduction of automatic methods of working. It would be necessary merely to instal switching equipment at selected points and cut back the long physical circuits passing through those switching points so as to provide as large a group of circuits as possible from the city to the switching centre. Carrier systems, however, cannot

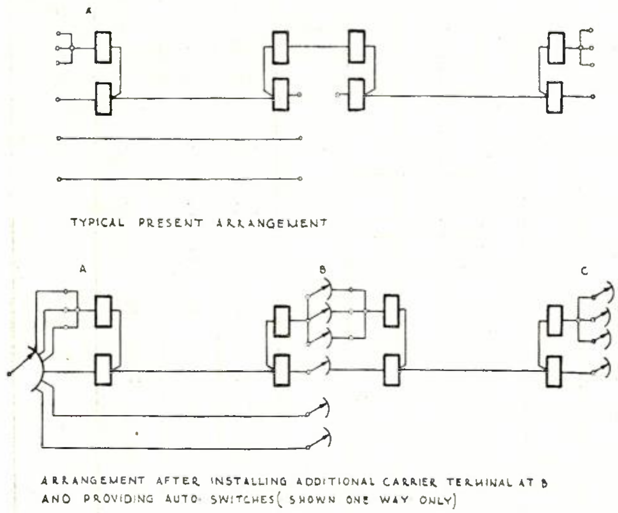
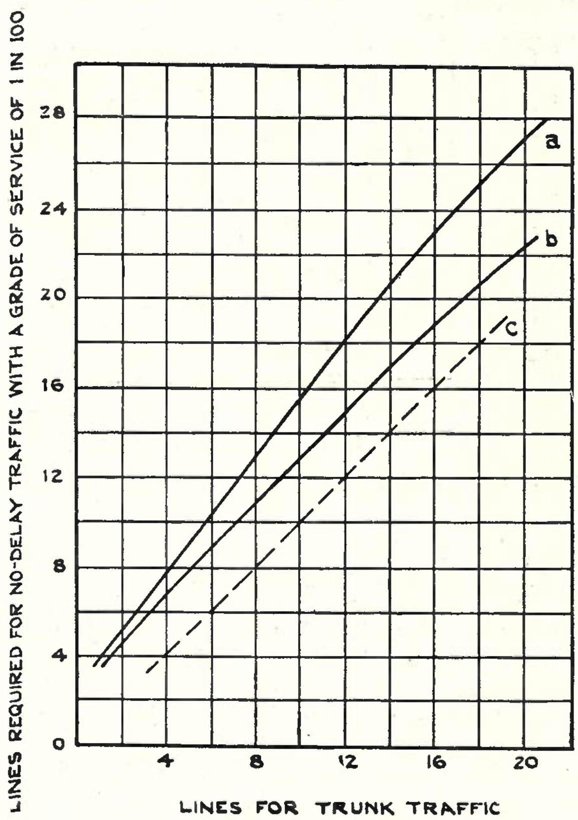


Fig. 16.—Possible modification of carrier systems for trunk switching.

be thus cut back so readily. They can be rearranged to give the same effect by installing additional terminals so that, for example, instead of a straightforward carrier system from "A" to "C" we can instal additional terminals at "B," the switching point, making two carrier systems in tandem "A" to "B" and "B" to "C." The switching equipment can then be installed at "B," treating the carrier system from "A" to "B" in the same manner as the various other circuits between "A" and "B." There is the obvious disadvantage that it is necessary to spend money on these additional terminals, and the point arises whether such an expenditure is justified. The answer, of course, can be obtained only by a proper study of the economics involved. It is quite possible that the additional costs involved will be small compared with the economies to be obtained in other directions. It is thought by some that where a three-channel system runs from "A" to "C" via "B," and the three channels are fully loaded, as normally understood by the traffic staff, that nothing can be gained by cutting the system up into two systems, "A" to "B" and "B" to "C," and merging the circuits from "A" to "B" with other circuits over that same route in an automatic switching group. They consider that if the three circuits from "A" to "C" are fully utilized, then they cannot carry any additional traffic simply by merging them with other circuits in a common group from "A" to "B." On the contrary, they state that the service between "A" and "C" may become less efficent because of the occasional occurrence of conditions where "C" cannot reach "A" because all circuits are in use at this moment for other traffic from "B" to "A." While "C" retains direct circuits to "A" it is independent of traffic conditions between "B" and "A." A great deal depends on the interpretation to be given to the statement that a group of three circuits from "A" to "C" is fully loaded. With entirely manual methods of working, it is rather difficult to decide when a channel is fully loaded. With entirely automatic networks, the application of probability theory and extensive practical investigations over many years have enabled administrations to decide on well-established principles to be followed in deciding the number of channels to be provided to carry various amounts of telephone traffic. Space does not allow repetition here, but the subject has been very well covered in many published papers and text books. It is relatively easy at present to determine from available curves the number of circuits which will be required to carry various amounts of traffic in order to give a predetermined "grade of service." If the service is to be perfect, no call should ever be lost or delayed due to lack of circuits. In practice, this provision would be unnecessarily extravagant, and consequently local automatic networks are laid out on the basis that an occasional failure to reach a particular exchange due to congestion may be tolerated by the subscriber. The number of calls per thousand which may be lost due to temporary congestion on a route determines the "grade of service." Thus varying "grades of service" may be allowed for, depending a good deal on many local conditions and the wishes of the administration. A typical grade of service for local automatic networks in Australian cities provides for two calls to be lost per thousand between one main exchange and another, for example. One of the fundamental problems in telephone engineering is the fact that telephone traffic does not flow uniformly but occurs in sharply defined peaks. If circuits are made available to carry the peak traffic (without any lost calls), then it is certain that circuits will be lying idle for a good many hours in a day. The overall tariff charges must be based on figures which will ensure sufficient return to cover all annual charges, even allowing for this amount of plant idle for portion of the day. With manual methods of working, some of the expenses in providing service can be regulated to meet this varying flow of traffic by simply varying the number of operators on duty at various hours of the day. With manual methods, also, a call is not lost merely because it encounters temporary congestion on a group of circuits. The operator can put the docket on one side and make repeated attempts until she finally obtains a circuit. If the delay in obtaining a circuit is more than a few minutes, the calling subscriber is usually not kept waiting but is called back by the operator later. This "delay" method of working has a pronounced effect on the number of channels required to carry a certain amount of traffic because, in effect, it takes some of the peak traffic over into the slack periods. See Fig. 17. By reducing



a = occupancy of trunk line, 45 mins.
b = occupancy of trunk line, 35 mins.
c = number of lines for trunk and no-delay traffic.

Fig. 17.—Additional lines required for the introduction of no-delay traffic.

the ratio of peak to average traffic, it helps to remove one of the fundamental difficulties in handling telephone traffic. This is the sole reason for using delay methods of working, and has been justified in the past solely because of the reduction in the number of channels which would otherwise be required to carry the traffic. The delay method of working, however, has many disadvantages, and some of these offset the saving in the number of trunk circuits. If sufficient circuits are provided to enable the operator to complete the trunk call "on demand," while the calling subscriber remains at the telephone, the manipulative time on the part of the operator is at a minimum. If, on the other hand, insufficient circuits are available and the operator has to put the docket on one side and make repeated attempts to obtain a circuit, and then has to call back the calling subscriber, it is clear that more operators will be required than would be necessary to give a "no delay" service (if sufficient circuits were available for this purpose). The additional operating salaries and attendant expenses in switchboard provision, etc., must be taken into account as an offset against the economies achieved by reducing the number of trunk circuits. See Fig. 18.

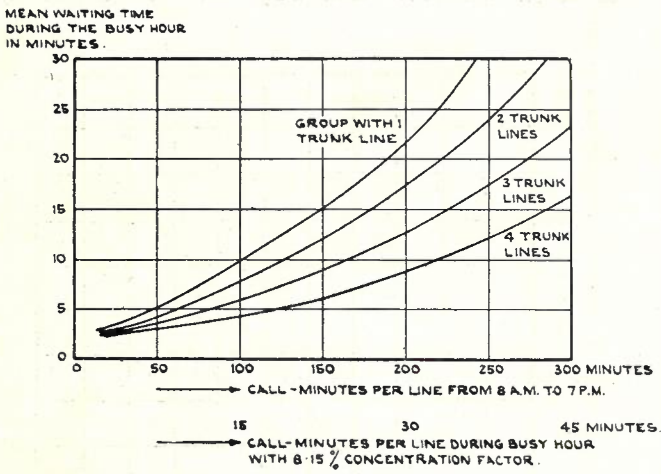


Fig. 18.—Mean waiting times on trunk lines as a function of load and the number of lines.

As another matter, of course, the service to the subscriber is an important aspect. Subscribers for many years have become accustomed to a no-delay service in city areas covering quite a large area of territory and involving many subscribers. They find the waiting period to get a trunk call through rather irritating, and in many cases they actually suffer financial loss if they have to sit around just waiting for the trunk call to mature. For this reason there is a marked trend towards the provision of a no-delay service to subscribers on trunk calls even where manual methods of working are in use. Refer to Fig. 19. In many countries, as mentioned earlier, it may actually be just as cheap to provide the additional channels to give a no-delay service as it is to put in special operating positions for a delay service. A difficulty facing Australia is to determine just where the various charges balance out and make the provision of a no-delay service possible. Automatic working over the trunk network eliminates the incoming operator on a trunk call, and the economies thus achieved can be set off against the increased costs involved in providing sufficient circuits for a no-delay service. There is, of course, the case encountered at times where it will still be necessary to retain an operator on a particular country switchboard to handle outgoing and, perhaps, local traffic, and where no actual operating economy can be achieved by arranging for automatic through trunk working. In general, however, it appears that the economies to be achieved by the reduction of operating staff handling incoming trunk calls is quite appreciable and merits serious consideration. The operating salaries have shown a tendency to increase in recent years, and there is a marked tendency for retiring rooms and other amenities for the traffic operating staffs to be more costly. These usually call for building provision and, in the medium and larger towns, the total charges involved in providing operators and these attendant facilities are quite large.

While it is difficult to assess in money terms the advantage to the subscriber in obtaining a no-delay service, there can be little doubt that the business community as a whole would be

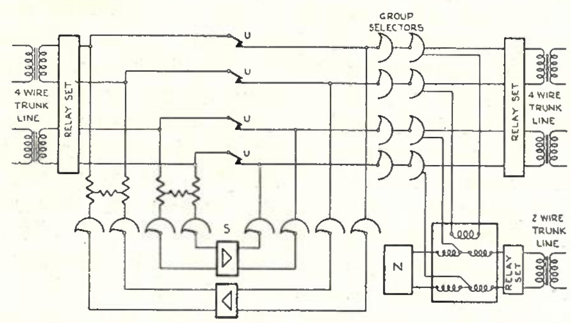


Fig. 19.—Insertion of automatic repeaters.

very much better served if trunk line calls in the majority of cases were provided "on demand." It seems to be taken for granted by most administrations throughout the world that the public's demands will never be regarded as completely satisfied until a trunk service on demand is provided at least under normal conditions. The immediate problem in Australia is, therefore, to decide just what is the best way of meeting this requirement, while avoiding extravagant provision of plant, which would require the tariff to be raised to an extent which would outweigh the advantages of a no-delay service in the estimation of the subscriber. It is at this point that the possible introduction of a complete automatic trunk line network begins to warrant thorough investigation. It is proposed to discuss this matter further in Part II. of this article.

(To be continued.)

CAPACITY BALANCING OF JUNCTION AND SUBSCRIBERS' CABLES—"CONTROLLED" METHOD

J. W. Read, B.Sc., A.M.I.E.E., A.M.I.E.(Aust.)

Introduction: During the next five years, a very large programme of underground cable installation work is to be carried out by the Department in order to overtake the arrears of the war years, as well as to cope with normal development. Apart from subscribers' services, the junction requirements of the major cities of Australia require the addition of considerable lengths of large size loaded underground cables.

These cables will require to be capacity balanced in order that the cross-talk characteristics will be within specified limits. The normal capacity unbalance requirements and the conventional methods of obtaining the desired cross-talk characteristics were described in the Telecommunication Journal, February, 1946, "Cross-talk Reduction in Telephone Cables," by J. C. Brough and O. J. Connolly.

The two methods described in the above article for the reduction of capacity unbalance in a loading section of 6,000 feet were:—

(a) 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.

(b) 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 of 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.

Both the above methods involve an appreciable amount of time in excess of normal jointing operations, and in view of the large programme involved, the shortage of skilled staff and the importance of the time factor, the additional work associated with capacity balancing is important, particularly when dealing with a large number of cables. With the object of reducing this time, a third method known as "Controlled" method has been devised and recently subjected to field trials. The results of these trials have been encouraging, and the object of this article is to give a brief description of the method and some of the results achieved in the field.

General Description: The method involves the testing of the four test lengths of the whole loading coil section in one operation from one end of the section. While jointing operations on a quad are proceeding at each of the three intermediate man-holes, the following quad is being tested. The "controlled" method retains the advantages of the method (a) in that all four lengths are considered simultaneously before a selection is made, but it also has the advantage that quads are jointed immediately they have been tested, with a consequent speeding up of the work, as is the case with method (b). It has an additional advantage in that the jointer doing the jointing is relieved of the actual testing, which enables him to joint more quickly. As only three joints are concerned in the test, less time is involved than in method (b).

Any balancing condensers required are connected during the jointing operations and a final check test is made of each quad after jointing as a check against any jointing errors. One important aspect of the new method is that the jointers and the testing officer work as a team under the control of the testing officer, with whom any communications can be made immediately by order wire. The testing officer in this case is normally a Line Foreman Grade 2, instead of a Senior Technician, as is generally the case with method (a). The testing and selection are virtually reduced to a relatively simple trial, and the testing officer's work is well within the capabilities of trained Lines Staff, who are able to give the necessary attention to the control of the team, to ensure expeditious and satisfactory work.

The balancing carried out is side to side balancing within the quads only, as described in the February, 1946, Journal, and the quads are connected to the corresponding quads in adjacent lengths.

The allowable limit of unbalance will be assumed to be 350 micro-microfarads, although this limit may be varied as required to suit special conditions and will be somewhat relaxed in the case of subscribers' cables.

Layout of Equipment: The testing equipment in the van consists of a simple capacity unbalance set and a combined 1,000 c/s oscillator and amplifier as described by J. C. Brough and O. J. Connolly. The set is equipped with a durable four wire test lead long enough to go down a man-hole.

Fig. 1 shows the test layout in schematic form and Fig. 2 details of the circuit arrangements. Fig. 1 shows the four lengths of cable, each approximately 1,500 feet, together making up a 6,000 feet loading coil section and the man--holes are referred to as A, B, C, D and E, starting from the testing end. The jointer in man-hole A connects the quads to the testing set and the jointers in B, C and D connect quads as required and do the jointing of tested quads. The cable in E is insulated and no staff is required in this manhole during testing operations.

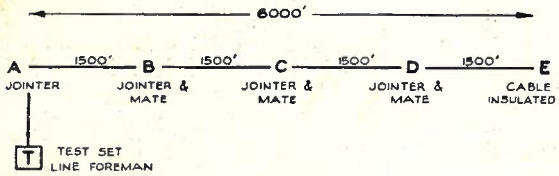


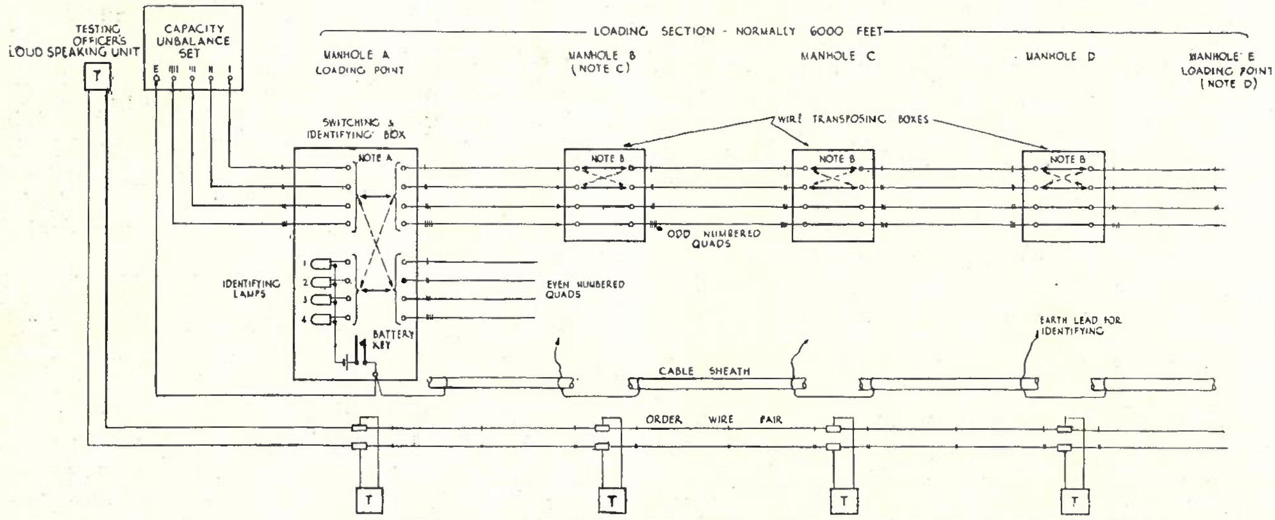
Fig. 1.—Schematic layout of test section.

Each jointer is equipped with a head and breast set, all of which are connected across a common order wire which is extended to a loud speaker unit in the testing officer's van. The loud speaker unit is equipped with a "press-to-talk" key; this enables the testing officer to be in communication without the necessity of removing his testing head-phones.

In addition to the above equipment, the jointer in man-hole A is equipped with a switching and identifying box, and each of the jointers B, C and D are equipped with a transposing box. The transposing box, which is illustrated as Fig. 3, consists of a small box having a set of four terminals at each end, respectively labelled I, II, III and IIII, corresponding to the wire markings in quad cable. The box has a single telephone type key marked "straight" and "Trans." The jointer in the man-hole locates the quad to be tested in the cable on both sides of the man-hole and connects the quad on one side to the appropriate terminals on one end of the box, and the quad on the other side to the appropriate terminals on the other end of the box. With the key normal, the quad is connected straight through the box. If the key is thrown to "Trans," wires I and II are transposed, and wires III and IIII are connected straight through. The terminals are of the press type, permitting the wires to be rapidly connected and providing good contact between the wire and terminal.

The switching and identifying box in manhole A (see Fig. 4) has four terminals for connection to the testing lead, and two sets of four terminals, appropriately marked, for connection to two quads in the cable, the 1st quad being "Odd," and the second "Even." It also has four small lamps labelled to correspond with the wire marking of the quad, a telephone type change-over key, and a battery key and terminals. The lamps provide a ready means of identifying wires. The change-over key is designated "Odd" and "Even." When the key is thrown to "Odd," the odd quad terminals are connected straight through the box to the testing lead and the "Even" quad terminals are connected to the four lamps and via the battery key to battery and earth. When the change-over key is thrown to "Even," the cable quads are inter-changed.

When the jointer in man-hole D earths the



Note: A. Full arrows show connections for "odd"; dotted arrows show connections for "even."
B. Full arrows show connections for "straight"; dotted arrows show connections "I and II" transposed.
C. Crosstalk suppression condensers connected in manhole B when required.
D. All wires insulated in manhole E.

Fig. 2.—Test section circuit arrangements.

wires of the quad in turn, the jointer in man-hole A sees the four lamps flash in the correct order, indicating that wires are correctly connected in all man-holes.

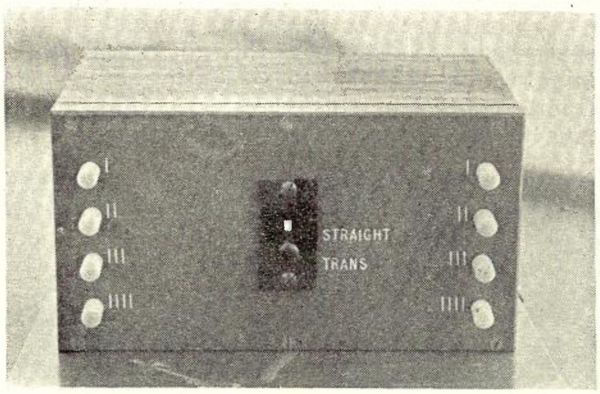


Fig. 3.—Wire transposing box used at man-holes B, C and D (Fig. 1).

Testing Procedure: The following procedure for testing is carried out by the team, the cable having previously been tested for insulation, resistance and continuity of wires, and jointing errors in any intermediate straight joints, between the man-holes A, B, C, D and E.

The cable is opened up at the four man-holes and prepared for testing, and the telephones and loud speaker unit connected to the chosen order wire, say, wires I and II of the reference quad in the outer layer, the quad being jointed through at each man-hole.

Under instructions from the testing officer, the first quad to be tested is then connected to the transposing boxes at B, C and D, and the "Odd" terminals at A, with the key thrown to "Even." A quick identification is then carried out from man-hole D to A, as previously described. The change-over key is then thrown to "Odd" and testing is proceeded with by the testing officer. The tests are carried out in the order shown on the recording sheet, illustrated in Fig. 5. This order is selected to involve a minimum of alterations between each test. The testing officer reads the unbalance when the keys are normal at B, C and D, and records the result in the fifth column on the recording sheet where there is a straight line shown under B, C and D, indicating no transpositions. Both magnitude and sign are recorded. If the reading obtained is within the allowable limit, the result is accepted and jointing instructions issued to joint the quad straight at all man-holes.

When the first test is not satisfactory, the testing officer instructs jointer B to throw his key, and takes an unbalance reading and records the result in column 7. If necessary, he then instructs D to throw his key, and takes a third reading, and so on. For the worst cases he may take eight readings and still not obtain a value below the limit. In this case he selects the com-

WITHIN QUAD CAPACITY BALANCING Q.L. CABLE - TESTING OFFICER'S RECORD SHEET.

Cable No. ______ Route - ______ No.of pairs - ______ Gauge ______ lb. Max.permissible unbal. ______ mmf.

Section MH ______ to MH ______ Sheet No. ______ of ______ sheets.

Layer	Quad	Key at A	Check A to D	Capacity unbalance mmf for connections.								Joints installed BCD	Condenser (mmf) installed between wires		Overall Residual Cap. Unb. mmf.
				BCD ---	BCD X--	BCD X-X	BCD XXX	BCD XX-	BCD -X-	BCD -XX	BCD --X		i & iii (-)	ii & iii (+)	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
		ODD													
		EVEN													
		ODD													
		EVEN													
		ODD													
		EVEN													
		ODD													
		EVEN													
		ODD													
		EVEN													
		ODD													
		EVEN													
		ODD													
		EVEN													

JOINTERS: A ______ C1 ______ D2 ______ Testing Officer - ______

B1 ______ C2 ______ Date - ______

B2 ______ D1 ______

Fig. 4.—Test record sheet.

bination giving the lowest reading and instructs the jointer at B to connect a balancing condenser. This condenser is connected between wires I and III if the reading is negative, and between II and III if the reading is positive. His instructions in this case might be, "joint transposed at B and C, straight at D, connect 600 mmfds., condenser on wires I and III at B." When these instructions are given, jointers B, C and D repeat them and proceed with the jointing, B selecting a suitable condenser from the supply which he has ready, and connects the condenser tail to wires I and III to the cable on the A side of the man-hole.

Immediately jointing instructions have been given by the testing officer, a jointer, assisted by a jointer's mate at B, C and D, disconnects the quads from their transposing boxes, connects the next quad to these boxes, and proceeds to joint the quad which has just been tested. When the next quad has been connected at all man-holes and connected to the "Even" terminals at A, jointers A and D identify this quad as previously, and A throws his key to "Even." The testing officer then proceeds to test the second quad. When the second quad has been tested and the first quad jointed, jointing instructions are issued for the second quad, jointer A throws his key to "Odd," and the testing officer checks the unbalance on the jointed quad which is still connected to the switching and identifying box. If

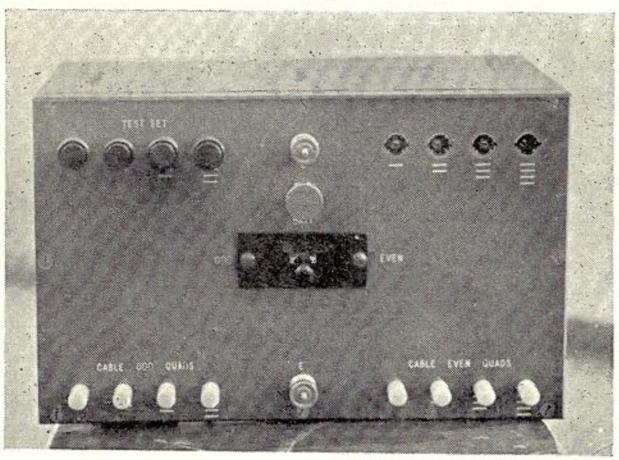


Fig. 5.—Switching and identifying box. Bottom terminals for connection to two cable quads. Top terminals on left go to test set. Identifying lamps are on top right, and change-over switching key is in the centre.

the result is in agreement with his previous test, the test on this quad is finished. It is disconnected at A and the next "Odd" quad connected at A and at B, C and D. Identifying and testing then proceed and the "Even" quad which has just been tested is jointed. Testing and jointing proceed in this manner, quads dealt with being alternatively "Odd" and "Even."

General: The success of the method depends on all instructions being promptly carried out, as any delay at one manhole holds up the work of the whole team. The order wire provides satisfactory communication and enables all instructions to be given briefly, and important instructions acknowledged. It is most important that the amount of talking on the order wire be kept to a minimum to avoid any confusion. Care is necessary on the part of all concerned to eliminate mistakes, but the testing officer has adequate control of the whole operation, and by means of the initial identifying with the lamps

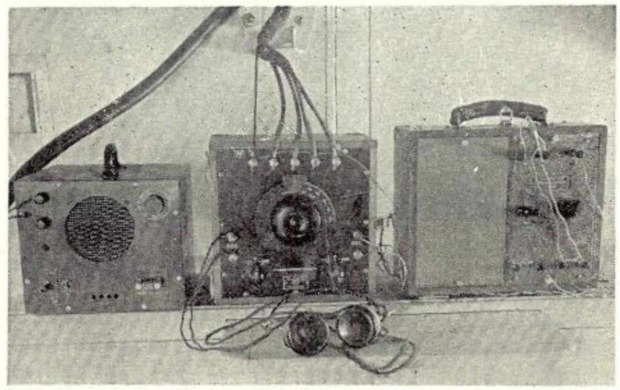


Fig. 6.—Testing equipment in test van. Loud speaker unit on left. Capacity unbalance set in centre and oscillator amplifier on right.

and the capacity unbalance bridge should be able to detect immediately any jointing mistakes. A final test, after jointing is completed, provides a further check of the jointing. Any errors can be rectified immediately by opening up the quad and re-testing in cases where the final result does not agree with the recorded test value. The jointer can thus proceed somewhat more rapidly with this method. Another advantage is that as the balancing condensers required are connected at man-hole B, there are no condensers in the loading coil man-hole where the loading coil stubs have to be connected. This is particularly desirable in the case of large cables where all pairs may not be loaded initially, and the cable may be subsequently opened at loading coil points to connect additional loading coils.

This method would be specially suitable for use in balancing working cables, where it would be possible to test a few spare pairs and transfer the working circuits on to quads as they are tested, throwing spare other quads for testing.

The jointing operations at man-holes B, C and D are comparatively little slower than straight jointing operations, and the only additional personnel involved are the testing officer and the jointer in man-hole A. The speed which can be obtained will depend to a large extent on man-hole conditions, but, under reasonably good conditions, about 70 quads per day could be satisfactorily dealt with, although up to 90 quads have been handled in a single day. A suitable procedure is to have a five minutes' break at the end of each hour's operations. The figure of 140 to 180 pairs per day compares favourably with straight jointing, bearing in mind, of course, that the opening and closing of the cable at the beginning and end of the day occupy a considerable time in the jointing of these large cables.

It will be noted that no jointer is provided for man-hole E during these operations. The provision of a jointer in this man-hole would permit the identifying to be done from A to E, but this is considered to be unnecessary, as any mistakes made by the jointer in D, which are not detected by the testing, would appear to be limited to the connection of a wrong quad, and this is not particularly important as the quad tested is the quad which is jointed. The error can be rectified when identification is made at the loading coil point. It would not be possible for the jointer at D to interchange the positions of the wires of the quad, such as taking I and III for a pair, as the testing officer would not be able to balance his bridge, and would immediately call for a check of connection. There appears to be quite adequate safeguards against any wrong connections, either in testing or jointing, and the testing foreman, being in communication with the whole staff, can readily check connections at all points in cases where the tests obtained indicate something abnormal.

In the initial tests before balancing commences, the buzzing out of the quarter loading section lengths as a check on the straight joints has been retained. This does not involve a great amount of time when the cables have been opened to check insulation and it does enable any faulty quads to be grouped so that a minimum number of pairs in the whole loading coil section are faulty, also less time is lost by the balancing team in dealing with any quads in which errors have been made in man-holes where straight joints have been made.

Test Results: A trial of the method has been made in Melbourne on an 800 pair 10 lb. star quad local type junction cable, and the results are summarised briefly in the following:

On two typical loading sections, 815 and 724 tests respectively (see columns 6-13 of Fig. 4) were required to reduce the capacity unbalance below the limit of 350 mmfds. on the 400 quads involved. The total possible number of tests of each loading section are, of course, 8 × 400 = 3,200. The distribution of quads in relation to the number of tests required to obtain a reading of the capacity unbalance below 350 mmfds. were:—

Number of tests	Loading Section No. 1	Loading Section No. 2
1	176	178
2	181	113
3	25	62
4	2	29
5	5	11
6	4	5
7	2	1
8	5	2

The five quads on loading section No. 1 and two quads on loading section No. 2 listed against "Number of Tests—8," required condensed balancing.

The tests were extended to determine the effect on the overall results obtained by carrying out all eight tests on every quad and selecting the jointing combination giving the lowest overall capacity unbalance. The results in terms of average side to side capacity unbalance over the group of 400 quads in a loading section were—

(a) Testing stopped when limit of 350 mmfds. reached—182 mmfds.

(b) 8 tests per quad when limit of 350 mmfds. reached—66 mmfds.

The additional testing involved an increase of approximately one-third in the overall time occupied in testing and jointing the cable. It is doubtful whether, under present conditions, the expenditure of this additional time is warranted, except in special cases.

Summary: The "controlled" method of capacity balancing provides a means of speeding up the testing and jointing of Star quad local type cables used for junction purposes. An essential requirement of the method is team work between the testing officer and associated jointing staff, and it is particularly applicable to large size junction cables.

Extension of the field trials is contemplated and these further trials may suggest some modification to the procedure set out in the foregoing.

A BRITISH TELEPHONE FACTORY IN PEACE AND WAR

A. J. Leyland, B.E., M.I.E.E.

On 1.4.47, at a meeting of the Postal Electrical Society of Victoria, Mr. Leyland, Director, Automatic Electric and Telephone Manufacturing Co. Ltd., Liverpool, England, delivered an address describing the problems of a telephone manufacturer in England in peace and war. A film entitled, "Where there's a Will," in which were explained many interesting and intricate processes used in the production of telecommunication equipment, was shown before the address was given.

After discussing briefly the subject of the film and the work carried out in the factory, Mr. Leyland continued with a description of manufacturing conditions which applied in England during the war, the problems associated with reconversion to peace-time production, and concluded with a discussion on the probable developments in the telecommunication art. Part of the address is reproduced in the following pages.
—Editors.

1. Production in War Time England

Shortly after Munich the whole of war-time potentiality in England was allocated to the various Supply Ministries, and we in Liverpool were earmarked for the Ministry of Aircraft Production, although about half way through the war this application was extended and a considerable volume of work was carried out for the Ministry of Supply on Line Transmission equipment.

A very rigorous control of the release of raw materials was instigated, as was a control of manpower, and both materials and manpower could only be used on priority contracts. To this extent there was set up in England an organisation with which many of you are acquainted by name at least—the Precedence Panel—whose responsibility it was to authorise production of essential telephone equipment for home and overseas demands. The extent to which this production was controlled can be visualised from the fact that at the end of the war period something under 12% of our total effort only was being allowed to be absorbed on telephone activities.

On the manpower side, Labour Boards were established, whose duty it was to make detailed periodic inspections of factories, and to reassign personnel to other factories if, in the opinion of this Board, the need of such reassignment was necessary. This task was rigorously carried out and, realising the importance of a full time concentration on the war effort, its objectives were conscientiously observed throughout the country by factory managements. In other words, it can really be stated that there was a full concentration on the war effort.

The increased employment under unusual conditions introduced many problems. For instance, it became necessary to establish a hairdressing saloon in the factory, to expand the Medical Service, and to greatly increase the canteen meal services.

The hours worked in the factory were normally a day shift of from 8 a.m. to 5.30 p.m., but this was more often than not extended by overtime until 7.30 p.m., and a night shift running from 8 p.m. until 7 a.m. On the night shift the tendency was only to use machine operatives, since it was found that piece part production always lagged behind assembly operations.

Naturally, the labour which it was possible to recruit deteriorated so far as concerns its industrial skill as the war progressed, and the fact that such labour had to be used led to many problems in the lay-out of operations. The tendency had always to be one of breaking every job down into the simplest possible operational units, and this threw a tremendous load on the production planning organisation.

2. Difficulties Associated with the Problem of Meeting Peace Time Communication Requirements

As a result of the intense concentration on the war effort, the position of the world telephone situation today, as related to switching equipment, can only be described as one of acute shortage, the early elimination of which it is difficult to foresee. You yourselves in Australia have a waiting list of some 80,000 applicants. In Great Britain the figure is 400,000 and, I understand, is still increasing. New Zealand reports a figure of 30,000 waiting subscribers, whilst in the States an astronomical total of 2,000,000 is revealed. Similar conditions hold in South Africa and South America.

These figures all relate to countries which suffered to a relatively small degree, or in no way at all, from physical destruction, but when they are augmented by the demands for the replacement of plants actually destroyed on the Continent—this destruction applying particularly to Holland, Poland and Germany itself—and when the requirements to cover normal replacement of obsolescence are added, an almost insurmountable total results. To meet this supply problem none of the manufacturing potentiality of Germany is available, this having been completely destroyed.

I have covered in some detail the position resulting from the war, since to my mind this has a direct bearing upon the possibilities relating to future developments, in that it is difficult to see how the desire to introduce innovations of equipment design can be balanced against the pressing and urgent demand for service, and it would appear that a compromise will have to be adopted. A policy which will permit of the gradual introduction of desirable services and facilities where these can be incorporated, without extensive work on designs and tooling, but one which relegates to the future any radical departures from current and well proven systems and standards will be essential.

Apart from the tooling effort required to put new designs into production, the design and development aspect has to be taken into account, and this has to be linked with the fact that the individuals who are able to conceive such designs, and have had real experience in their application, have for a period of six years been devoting the whole of their energies to other channels. Reorientation is not easy.

To illustrate this problem, and again taking the Liverpool organisation as an example, I recollect that in 1939 we had 47 people engaged upon planning and ordering automatic exchange equipments. In 1945 this figure had been reduced to 7.

Therefore, it would appear that whilst the war did stimulate discovery and development to an extraordinary degree in many spheres, we are confronted with the fundamental fact that a standstill period, such as will allow the application of these developments to telephone switching technique, is, on account of the supply position, not possible; in other words, in a world of plenty there is a comparative shortage.

There are, however, many projects that are actively being investigated, these being primarily associated with the improvement of mechanical and electrical components. On the mechanical side many of the improved manufacturing methods developed during the war are being incorporated in production.

One very important step which has been taken is the installation and equipping, on most modern lines, of a very extensive gauge room, where accurate measurements by means of projectors, comparators, and such instruments, can be made. A routine is in being whereby every gauge in factory use is checked at least once per week, and the effect of this check on the accuracy of the piece parts can well be imagined.

On the electrical side new materials, particularly in the insulation field, are gradually becoming available and are being considered, tried out and applied wherever possible.

3. Future Trends and Developments

Considerable stress is being laid on the development of automatic routining aids, which are becoming more and more necessary as the availability of trained maintenance personnel is decreasing, and the future tendency must be one of introducing mechanical aids to the fullest extent, so as to bring about economy in maintenance.

Other than these process developments one cannot visualise the introduction of revolutionary new principles for some years to come.

The destruction of the Siemens Halske plant in Berlin has left many Continental administrations in a quandary in that they cannot obtain any of their existing types of equipment for maintenance or extension. The maintenance parts are largely being obtained by sabotaging existing equipment, but for extension requirements a system has been designed such that it will work into the existing system without any plant modifications. Existing partially equipped racks can, under certain circumstances, be fully fitted. Equipment of this type is being supplied to Holland.

On the switching side, which I define as the application of the mechanisms available, it is probable that much more can be accomplished at an earlier date, since such applications are largely a direct demand for circuit design ingenuity.

One of the major problems in this connection which is being considered by all administrations is that relating to the possibility of extending the local subscriber's dialling area. With such an extension arises the associated problems of impulse repetition, and the method of registering the subscriber's call on a multi-fee basis, or by the alternative possibility of automatic ticketing.

Dealing first with the extension of the local subscriber's dialling area, there is no fundamental difficulty in overcoming impulsing problems provided line conditions are suitable, and in both Switzerland and Holland all country dialling is at present in operation. In both these countries a combination of D.C. and A.C. dialling methods is used, and in cases where A.C. dialling is necessary the tendency has been to increase the frequency employed to a figure between 2,000 cps. and 3,000 cps. These frequencies have been adopted on the claim that they give, under service conditions, greater immunity from maloperation arising from voice frequency interference. It appears likely that the adoption of a higher frequency will be universally recommended.

Thus, from a technical aspect there is nothing insurmountable in the problem of extending the dialling field, but the resultant difficulties as concern operating procedure and administrative accounting loom very much to the fore; in fact, a position has almost been reached where, to use a medical simile, it can easily become true that "The operation was successful, but the patient died," unless registration and accounting procedures keep in step with dialling advances.

Any extension of the subscriber's dialling area automatically throws on to the subscriber the onus of dialling correctly the requisite routing digits. In Holland, in the extreme case, the subscriber is asked to dial ten digits, and the interference with, and unnecessary hold up of, expensive junction plant arising from dialling errors, has to be seriously considered by the operating administration. In Holland the tendency is to overcome this problem by charging the subscriber for the use of the plant whether such usage results in a successful call or not.

The recording of subscriber dialled long distance calls and the presentation of accounts is also a problem of magnitude, and, both in Holland and Switzerland such calls are merely recorded on the subscriber's meter on a time and zone basis, and no separate account is taken or rendered of individual trunk calls. The success of such a policy seems to be intimately linked with the education of the subscriber, but whilst it is undoubtedly being applied in these countries, to us it cannot help but appear a policy of questionable value, and possibly one which would not be accepted by the public as we know it. I understand that in some cases of a single call, as many as thirty registrations are recorded on the meter and that, in the case of particularly busy subscribers, the complete train of meter recordings is gone through within a single week's operation. The problem of meter reading under such circumstances can well be imagined.

Looking at the position rationally, it would seem that a mid-way policy will ultimately prove to be the general answer—one such that the subscriber will be able to dial himself along routes where possibly one or two routing digits are necessary, but on routes where the trunking lay-outs demand the transmission of a larger number of digits, a single operator at the originating end of the call should be brought in. In any event, the problem of working into existing equipment causes no little complexity.

In either case the question of presenting an account to the subscriber arises, and designs are already in being, and equipment is functioning in service, whereby the necessary information—the calling subscriber's number, the called subscriber's number, the duration of the call and the summated resultant charge, are all automatically produced. The incorporation of such plant in trunking schemes seems to be a necessity for the future—in the case of subscriber dialling to present a separate record, and for operator assisted calls, to obviate the necessity of manual docketing and so to increase the call handling capacity of the operator.

It is obvious, however, that the successful application of equipment of this type is entirely dependent upon the availability of an adequate junction plant, since to be successful calls must be capable of being put through on a demand basis. Any introduction of delayed call working can only lead to confusion.

The problem of designing the equipment so that it can be applied economically to the smallest satellite, or possibly rural exchange, is one that has to be considered, but schemes have been worked out which seem to indicate that there is full hope for economic application even in these extreme cases.

An ultimate extension of automatic recording facilities on trunk calls would seem to be possible by having a central organisation in each area, such that the information can be punched directly upon machine recording cards. By this means, sorting and ultimately the preparation of subscribers' accounts could be accomplished mechanically without human intervention of any description.

The extension of subscriber dialling would also appear to demand facilities for automatically directing a call over an alternative route, in the case of an all trunks busy condition being encountered on the first trial, and generally such complications of equipment would be demanded as must warrant careful consideration and study of the relative economics, before adoption by any administration.

It is becoming apparent that the great increase in long distance traffic is demanding in turn an increase in the size of the manual boards to handle such traffic, so much so that for large trunk centres it would appear that automatic switching aids will have to follow, and it is considered that the successful application of these must depend upon the possibility of searching at high speeds over large groups of junctions.

It is apparent that a great demand will arise in the near future for the provision of a full twenty-four hours' service in isolated rural areas. This, as you will all be fully aware, has always been one of the outstanding problems, particularly as regards the economic provision of such a service.

In the past there have been various schools of thought ranging from the provision of a fully automatic service for rural areas, to the compromise possibility of providing such service on a semi-automatic basis whereby the necessary manual switching operations can be concentrated at a single switching centre for each area.

In certain Continental countries prior to the war a leaning was shown towards semi-automatic operation, but from our experience of networks, actually installed on a semi-automatic basis in Portugal, the theoretical advantages are not by any means proved in practice. The universal hope of the administration in adopting semi-automatic systems is that they will economise on the provision of junction circuits, but the resulting congestion has, in practice, disproved the theory, and the administration has invariably been forced to increase the junction provision. This, in many cases, has been necessary to such an extent that a fully automatic service could very conveniently have been given, but, unfortunately, capital has already been sunk in the provision of semi-automatic units.

From our experience, it would appear that semi-automatic operation has, in practice, nothing to commend it.

The economic provision of rural exchanges is undoubtedly linked up with a standardisation and simplification so far as concerns facilities, and it is indeed unfortunate that a standardisation of these facilities could not be universally adopted throughout the world. If this standardisation could be realised I am sure that the advantages of mass production possibilities would quickly reduce the cost of the present expensive small sized exchange.

On the transmission side, it would appear that a much more extensive use of co-axial cable is bound to be made. In England during air raids it was found that the ease of repair of a co-axial cable, as compared with a lead covered paper insulated cable, well justified the former, and actual operating economics seemed to be pointing towards the introduction of co-axial cables on routes even down to fifty miles in length under suitable traffic conditions.

The trunking plan for the European network now being considered by the C.C.I.F. contemplates the installation of a ring main co-axial cable round the entire central European territory, with spurs branching off to the more distant countries. This plan appears to have universal acclamation and it is intended that some of the first circuits will be in operation by 1949.

In the more sparsely populated countries it would appear that multi-channel telephony of 12 or 17 channels on open wire routes will hold the field, but you yourselves have had far more experience in operating these than we have had in England.

The tendency in design on all terminal and repeater equipment will undoubtedly be towards miniaturisation of the components, since in large metropolitan areas the cost of housing the necessary equipment as related to land purchase values is already proving a controlling factor in the economical application of the equipment.

In this case work which has been performed during the war in the production of miniature valves, resistors and capacitors will be of direct use to the designer for peacetime application.

On the telegraph side, it would appear that a more extensive use will be made of the teleprinter, and this will probably go to the extent of installing automatic teleprinter switching exchanges, whereby the user can automatically connect himself to any other teleprinter subscriber on the network. Considerable strides in this direction had apparently been made in Germany by the German State Railways, and much useful information has been collected since the war.

The use of V.F. telegraph systems will provide the possibility of multi-channel operation.

For tandem working in cases where direct teleprinter to teleprinter service cannot be given, a regenerative reperforator will be needed so that messages can be automatically received and retransmitted on a five digit code basis. In such cases it will be advantageous for operational purposes to overprint the five digit code perforations by straight alphabetical characters so that re-routing operations can be carried out by relatively unskilled staff.

As a competitor to all wired communications, the possibility of the utilisation of multi-channel radio links on a V.H.F. basis has to be considered and no doubt the radar technique developed so extensively during the war will be capable of application in this direction. At the present moment, as you are probably aware, there are multi-channel radio links operating between England and Northern Ireland, and the enormous experiment at present being carried out by the A.T. & T. in America on the New York-Boston route is also a pointer which indicates that radio links will be more extensively used in the future.

The operation of teleprinters over radio links is also a problem which will find considerable application, and again, I understand that a successful London to Cairo teleprinter link is at present in full operation.

The ultimate success of the operation of all radio links would appear to be associated with the nearness to which a full twenty-four hour service can be given.

Generally, the vista which can be opened up on possible developments seems to be without limit, but the present position is one of fluidity and it is difficult to forecast accurately what the ultimate outcome will be. One thing the war has shown is the importance of scientific research and development, and every effort is being made to apply the discoveries of war to the applications of peace.

Realising this, every concentration is being applied to technical training, and in most factories in England the extent of student training courses is being augmented. These courses are proceeding along lines such that they supplement, by specialist application to the telecommunication industry, the more general training courses which are provided by the Universities and Technical Colleges. There is a tendency to depart from the past usage of night training courses only, and all junior employees in industry are being given facilities to take day training courses to the extent of one day per week.

The fruition of such schemes must demand time, but I think that portents are already being shown such that the communication industry will not be long in fully re-establishing itself to the position of eminence it held before the war.

THE SHEPPARTON INTERNATIONAL BROADCASTING STATION, "RADIO AUSTRALIA"

R. B. Mair, B.E.E., A.M.I.E.(Aust.)
A. J. McKenzie, M.E.E., A.M.I.E.(Aust.)
W. H. Hatfield

DESCRIPTION OF EQUIPMENT
PART 2

In the February, 1947, issue of the Journal, Part 1 of this article described in some detail the radiating systems, radio frequency transmission lines, aerial switching system, power supply equipment, and buildings of the high frequency broadcasting station "Radio Australia." This part describes transmitters Nos. 1 and 2. The third transmitter will be described in the next issue.

The three high power transmitters operate under the call signs VLA, VLB and VLC.

No. 1 and No. 2 Transmitters

The No. 1 and No. 2 transmitters (VLA and VLB) are of the same type, jointly manufactured in Australia by Messrs. Standard Telephones and Cables and Messrs. Amalgamated Wireless, to the general design requirements of the Postmaster-General's Department. The guaranteed output of each transmitter is 100 kW for frequencies up to 15.2 Mc/sec, 95 kW at 17.8 Mc/sec and 80 kW at 21.6 Mc/sec. Each transmitter comprises a driver unit capable of an output of approximately 8 kW for driving the high power channels; two high power channels, either of which may be driven by the driver unit; a modulator unit which may be employed to modulate either of the high power channels, and two high tension rectifiers, which are normally employed to supply power to the anodes of the modulator and working high power channel, respectively. In addition the driver unit includes a modulator unit which may be employed in the event of failure of the high power system, to modulate the driver output which may be fed directly to the aerial system. In the case of each transmitter, the driver unit incorporating its own rectifiers and emergency modulator, comprises a self-contained transmitter of seven adjacent cabinets, located on one side of the transmitter hall, with front and rear access doors. On the same side of the transmitter hall and at the back of the driver unit are located the two high tension rectifiers for the high power stages. Between the rectifiers is a small room accommodating two working and two spare blowers, one supplying air to the driver stages, and one supplying air to the high power stages. On the opposite side of the transmitter hall are located the two high power radio frequency channels, and between them the high power modulator unit, with its audio driver stages and associated power supplies.

Two cubicles for each transmitter on the side of the building on which the high tension rectifier units are located, each house the high tension transformer and choke for the associated high tension rectifier. These cubicles are adjacent to the transmitter hall, and have steel shutters opening into a gangway adjacent to the external wall of the building. On the side of the building on which the high power transmitter units are located, and adjacent to the transmitter hall, a similar cubicle for each transmitter accommodates the high power modulation transformer and choke, and auxiliary equipment such as modulator blocking condenser, feedback resistor and partial modulation resistor. Cooling equipment is located in the basement, as well as external to the building. A block schematic of the tube set up of the transmitter is shown in Fig. 12(a).

Driver Units

A description of the driver unit will be given first. It comprises seven adjacent cabinets which are designated as follow:—

EHT rectifier No. 1;
1 kW unit;
8 kW amplifier;
Modulation Transformer unit;
Modulator unit;
Power control unit;
EHT rectifier unit No. 2.

With the exception of the modulation transformer unit, each cabinet is provided with a front door which, when opened, displays all the power and tuning controls. The more important circuit meters are located on sub-panels above the doors, and are visible with the doors closed.

In the radio frequency part of the driver unit, the low power radio frequency is generated and amplified to 1 kW in the 1 kW unit, which is a self-contained unit with its own power supplies. The upper half of this unit shown in Figure 13 embodies three "jack-in" chasses. The lower of these is the frequency control unit, and comprises the crystal controlled oscillator, and the "master" oscillator followed by an untuned separator stage, and two tuned multiplier stages. All the tubes in this unit are R.C.A. 807 type. Above this is an amplifier unit employing two R.C.A. 813 pentode tubes in push pull, and at the top of the cabinet an amplifier giving an output of about 1 kW and employing two 833 type tubes in push pull.

The crystal oscillator is of the Pierce type employing 10 "plug-in" crystal units each incorporating its own crystal oven. The crystals are selected by means of a 10 position switch operated from the front panel. This switch carries a bank of contacts connected in series with aerial switching contacts, preventing power being applied to any aerial from the transmitter unless the switch is located at a position corresponding to the appropriate aerial frequency. This condition applies even when the master oscillator is in use, i.e., the crystal switch must be thrown of the transmitters, the frequency drift amounted to 0.05 parts in a million. The crystals employed vary in frequency between the limits of 3.1 Mc/sec. (half the lowest transmitter output frequency) and 5.4 Mc/sec. (one quarter of the highest transmitter output frequency). Following the oscillator stages, a separator stage employing a single 807 type tube operates without tuning or other adjustment for any frequency

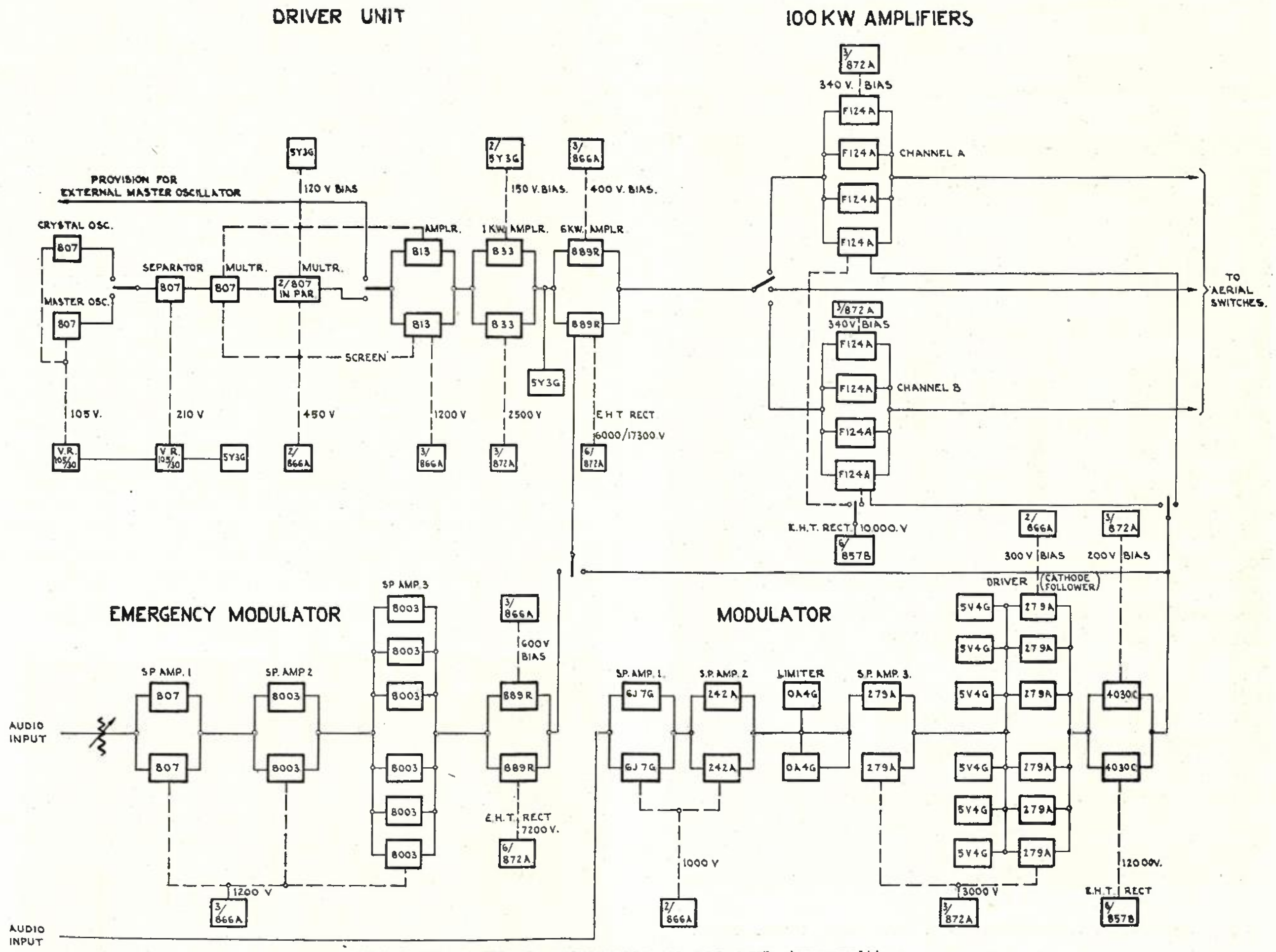


Fig. 12(a).—Block schematic of 100 kW. transmitter.

to a crystal of the aerial frequency. The master oscillator is of the "Colpitts" type. A variable tuning inductance is employed comprising a copper wire helix having a rotating tapping arm driven by a lead screw operated by the dial. Condensers are selected by a three-position switch, and the condensers employed are proportioned to give temperature compensation to the oscillator. The frequency drift using the master oscillator during two 18 hour heat runs on one of the transmitters was less than 100 parts in a million.

In the case of the crystal oscillator, the frequency may be adjusted to the desired value by the trimmer condensers, and a frequency stability of 10 parts in a million was guaranteed by the contractor. During an 18 hour heat run on one employed. This successively feeds two multiplier stages consisting of a single 807 tube, and two 807 tubes in parallel, respectively. The first multiplier stage is used as a doubler at all frequencies. The second multiplier stage is normally used as a straight amplifier at frequencies below 11 Mc/sec., and as a doubler for frequencies above 11 Mc/sec. The output of the second multiplier is "link" coupled to the 813 push pull stage, a variable "phasing" condenser being connected across the link coil in the multiplier stage, to enable the degree of coupling to be varied. Provision is made for switching the input of the 813 stage to an external master oscillator if desired. A small amount of cross condenser neutralizing is provided in the 813 stage, and this requires no adjustment over the whole frequency range. The output of the 813 stage is link coupled to the 833 stage, a parallel "phasing" condenser being provided for adjustment of coupling. Neutralizing (of the conventional cross condenser type) is provided, the condensers being adjusted from the front of the panel, and requiring slight adjustment at each operating frequency. The output of this stage

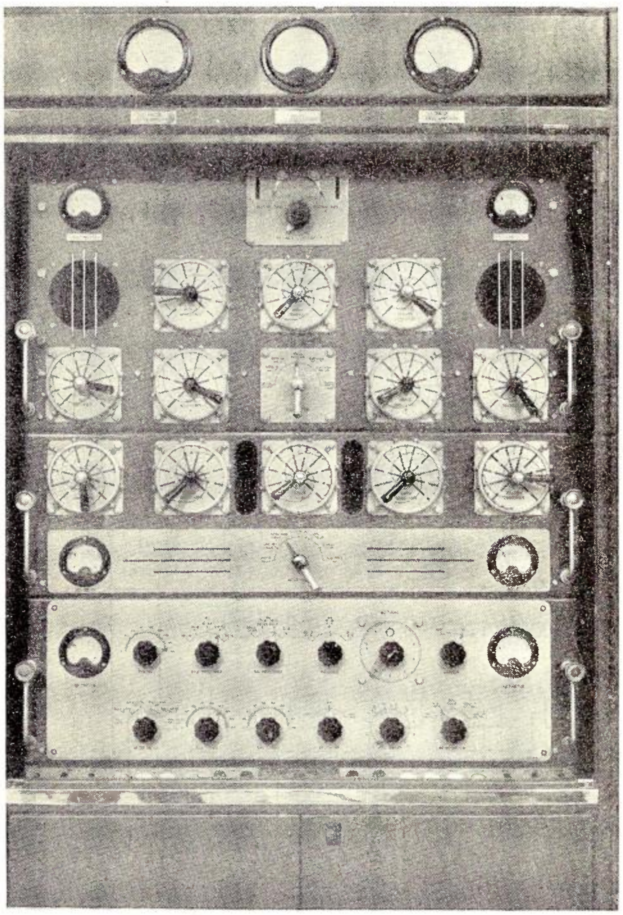


Fig. 13.—100 kW. transmitter, 1 kW. unit, front view.

is fed by means of a short transmission line to the grids of the 889 R. stage, inductive "link" coupling being employed as elsewhere, with a "phasing" condenser across the output coil. A balanced diode voltmeter is provided across this line to give a relative indication of output voltage from this unit.

In all the stages of the 1 kW unit, tuning is effected by means of variable air condensers as well as by tappings on the coils. Tappings are selected by switches, and where coils are coupled for "link" coupling, both of each pair of coupled coils are tapped by means of the same switch. This applies in the case of the coils up to the grid of the 833 stage. In the anode of this stage separate switches are provided for the two sides of the anode inductor, and one for the output inductor. Metering is effected by means of multimeters on the individual chassis with the aid of selector switches. Meters are also provided on the panel at the top of the unit for indication of grid current, anode current and anode volts in the 1 kW stage. All tuning and metering control and switching are effected from the front of the panels. Power and control equipment for the 1 kW unit are provided in the lower part of the unit making it self-contained.

The control equipment is conventional, time delay being provided to allow filaments to heat up before switching on anodes. Anode voltages are switched on through resistances in the transformer primaries which are subsequently short circuited. In the case of the 1,200 volt and 2,500 volt rectifiers, provision is made by means of switches in front of the panel to prevent these resistors being short circuited, in order that the anode voltage may be reduced for testing purposes. Overload protection is provided in the case of the 450 volt, 1,200 volt, and 2,500 volt rectifiers, and in the individual cathodes of the 833 stages. These overload relays energise a relay which locks out the anode voltages preventing recurrent reclosing of the anode voltage supply. The anode voltage is restored by pressing the normal "anode on" push button. The 1 kW unit is completely self-contained in regard to power supply, and may be operated from push buttons on its own panel, but it is normally operated from the power supply unit or from the control desk.

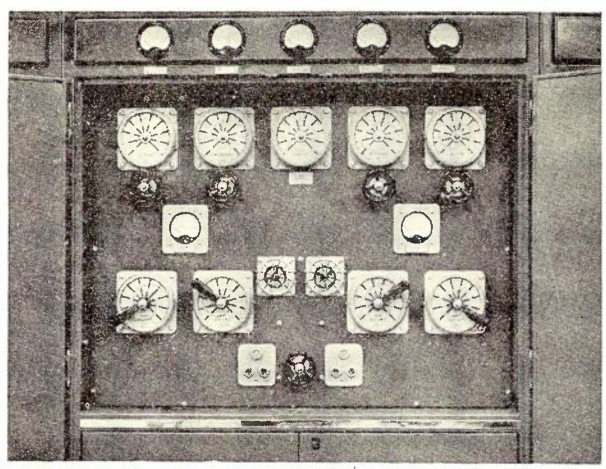


Fig. 14.—100 kW. transmitter, 8 kW. unit, front view.

The 8 kW amplifier unit, a front view of which is shown in Figure 14, employs two Type 889 R. air-cooled external anode tubes in push pull, cooled by air blast supplied by blowers in the unit. The amplifier is of the conventional push pull type with cross-connected condenser neutralizing. The grid circuit is inductively coupled to the link from the 1 kW amplifier. The output circuit is a balanced "Pi" network. All controls, including the neutralizing condensers, output coupling condensers and tuning coil taps, are operated from the front panel. The output from the unit is fed over a four inch overall diameter balanced shielded line, which extends along the ceiling of the basement to a switch under the high power modulator unit, and feeding either the aerial systems, or either high power channel. The anode voltage is modulated either from the emergency modulator when feeding direct to the aerial system, or from the output of the high power modulator when feeding a high power channel. In the latter case, only partial modulation is applied, of capability of the order of 60% and is required to ensure that the high power stage is driven to saturation during peaks of modulation. This modulation is applied through a resistance and condenser located in the modulation transformer cubicle, and through a 4-inch co-axial line extending along the basement ceiling. For both methods of modulation, the modulation choke must be in circuit, and changeover is effected by means of a switch in the modulator unit.

The two EHT rectifiers in the driver stages are similar in design, one normally feeding the 8 kW amplifier, and one the emergency modulator. They may be transposed by means of a changeover switch on the modulator unit. The rectifiers each employ six 872A tubes in a three-phase voltage doubler rectifier. Voltage control is effected from the front of the panel, by a star delta switch, and a tapping switch on the transformer primary. Provision is made for switching on the anode voltage through resistors in the primary transformer supply and subsequently short circuiting these resistors. The short circuiting switch may be frustrated by a switch on the front panel to reduce the anode voltage for testing purposes.

The emergency modulator unit employs two 889R. external anode air-cooled tubes driving a push pull modulation transformer whose output is choke coupled to the modulated amplifier unit. It is driven by six type 8003 tubes operating as a push pull cathode follower. The earlier speech amplifier stages are of conventional design.

The power control unit houses the main relays and contactors for the power control circuit, as well as the Westinghouse de-ion circuit breakers operated from the inside of the unit, and protecting and isolating individual circuits. The power supply to the driver stages is 400 volts 3 phase, and is derived from one of the regulated (tap changing) 500 kVA transformers associated with the 400 volt switchboard and supplying power also to the filaments of the high power stages. The power control unit is provided with two motor operated selector switches which switch on blowers, filaments and anodes in the correct sequence. The filament selector switch controlled by "on" and "off" buttons on the power control unit or the transmitter control desk, switches on equipment in the following sequence:—

- 8 kW stage blower;
- Modulator blowers;
- Main air blowers (in cooling room);
- 8 kW stage filaments;
- Modulator filaments;
- 1 kW drive unit filaments, and bias and oscillator anode rectifiers;
- 8 kW stage miscellaneous filaments;
- Modulator miscellaneous filaments;
- Main rectifier 1, filaments;
- Main rectifier 2, filaments.

When the switch on the modulator unit is operated to the remote modulated position (modulation of the 8 kW stage from the high power modulator) the switching on of the blower and filaments associated with the modulator is frustrated. A standby switch is provided in the power control unit which, when thrown to the standby position, switches off the main air blowers, the 8 kW unit and modulator miscellaneous filaments and the 1 kW unit filaments, and reduces the voltage on the 8 kW stage and modulator (889 R. tube) filaments. This facility enables the 889 R. tubes to be run at low voltage during short "off the air" periods, and enhances the life of these tubes. Voltage regulators are provided in this unit for the 8 kW stage and modulator filaments. They comprise a voltage relay which actuates a motor operated switch selecting transformer tappings. If so desired, the relay may be cut out of circuit and the motor operated by "raise" and "lower" push buttons.

Bias and anode voltages may be switched on by means of a high tension selector switch on the power control unit. This switch is made available by a "local-auto" switch on the control unit. When it is in the local position the selector switch is operated by on-off push buttons on the power control unit or on the transmitter control desk, and switches on the rectifiers in the following sequence:—

- 8 kW stage bias rectifier;
- Modulator bias rectifier;
- Speech amplifier anode rectifier;
- 1 kW stage anode supplies;
- 8 kW stage anode rectifier;
- Modulator anode rectifier.

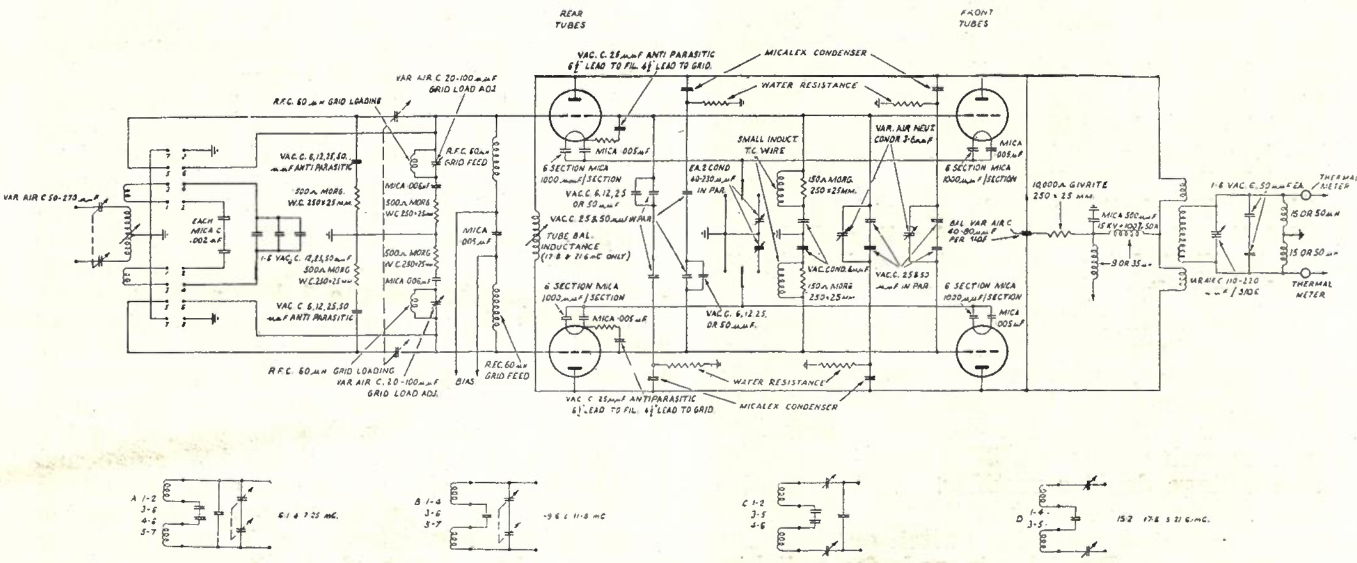
As in the case of the filaments, the setting of the modulator selector switch on the modulator at "remote" frustrates the operation of the modulator and speech amplifier rectifiers. A switch is provided at the power control unit to stop the selector switch during its course. When the "local-auto" switch is thrown to the "local" position, all these rectifiers must be switched on at the 1 kW unit, 8 kW unit, and modulator unit.

Conventional protective features are provided in the power control equipment. Time delay on anode closing, bias failure protection. and overload protection are provided. The overload protection provides for reduction of anode voltage in the event of a fault and recurring reclosure until such time as a time delay relay operates, locking the anode voltage at the low value.

High Power Units

The 100 kW channels each employ four Federal type F124A tubes in parallel push pull. A schematic circuit of a single high power channel is shown in Figure 15. The circuit is a conventional cross neutralized push pull circuit and the layout is designed to reduce stray inductances of the rods are insulated from the anodes by means of pyrex insulators, the series bridge being connected diagonally between the top and bottom rods, adjacent to these insulators. Coupling to the transmission lines is inductive and the coupling circuit employs a truck mounted variable air condenser ("butterfly" type) which carries an inductance similar to the anode inductance.

The mutual inductance between the output and anode inductances is varied by moving the truck towards or from the tubes. Control of coupling,



GRID CONNECTIONS

Fig. 15.—Schematic of 100 kW. power amplifier.

and capacities. A photograph of the actual stage taken inside the channel enclosure is shown in Figure 16. The pair of parallel tubes for one side of the push pull circuit are mounted in a metal frame which supports the anode jackets of the tubes. The frame is mounted on pyrex glass insulators, and is metal covered, and forms one electrode of the anode tuning condenser. Variation of capacity is effected by moving a central electrode up between the anode electrodes, a hole in the floor being provided to accommodate it, and operation being effected by mechanical drive from a handwheel in front of the high power unit. The electrode consists of a number of parallel vertical tubes of diameter about 6 inches and almost touching, and terminated at the top in hemispheres of their own diameter. This design has been adopted in preference to a solid plate electrode to eliminate possible eddy current troubles. The anode inductance is provided by two or four rods (of diameter about 4 inches) screwed to the anode framework. These rods are replaceable and are connected by bridging links to provide "U" shaped or transmission line type inductors. They may be series or parallel connected as desired. A series connection is shown in Figure 16, and in this case two as well as adjustment of the variable air condenser, can be effected mechanically by handwheels on the front of the channel enclosure. The condenser and inductance form a parallel tuned circuit across the output transmission line. Connection to the output transmission line is made through two inductance shunted 1 Amp. thermal meters, and a pair of telescopic rods which form part of the 307 ohm output line. At low frequencies suitable vacuum condensers are series parallel connected across the truck mounted condenser. It has been found that at frequencies above 15.2 Mc/sec., the load between the front and back F124A tubes connected in parallel is unequally divided, and to reduce this unbalance a short transmission line inductance is connected in parallel with the main inductance between the anode frameworks at the back of the unit. To provide some adjustment of load between the sides of the push pull stage, an adjustable vertical rod may be moved in proximity to either side of the main anode inductance. This rod is connected to the centre plate of the anode condenser, and forms a small differential condenser. The anode condenser and main tuning coils are free of sharp edges and are chromium plated to eliminate possibility of corona trouble. The grid and filament equipment is mounted above the tubes, which are provided with six phase filaments, in order to reduce carrier noise. A six section mica condenser is mounted just above each tube to bypass the filaments.

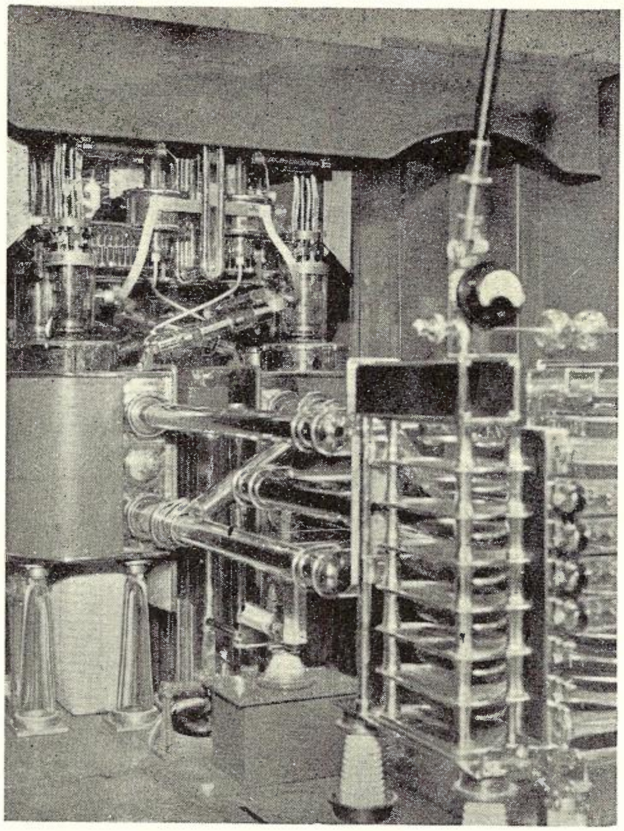


Fig. 16.—100 kW. transmitter power amplifier.

For frequencies of 15.2 Mc/sec. and higher, the radio frequency filament circuit is provided with series variable air condensers to reduce the reactance in the filament circuit, and reduce the possibility of parasitic oscillations at or near the operating frequency. The neutralizing circuit is built up of series banks of vacuum condensers connected between grid and anode of opposite tubes both front and back. The use of series condensers alone would result in a doubtful distribution of d.c. voltage across the condensers, and to eliminate the d.c. from the vacuum condensers these condensers are shunted with sections of rubber hose pipe carrying cooling water from the anode to the grid circuit loading resistors and acting as shunting resistors, while small micalex condensers connected between these and the anodes carry the d.c. voltage. Fine adjustment of neutralizing capacity is effected by means of short sections of concentric cylinder condensers, the outer section of cylinder sliding co-axially away from the inner section. Mechanical control is effected by a handwheel outside the channel enclosure. The crossed banks of neutralizing vacuum condensers may be seen in the photograph of Figure 16 connected between the front tube grids and anodes and above them the sliding cylinders of the variable air neutralizing condensers. The grid circuit is inductively coupled to the inter-unit 4-inch balanced line which runs from the switch on the ceiling of the basement below the modulator unit to the top of each channel. Replaceable coupling and grid coils are provided, and various grid connections are obtainable by means of links for the circuit variations required with frequency. A bank of vacuum condensers is used for coarse tuning, and these are connected across the grid tuning inductance forming a parallel tuned circuit, or in series with the two halves of the grid inductance. The variable air condensers used for fine grid tuning may be connected either across the grid inductance, or in series with it and the tubes. Water cooled grid load resistors are provided as well as a number of anti-parasitic condensers and resistors. Variation of grid coupling and grid tuning are effected mechanically by handwheels on the outside of the channel enclosure, as is the adjustment of two series condensers in the output of the feeder line from the driver stages.

The vacuum condensers referred to consist of glass tubes about 2 inches in diameter and 6 inches long with metal end caps forming a plug-in unit. The condenser electrodes are interleaved concentric cylinders about 1 inch long, and of maximum diameter about 1 inch. Condensers of identical physical dimensions and having capacities of 6, 12, 25 and 50 micromicrofarads are in use. The flashover voltage rating of these condensers is about 32 kV peak. These condensers are very convenient for use at high frequencies, as their high Q value enables them to work at a high rating of kVA without heating, the limitation up to 20 Mc/sec. being voltage rating. They thus occupy considerably less space than mica condensers of similar rating.

At the rear of each channel enclosure and behind the actual F124A stage, is a cabinet in which are located the filament supply transformers for the F124A tubes, and the filament protective relays. These are differential relays which remove the high tension in the event of the filament current in any of the six phase strands of an F124A tube differing from the currents in the others. The bias rectifier is also located in this cubicle. The channel enclosure is a metal walled enclosure provided with a single access door from one side of an "alcove" between the modulator and the channel enclosure. The access door is of the "grill" type allowing the inside of the enclosure to be observed. A glass panel is also provided for the same purpose on the front of the enclosure. The main meters indicating total water flow, grid current A and B, total plate current and anode voltage are located on the front panel, as well as grid coupling and tuning, anode tuning, and output cooling and tuning controls. Anode voltage "on-off" and voltage control are also provided. On the side of the enclosure in the "alcove" are located individual cathode meters, leakage and bias meters, and a diode meter indicating voltage on the output line, as well as neutralizing and filament tuning controls. An interlocking key is provided on this panel, removal of which prevents application of the anode voltage, and which is used to open the door of the associated section of the cooling room in the basement.

Modulator Unit

The modulator unit is housed in an enclosure similar to the channel enclosures, and located between them. The unit employs three conventional amplifier stages using resistance and choke coupling. The fourth stage employs six type 4279A tubes, operating in push pull as a cathode follower, and driving the two 4030C modulator tubes. The cathodes of this stage are fed through a single two-section choke, and are directly connected to the modulator grids. Diodes are connected across the cathode follower grids to reduce the distortion due to negative grid current in these tubes. The output from the modulator unit is fed through the conventional modulation transformer and choke circuit to the modulated amplifier channel. The modulation transformer was supplied by Messrs. Ferranti Ltd., London, and is capable of handling an audio frequency power of the order of 100 kW. Partial modulation is fed through a resistor from the modulation transformer output to the anode of the driver stages. This resistor is oil cooled, and is housed in a metal case of considerable proportions. Feedback of the order of 16 db is provided over the whole audio system, a resistance potentiometer being connected across the modulation transformer circuit. Two noise neutralizing circuits are provided injecting 100 c/s and 200 c/s voltages (derived from 50 c/s full wave rectifiers feeding tuned transformers) into the grids of the second speech amplifier. Neutralization is provided in the third speech amplifier, to avoid reduction in the high audio frequency response. A limiter is provided between the second and third speech amplifier.

Figure 17 is a photograph of the modulator tubes which are floor mounted in the centre of the enclosure. Spare modulator tubes are provided, whose filaments and grids are switched in circuit by means of mechanically operated and electrically interlocked changeover switches. Behind the modulator tubes is a cabinet with front and back doors, housing the speech amplifier stages including auxiliary bias and anode rectifiers. In the front of the modulator unit is a floor mounted switch which is employed for changing over the anode supply to the two high power channels, and which ensures that the anodes of the unused high power channel are earthed. This switch is operated from a handwheel on the front panel of the modulator unit in conjunction with the selector switch in the R.F. line, from the driver stages located in the ceiling of the basement. This switch, in conjunction with the interlocking of the access doors, ensures the safety of personnel working in the channel which is not in use, while the other

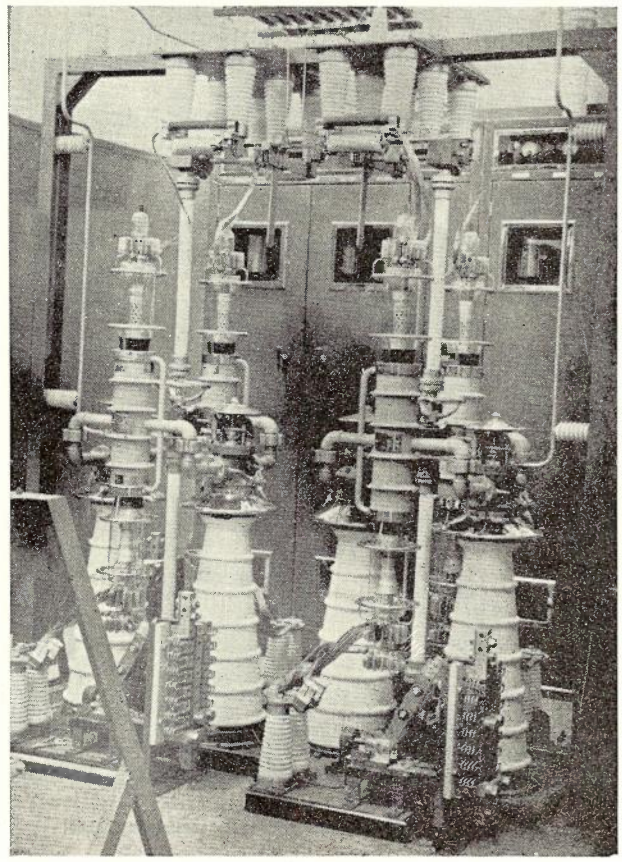


Fig. 17.—100 kW. transmitter. View of high-power modulator unit.

channel is operating. The main modulator and driver meters are located in the front of the modulator unit with the less important meters in the alcoves at the side of the modulator unit and inside the unit. Push buttons for anode voltage "on-off" and for anode voltage variations are located on the front panel. The filaments of the modulator stage are Scott connected. Parallel connection of these filaments, although giving a better noise level at zero modulation, introduces modulation of the audio frequency output of the modulator at twice the power supply frequency.

Two anode supply rectifiers are supplied for the high power stages and are identical in design. They each draw power from the 6600 volt supply, and voltage is controlled by means of "on load" tap changing transformers. The taps are selected by a switch which is motor operated through a "Geneva" star wheel. Control of these stops is effected by means of "raise-lower" push buttons which are located on the channel and modulator panels, and on the transmitter control desk. Depression of a button causes the voltage control to move one step in the appropriate direction. This control is effected through a preselector switch which may also be operated by hand from a control on the front panel of the rectifier. On switching off the transmitter, and switching on again, the initial voltage applied to the rectifier is always the last voltage applied before switching off, or the preselector switch voltage, whichever is lower. The position of the tap changing switch is indicated by meters on the rectifier panels and on the transmitter control desk. These consist of milliammeters supplied from a voltage controlled rectifier in series with a variable resistor operated by the preselector switch. Anode voltage is normally applied through oil cooled resistors in series with the rectifier transformer primaries, and these are short circuited after a suitable delay, by means of an oil switch in the cubicle which houses the rectifier transformer and choke. A hand operated "off load" tap changing switch is also provided on each rectifier transformer for coarse adjustment of rectifier voltage for testing purposes.

Each rectifier employs six 857B tubes in a six phase voltage doubler circuit. Two spare tubes are provided in each rectifier for rapid connection in the circuit in the event of a tube failure. The two rectifiers normally supply the working modulated amplifier channel and the modulator respectively. Provision is made for switching these loads in parallel to the output of either rectifier. The transmitter must then be operated at reduced power.

Protection

An elaborate protective scheme is provided in the transmitter. The usual filament and bias voltage protection are supplied, as well as time delay protection for switching on anode voltage subsequent to filament voltage. Overload protection is provided in the cathode circuits of the various tubes. Provision is made for reclosure of the anode voltage three times, following an overload and for locking the anode voltage out after the third reclosure. In each case after the fault is cleared the anode voltage is restored at a low voltage, and then brought up to full voltage. A complete personnel protective system is provided, all cubicles being provided with keys which are mechanically interlocked with the oil circuit breakers controlling the supply of power to the cubicles so that unless the cubicle shutters are closed and the keys removed and inserted in the circuit breakers, the circuit breakers cannot be closed.

Cooling System

The air cooling for each transmitter is supplied from two blower units with spares in a blower room in the main transmitting hall. Air is drawn into the room from the gallery outside the transmitter hall through an oil type air filter. From the 8 kW blowers a duct runs along the tunnel ceiling below the main transmitter hall to the modulation transformer unit in the driver stages, which it enters through a hole in the floor whence it is distributed to the individual driver units. Air is supplied from the same blower to the 857B tubes in the E.H.T. rectifiers. From the 100 kW blower, ducts run along the basement ceilings to the F124A tubes in the high power amplifiers and air is blown up past the anode to the glass envelopes of the tubes, and along the pipes forming the anode tuning inductors. A branch tube from one channel feeds air to the speech amplifier cabinets in the high power modulator enclosure. Flow of air to the channel amplifiers is controlled by means of solenoid operated valves.

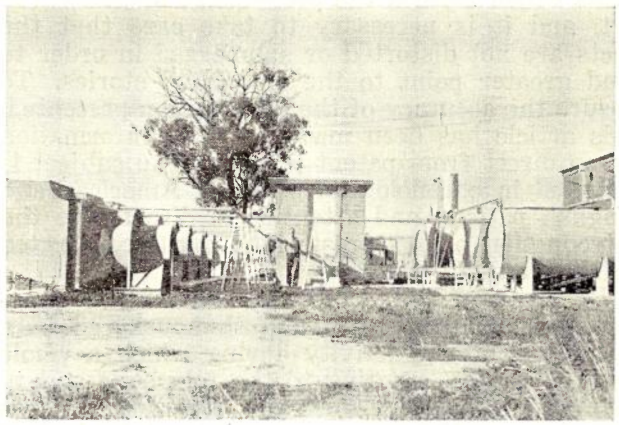


Fig. 18.—100 kW. transmitters. View of outdoor cooling system.

A room is provided in the basement below the high power stages to accommodate the insulating water tubes supplying the anodes of the high power tubes. These tubes are straight sections of porcelain tube connected in series. The room is divided into three sections by means of wire grilles and each section has a separate access door, whose key is mechanically interlocked with the interlocking switches on the modulator panel, preventing operation of the equipment unless the key is removed from the door to the associated enclosure in the main transmitter hall. In each section are also located leakage current electrodes and flow meters. In the basement adjacent to the water pumps is a switchboard common to both transmitters for control of cooling system pump and fan motors and carrying temperature indicators and other supervisory equipment. Figure 18 shows a general view of the 100 kW outdoor cooling equipment.

Control Desk

The transmitter control desk incorporates the various push button controls for control of blowers, pumps, filaments and anodes.

In addition an "on the air" key is supplied with an input level control, as well as a key switching the monitoring loud speaker on the desk to "audio input," "high power," or "low power" diodes, and a loudspeaker volume control.

(To be continued.)

THE DEVELOPMENT OF THE AUTOMATIC SELECTOR

J. A. Kline, B.Sc.

The bi-motional switch is the fundamental unit in machine switching of telephone circuits in the systems used by this Department. The invention of the prototype of this switch was the first step in the process of replacing manual operation, and the story of its development over the last 60 years forms practically the history of automatic telephony. There are many interesting and romantic tales told of the men associated with the production and marketing of the various new ideas which formed the progressive stages in the art, and it is necessary to take care that the facts are not distorted or submerged in order to lend greater point to the associated stories. To ensure the accuracy of the information presented, this article has been made up from information taken direct from patent records. The subject is followed in chronological order of American and English patents and attention is directed to the introduction of features which are incorporated in the present standards.

Dr. Graham Bell gave the world the first practical telephone in 1876, and thus ushered in a period of intense activity during which a whole host of patents relating to the telephone and to manual switching of lines was recorded. In this group one of the milestones was the introduction in 1879 of the multiple switchboard for manual working. This was patented by Scribner in England. In that same year automatic telephony was born.

On September 10, 1879, three Americans—Connolly Bros., and McTighe[1]—filed in New York the first patent for an "Automatic Exchange," as they termed the switch which was to obviate the necessity for manual operators.

They described a switch of doubtful practical value but of very special historical interest.

As one would expect, the ideas are based on manual practice, then well-established although only three years old. Certain characteristics of present-day switches were included in this origin of the species. They were:—

(a) Selection by impulses,
(b) Rotary type of switch,
(c) Ratchet device, and
(d) Preventing interference to engaged lines.

Fig. 1 gives the elements of the invention as disclosed in the patent.

There is one switch for each subscriber's line, all being mounted on a common shaft E one above the other The wiper W of the switch associated with the calling line is moved over contacts of each subscriber by a ratchet and pawl, and when the connection is established the contacts of the called line are withdrawn from the track of the wiper of any other switch.

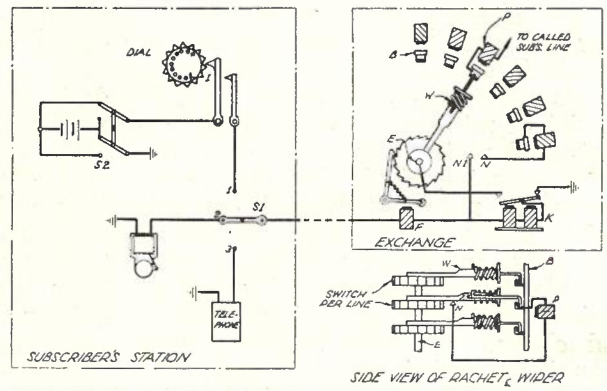


Fig. 1.—Principles of first automatic exchange, 1879.

The subscriber's station has a controlling switch, S1, a signalling battery with reversing switch S2, a bell, a telephone and some sort of impulsing device. It is stated that a telegraph key can be used for giving the required makes and breaks, but the patent describes a "rheotome" for this purpose which is fitted with an indicator to show the number of breaks given. A single wire can be used to connect the substation to the exchange.

Switch S1 is normally in position 2 with line connected to the bell. When the subscriber wishes to make a call the switch is set to position 1 and impulses sent which operate magnet F but do not affect magnet K. This sets the subscriber's switch to the contact of the wanted line. When impulsing is finished the calling subscriber changes over his switch S2 to reverse the battery. This operates magnet K but does not affect F, and the calling line is switched to the wiper and to the called line through magnet P. All the contacts of the called line are in a vertical column attached to a bar B which is pulled by the magnet P to take all the contacts out of the line of a rotating wiper of any switch. There is a clutch device on the end of the wiper which hooks on to, and is pulled out by, the contact which has been already established. Since the calling line has the outgoing connection broken at the off normal contacts N and N1 both lines are isolated to prevent interference.

Switch S1 is placed in position 3 to speak. Release is effected by switching and dialling the correct number of impulses to bring the switch to its normal position.

As might be expected, in the first scheme of this kind, the arrangements are crude as judged by present standards. It is stated that 100 lines

1. U.S.A. Pat. No. 222458, filed September 10, 1879, granted December 9, 1879, Connolly Bros. and McTighe, Lawyers and Patent Agents. Same patent granted in England, No. 5114/79, dated December 13.

can be connected and diagrams in the patent show a complete circle of connections. Doubts of its practicability are somewhat dispelled by the fact that a model was exhibited and operated at the Paris Exhibition in 1881. One of the Connolly brothers had some faith in the switch, for he filed patents of improvements two years after the original, though they are of no importance in our present examination.

This same inventor filed two patents for a power-driven switch on April 26 and October 25, 1883.[2]

The switch consisted of a row of vertical bars fitted in front of a set of horizontal bars, each subscriber's line being connected to one of the bars in each set. So soon as a call is originated slides move continuously along one set of bars while on the other set, slides move step by step, according to the dialled impulses. Contacts of the slides at the required crossing point gave the connection between the calling and called lines. Both these patents were abandoned.

Up to this stage the automatic switches described were of American origin, but development work was being carried out in Glasgow, and records show that in 1883 D. Sinclair[3] produced an automatic board whereby five subscribers had common use of a junction to a manual exchange. This, in effect, was the forerunner of the present R.A.X. Three patents were taken out dealing with this same subject. Our search for progress, however, takes us back to America, for what has proved to be the most definite advance of all.

There is no doubt that Almon B. Strowger raised the curtain of the practical commercial automatic exchange when he filed his patent in Kansas City, Missouri, on March 12, 1889,[4] just ten years after patents of the first automatic exchange system were published.

The patent describes a switch having a vertical and rotary motion operated by electromagnetically controlled pawls—similar in this respect to the switch in use today. It is stated that the switch cylinder bank may be of wood or glass with rows of perforations into which the wires are placed to form rows of contacts. One switch is provided for each subscriber. Strowger followed a good practice in his patent in not going too deeply into details, giving only the principles and a brief description of a workable apparatus. The fundamental system of operation and many of the minor characteristics are still in use today. Fig. 2 gives a sketch of the switch from the patent and also shows the method of operation.

There are five wires from the subcriber's premises to the exchange, four for switching—one for each of three trains of impulses and one for release; the other wire is for speech, each circuit being operated with an earth return. As shown in the records, the impulses are sent by keys.

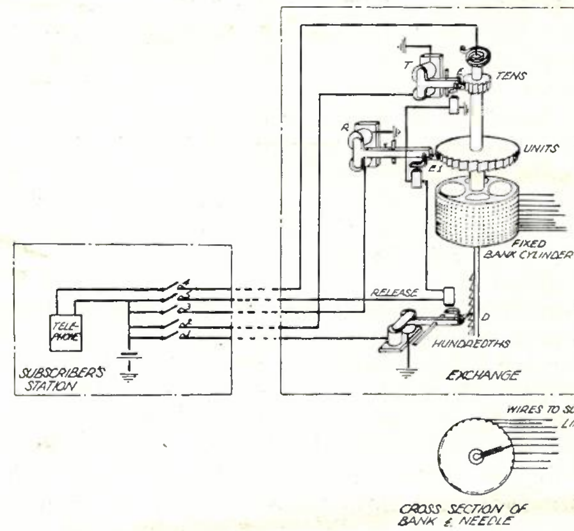


Fig. 2.—First Strowger switch and circuit, 1889.

The "switch cylinder" has ten rows of 100 holes and contact is made on the wires, which protrude on the inside of the cylinder, by a "needle" C, extensible by a spring. The needle (wiper) which is carried on a shaft down the centre of the cylinder can be raised axially and also rotated by means of the ratchets D, E and E1. The ratchet D raises the "needle" vertically along a slot in the hollow shaft to select the hundreds group while the ratchet E rotates the "needle" over ten contacts at a time—the tens digit—and the ratchet E1 over one contact at a time for the units. The influence on our present development is mainly—

- (i) Vertical as well as rotary stepping of the wiper,
- (ii) The assembly of the bank contacts in cylindrical form,
- (iii) Separate release magnet.

It is also interesting to note the following points:

- (1) The method of making a sliding heavy contact by means of the spring on the wiper tip.
- (2) No means is provided to prevent intrusion of a call even though this was common practice in manual and was also incorporated in earlier automatic systems.
- (3) The interesting way of applying 3 impulse trains to one switch for selecting one of 1000 subscribers.
- (4) The separation of the vertical and rotary movements giving lightness and low inertia which would be absolutely necessary with such a system.

Reviewing this invention in the light of subsequent development, it would seem that the most important idea, and one that has made

2. English Patents, Nos. 2117/83 and 5081/83.

3. English Patents, No. 3380, of 7th July, 1883; No. 5964, of 31st Dec., 1883; No. 8541, of 3rd June, 1884. Sinclair and Corbett.

4. U.S.A. Patent No. 447918, of 12th March, 1889, granted 10th March, 1891.

Strowger's name a by-word in automatic telephony, is the method of arranging the line contacts on a curved surface in a manner which allows a wiper to choose a group and then one contact in that group.

It is interesting to note that the same specification was filed in England[5] in 1891, two years after the original filing in America.

Before the filing of Strowger's patent in England, however, a company called the Automatic Electric Exchange Company, of Illinois, U.S.A., had patented both in England and in America an elaborate description of a complicated system in which a wiper was rotated over a flat ring on which were set the contacts of the lines in the exchange.[6]

It included a means for giving a busy signal and preventing interference to an established connection. Its complexity prevents detailed description. It would appear, however, that the Company was driven to produce some automatic device, for the specification states that the purpose of the invention is to "obviate the effects of the indolence, ignorance, fatigue or absence of the operatives as now employed."

Strowger followed up his first patent by a much more elaborate scheme, filed in February, 1892, in which only two wires are required between the subscriber's station and the exchange[7] —one for signalling and one for speech—or one wire could be used with a switch at the subscriber's station, and of special note is the use of a table fitted with 10 concentric rows of 100 contacts each, in place of the cylinder. The contact assembly is somewhat similar to the layout disclosed by the patent of the Automatic Electric Exchange Company, which suggests that even Strowger did not

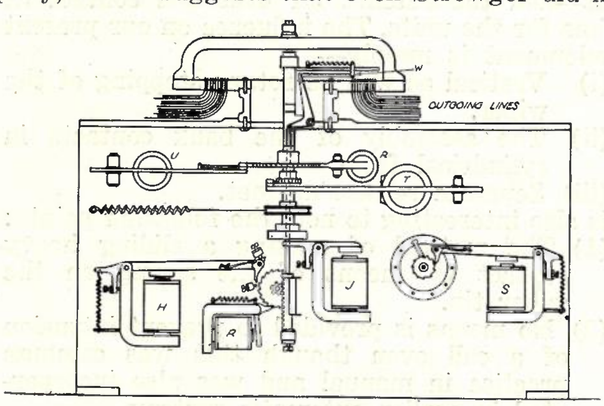


Fig. 3.—Strowger selector, 1892.

realise the advantages which were to be obtained eventually from his original idea. The principles of this second switch of Strowger's are shown in Figs. 3 and 4.

5. English Patent No. 7850/91, 8th May.
6. English Patent, No. 18890/90.
7. U.S.A. Patent No. 486909, filed February 19, 1892; English Patents, Nos. 11424 and 11426, of June 18, 1892.

The operating procedure is given in simplified form in Fig. 4. R, H, T and U are polarised magnets, R being for release and the others for positioning the selector. Switching from one magnet to another is done at the exchange by a side switch S. Although the current from the line passes through the winding of S, it is only operated when the battery is reversed. The side switch became an important feature on later selectors.

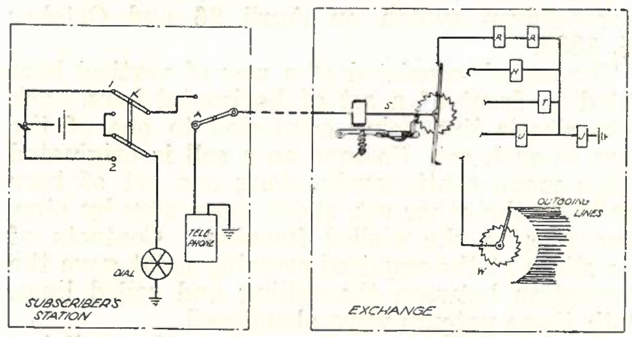


Fig. 4.—Line circuit for Strowger switch, 1892.

On making a call, the subscriber throws key A to the dialling position to connect battery in such a direction that it operates the side switch magnet S, but not magnets R,R,H, etc. The switch makes one step, the battery is then reversed by key K and the 100s digit is dialled to operate magnet H without altering the position of the side switch. Switch K is then moved to position 1 and one impulse sent to step S as before, so connecting the line to magnet T. Battery is reversed and impulses sent to operate T and U in turn with the tens and units digits, and finally to connect the line to wiper W which has been directed to the wanted line. The subscriber's telephone is connected to line by throwing switch A. To effect release, the side switch is again operated, battery reversed and an impulse sent through the release magnets R,R which, when energised, withdraw the holding pawls and allow the switch to return to normal under the control of restoring springs. Fig. 3 shows the general mechanics of the switch, in which will be recognised several features which have been carried through to the present time. The method for moving the wiper W can be traced from the details in Fig. 3. The wiper is stepped first radially by operation of magnet H, then rotarily in big steps over 10 contacts by magnet T, followed by small rotary steps over single contacts by magnet U.

The features of this patent, worthy of special notice, are:—

(a) the introduction of the side switch which, in a different form, was a feature of the early Australian installations;
(b) the control of signalling and communication over a single circuit to the exchange;
(c) the arrangement of ratchet and pawls in a manner similar to that used in modern switches.

The same scheme is shown in another patent[8] of 1893, but there were improvements in the flat disc arrangement of contacts, particularly in that the friction of the wiper was overcome by causing it to jump on each step.

The "jumping" magnet was operated each time one of the setting magnets was energised, its connection being shown in Fig. 4, and it is included also in Fig. 3 to avoid a second set of figures. It was this flat disc two-wire side switch type which formed the first commercial installation. This was carried out in La Porte, Indiana, U.S.A., and opened to the public on November 3, 1892, with 45 subscribers.

The next record is of the Ericsson Bros., patenting in March, 1893, a flat rectilinear type of switch. Although this probably formed the basis of later developments by these patentees, this particular one does not appear to have been very successful, for the patent was dropped.

Just at this time there appeared two very interesting and remarkable applications, filed by a Canadian, R. Callender,[9] on January 2, 1894.

The first patent covers some 70 pages of printed matter with 27 good drawings, the description being complete in all mechanical and electrical detail. The basic switch described is very similar to the present uniselector, but has ten contacts in the bank, each contact leading to another similar switch, and so on in a series, to provide for selection in any size of exchange. To avoid an excessive number of switches, a limited number of switching groups was provided and an "isolator" disconnected all lines but the one setting up the call, but allowed established connections to remain.

The second specification is also in great detail. Fundamentally, the arrangement depended upon the connection of the calling and called line on a horizontal switchboard where the subscribers' lines are in two rows at right angles, similar to the scheme disclosed in Connolly's patent in 1882 and in use now in the pyramid switchboard. The novelty lies in the means of selecting the required crossing and the unique method of effecting the contact. Ten point uniselector type switches set in a horizontal position stepped a wiper which carried a short half cylindrical chute which, in each position, came opposite to a fixed similar channel leading away to other switches. An idea of the scheme is given in Figs. 5 and 5a. S is a switch and R the chute stepped by the impulses to register with a chute or runway leading to switches T1 to T10. These in turn are set by the following impulse trains, the final switches leading to the various crossings of the cross bar switchboard such as the one shown at W. When the switches are set, a metal or conducting ball —like a ball bearing—is set in motion at the first switch, and as the chutes are on an incline the ball rolls down the groove and is directed to a plug hole to make the desired connection when the ball drops into it. As the ball passes each switch, that switch returns to normal, ready to set up the next call. When the release signal is given, the ball is tipped off the connecting plates into a chute, which leads to a point underneath the starting position, when it is carried by an elevator, shown in Fig. 5(a) up to the proper height ready to be used again.

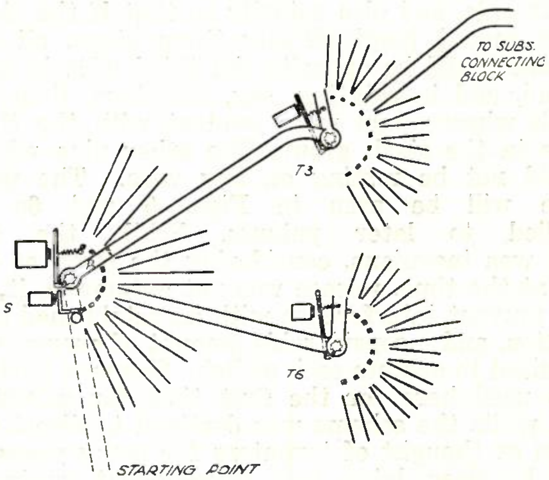


Fig. 5.

Sufficient switches were provided to accommodate the busy hour traffic, and statistics are given in the specification to indicate the requirements. Only one call was set up at a time by this "by-path" system. It was shown how calls could be stored if the switches were busy, and connection could be made when the channels were free. Two balls are used to obtain metallic circuit connection. This system also introduced the principle of relays controlling the switch magnets, and there is the first glimpse of selection of free switching links. In this specification, what we now call a group selector is termed a "percentage switching selector," and the inventor states this "allows a limited number of short switching lines to accommodate themselves to a large number of possible signals or calls." He makes calculations to show that 111 switches would be sufficient to provide for 10,000 lines. Thus was started the modern trunking analysis and mathematical consideration of switch provision.

After this diversion, development returns to the Strowger type of switch. It is evident that practical difficulties were being experienced with the multipling of contacts in the switch banks, and this is not surprising, considering that the idea appears to have been to place the contacts for all the subscribers' lines on each switch, and exchanges of at least 1000 lines must have been contemplated. As now, the bare wire multiple suggested a solution of the bank contact problem and a switch with a piano wire type of bank was

8. American Patent, No. 492850, of March 7, 1893.
9. English Patents, Nos. 139 and 140, granted 1894.

invented by A. E. Keith, Lundquist and Ericsson.[10]

In this ingenious scheme the bank contacts consisted of horizontal rows of piano wires arranged in groups of ten. Above the wires were a series of horizontal shafts at right angles to the wires, each shaft being fitted with a wiper for each group of wires, but set at a different angularity for each group. The shafts can be moved by the controlling subscriber in the direction of the shaft axis, and also rotarily so that if the shaft were moved longitudinally three steps, all the wipers would be opposite the third wire in each group, and in rotating, say, six steps, then the sixth wiper would make contact with the third wire in the sixth group. The other nine wipers would not be resting on any wire. The principle will be seen in Figs. 6 and 6a as applied to later patents. While the circuit was ingenious, considering the state of the art at the time, release was not automatic, it did not prevent interference with an established connection, and a considerable amount of energy was required to operate each switch. Common battery was used here for the first time for selection, and while the scheme was destined to direct the train of thought of inventors for many years, it will be clear, later, how development gradually came back to the original Strowger principles, carrying with it, however, many features of this piano wire diversion.

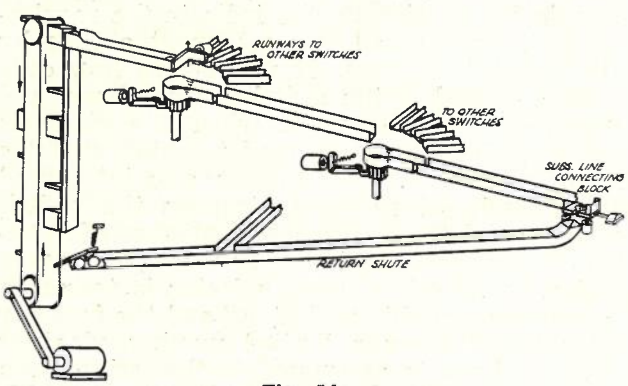


Fig. 5A.

Developments of this latest invention gave privacy by isolating an established connection and automatic quick release by gravity and spring control. However, magnets were still retained in the speaking wires. This improved system was installed in La Porte in July, 1895, and in August a similar 200-line board was installed in Michigan, followed by one in Rochester, U.S.A.

In 1896, two new ideas were patented which greatly influenced subsequent switch design, although not actually part of that unit. They were the dial giving impulses on the return movement under spring and governor control, and release as a result of restoring the switch hook of the telephone.

The next switch patented shows unmistakably the emergence of the pattern which has become known as the Strowger switch, destined to dominate development even up to the present time.

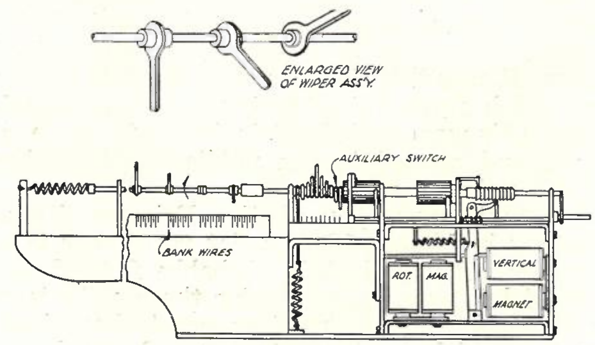


Fig. 6.

The form is shown in Figs. 6 and 6a—the main specification and improvements thereto[11] were filed in 1897 and 1898.

The double magnets, together with the method of shaft control by vertical and rotary ratchets, will be familiar, and it will also be noted that the shaft has a bottom support which has lately been re-introduced, after being discarded. There is a bare wire multiple contacted by separate wipers according to the angle of rotation of the shaft, and it provides also a subsidiary switch operated by a separate rotary magnet actuating a wiper on a hollow shaft fitted over the main shaft, which will be seen about half-way up the diagram. This allowed the 100s digit to be dialled into the same switch as the 10s and units digit. It was stated that a cylindrical bank of contacts could be used.

It is rather a startling fact that from the first patent in 1879, up to 1898, practically all the recorded development in automatic telephony took place in America. Perhaps engineers in other countries had interested themselves in the subject, but had not realised the importance of patenting their ideas. However, European interest was shown by installations of the Automatic Electric Company's (U.S.A.) system in Amsterdam in 1898, and in Berlin in 1899, each having a few hundred subscribers.

Search over bank contacts was introduced at this stage, the subscriber having to dial "O" and the stepping wiper being stopped over an idle contact, but an important advance was made by an installation at New Bedford, Mass., in 1900, when automatic search was first used. Test was made for battery to denote an idle line. The talking circuit was poor, as there were as many as eight relays in the speech circuit, and this led to the use of copper-sleeved relays to reduce impedance to speech.

10. U.S.A. Patent, No. 540168, of 1894; English Patent, No. 8607/94.

11. English Patents. Nos. 23239/97 and 22545/98; U.S.A. Patent, No. 638249.

A system was patented by the General Electric Co., in 1901, invented by A. M. T. Thomson, of South Africa, in which the number was dialled into exchange apparatus, and was displayed in lights before an operator who completed the connection. The system was not used.

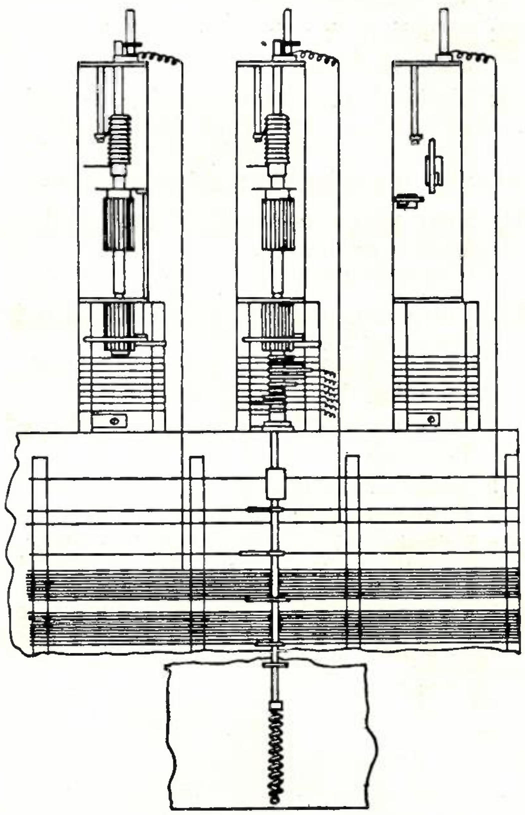


Fig. 6A.—Piano wire or zither switch.

There were now a spate of developments of separate features of the switch, the stage having been passed when any completely new unit was recognisable. In an installation in Chicago in 1902, innovations included automatic metering with time limit, P.B.X. facilities and connection of relays in a bridging instead of a series circuit. Further improvements appeared in a system installed in Los Angeles in 1904, including the private or third wire for control, and the separation of the switch mechanism from the bank which was wired in place, the mechanism being added only when necessary. The transmission bridge of the "Stone" type was placed in the final selector. Perhaps the most important feature of systems used at this time was the introduction of the Keith line switch[12] for reducing the number of selectors to fit the traffic, instead of having one selector for each subscriber.

Some new types of systems with special switching devices appeared in 1907 and 1908, the Western Electric Panel construction, which was a revision of methods tried out earlier, was patented by A. F. Dixon,[13] in 1908, and in the same year the now renowned McBerty entered the field of automatics and originated a power-driven rotating shaft system, which was adopted by the Western Electric Co.[14] It is interesting to note that some of the latest patents for new systems of automatic telephony of the present day are being produced by this same McBerty. Lorimer[15] filed a patent in 1907 for a power-driven switch, which has been used in Canada; the patent, however, was not granted until after the original McBerty patent.

It is quite natural that a system should be devised depending solely on relays and requiring no switch at all. E. E. Clement is responsible for such patents and the Relay Automatic Company developed a system which has been used commercially for many installations. The clever though complicated sequence switch, which was the main control unit of the Western Electrics Company's rotary system, was patented by McBerty[16] in 1908.

Amongst the patents for improvements were many ideas for giving speed and economy—for instance, to give quick selecting action a pneumatic device was described in patent 14851/06 for projecting a wiper over contacts until it came to a free link where it was brought to rest by electromagnetic means. Also, considerable attention was being devoted to the line switch,[17] principally in patents by Siemens & Halske (1) in Germany, Kellogg (2) and Keith (3) in America:

Fig. 7 is the picture of the selector switch as developed up to 1908, and at that time it was being manufactured in fairly large quantities for use in America. The first automatic switches installed in Australia were similar to this type. The controlling relays were mounted vertically on top of the selector, while the side switch, operated in conjunction with an escapement device, formed an important part of the unit. The switch was operated by sending impulses over one of the two subscribers' wires in an earth circuit, followed by a single impulse over the second wire to operate the private magnet, which set the side switch and so connected the appropriate magnet for the next train of impulses. Search for a free line in a group was controlled by an interrupter. Impulsing over a subscriber's loop and the use of copper-slugged relays allowing the elimination of the side switch, were introduced by Clement[18]. It became known as the "side switchless" circuit.

12. English Patent, No. 26301, of November 20, 1906.

13. U.S.A. Patent, No. 918313, April, 1908.
14. U.S.A. Patent, No. 922802, February, 1908.
15. U.S.A. Patent, No. 1019166.
16. U.S.A. Patent, No. 1009089, September, 1908.
17. (1) English Patent, No. 12554/02; (2) English Patent, No. 7998/06; (3) English Patent, No. 26301/06.
18. English Patent, No. 28091/6.

He employed a switch giving the rotary motion before the vertical, as was later used by the Peel Connor Co., in England. Also, impulses were sent by making the circuit and not by the break as employed in modern practice, and also the testing relay operated on circuit pick-up, being released

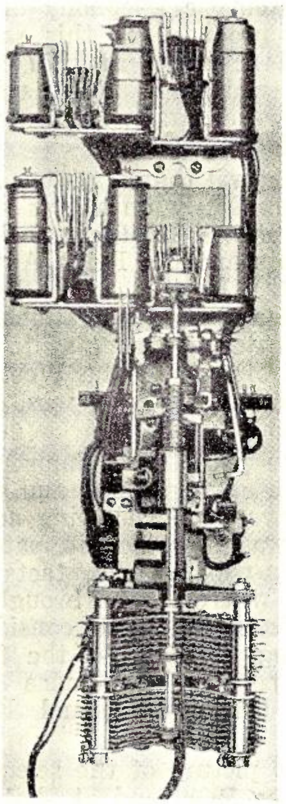


Fig. 7.

when testing in to a free line. In 1910, E. A. Millinger[19] further developed the slow acting relay to replace the side switch, and included an automatic drive which did away with the interrupter.

When the switch was introduced to Australia its general form had become well established and subsequent changes were more in the nature of refinements. There were, of course, patents which were revolutionary in character, and some of these were commercialised, but they did not affect the development in Australia to any extent.

The progressive changes in the switches installed here reasonably represent the developments over the last thirty years or so in this bi-motional type of switch. These changes will be known to many readers, and have been well recorded in current publications, this Society having been responsible for some of the records. Fig. 8 is the picture of a connector taken from a lecture to the Postal Electrical Society, and published in 1913, which described the first Automatic Exchange installation in the Commonwealth. It has been shown how this switch represents the ideas of many inventors, and it will be seen from the following summary how its various patented features were brought together to form the standard switch of that period:—

1879: Selection by impulses and use of a ratchet device.

1889: Vertical and rotary motion for selection of a group and then individual outlets.
Contacts in the form of a cylinder.
The inclusion of a release magnet.

1892: Two wires connecting each subscriber to the exchange.
The side-switch.

1894: The group selector provided on a traffic handling basis.
Relays controlling switch magnets.
Common battery operation.
Automatic release on restoration of the receiver.

1897: Double Magnets.
Copper slugged relays.

1904: Private wire control giving three-wire circuits in the exchange.

1906: The inclusion of the line-switch to reduce the number of bi-motional switches.

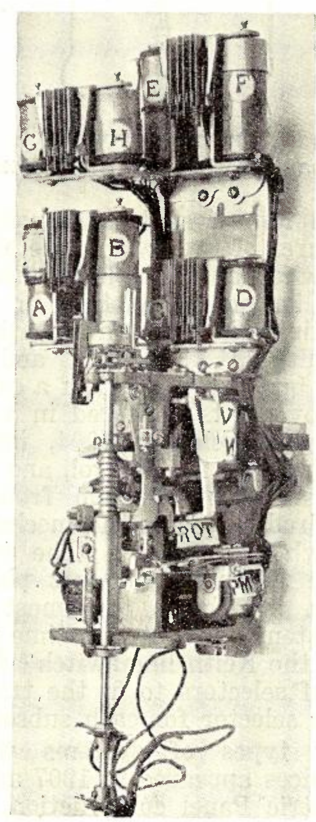


Fig. 8.—Automatic switch (connector) as first installed in Australia, 1912.

19. English Patent, No. 1298/10.

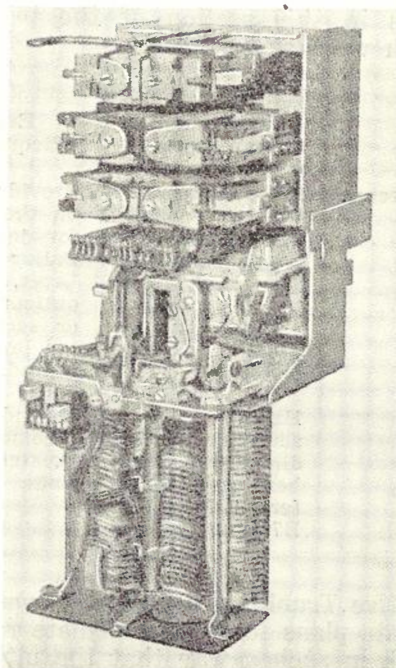


Fig. 9.

The history of the switch since its introduction to Australia will not be given in detail, but it may be of interest to glance at the latest switch, a picture of which is given in Fig. 9, and to note the following main changes which have been made:—

Elimination of the side-switch.
Change in materials—such as use of cast iron for the frame, and elimination of fibre from the banks.
Horizontal mounting of the relays.
Use of a dust cover for each switch.
Change to relays of 3000 type.
Magnets with single coil and elimination of the release magnet.
Bank increased to 200 outlets.

The present switch is an example of evolution resulting from development and experience extending over nearly 70 years, during which substantial changes were made every few years, and to which refinements are still being added. The indications are that finality of design has not yet been reached, and that just as big changes can be expected in the future as were made in the past.

USE OF T.D.F. EQUIPMENT IN A PRE 2000 TYPE EXCHANGE

D. J. Mahoney [redacted]

An interesting trunking and equipment problem at City North Exchange in the Sydney Metropolitan unit fee area was solved recently by the use of 2000 type T.D.F. equipment. In addition to satisfying immediate requirements, the work carried out will simplify future rearrangements planned for the exchange.

City North Exchange Area: City North is a pre 2000 type main exchange with mixed 5 and 6 digit numbering and is equipped with 113 Keith type and 19 rotary type uniselector line units. There are some 12,300 subscribers connected to the exchange which also handles traffic for specialised services such as Trunk Exchange, Phonograms, Departmental P.A.B.X. trunk dialling circuits, etc. The bulk of the selector equipment is provided with "fish back" type terminal assemblies and the trunking pattern is arranged in simple groups of 10 outlets from slip multipled banks, which was the conventional method in such cases.

Prior to the installation of T.D.F. equipment in City North, the B group consisted of two exchanges arranged as follows:—

(a) City North with number groups ranging from B1 to B7 and from BW1 to BW7.
(b) The temporary BX exchange in the G.P.O. (a separate building) with number groups ranging from BX1 to BX2.

In order to provide for development in the City North area it is planned to convert the whole of the subscribers to 6 digit working and utilise the second selector levels thus freed for additional exchanges of 10,000 lines as required. Fig. 1 shows the relevant portion of the City North trunking scheme as it was before the installation of the new T.D.F. equipment and Fig. 2 shows the method of development for which provision is being made.

Preparatory Work in City North: As will be realised from the trunking scheme, considerable rearrangement work is necessary to implement the development plan, the principal moves being:

(1) Free the B4 (BJ), B5 (BL), B6 (BM) and B7 (BU) levels;
(2) Establish junction groups on these levels as required;
(3) Transfer subscribers from City North to each new exchange as it is established.

One of the first steps undertaken was to free the B7 level to permit its use for Dalley Exchange (BU). This involved a change of number for the 620 subscribers connected to the B7 group and in order to avoid as much as possible a second number change in the future it was decided to establish the BU number group immediately in City North Exchange and transfer subscribers from B7 to their ultimate numbers in the BW, BX and BU groups. The B7 subscribers included some in the ultimate Central

(BL) area and it was decided to give these BW numbers pending the release of the B5 level. Approximately 330 of the B7 subscribers were in the proposed Dalley (BU) area and 5 of the B7 primary units were changed to BU. This provided a reserve of spare numbers in the BU group for development purposes.

The restricted floor space in City North Exchange is a factor which governs to a large extent the scope and nature of any undertaking in the building, and this was evident when the establishment of the BU group was being planned. New groups of BU third and fourth selectors were required immediately as well as auto-auto repeaters for junctions to the Dalley Exchange at a later date. The space problem as far as fourth selectors were concerned, was solved by the fact that 5 line units only were to be in use in the BW5 group and rack space was available for handling 10 units on the fourth selectors. This space was made use of by numbering the BU line units BU55 to 59 and strapping the BW and BU levels on the second selectors. Additional BW third selectors, however, were also required to cater for these additional subscribers and also for subscribers to be transferred from B7 to BW. This extension of the BW group presented a further problem.

In summary, the immediate and eventual requirements in this section of the problem in City North were as follow:—

Group	Immediate Requirements	Eventual Requirements
Second selectors	Strap BW and BU levels on 11 "fish back" type trunk boards to allow BU group to be opened using BW5000 group spare levels.	Provide outlets on the BU level for junctions to Dalley (BU). Later, provide outlets from other second selector levels as required.
BW third selectors	Extend group to accommodate additional subscribers to be transferred from the B7 group.	Extend group to accomodate ultimately 10,000 lines.

Alternative Trunking Methods: It was desired to formulate plans for the immediate rearrangement work in such a way that the ultimate requirements could be met in the most economical and practical manner. The main problem in the future would be the provision of new groups of outlets from the second selectors and consideration was given to the several methods of

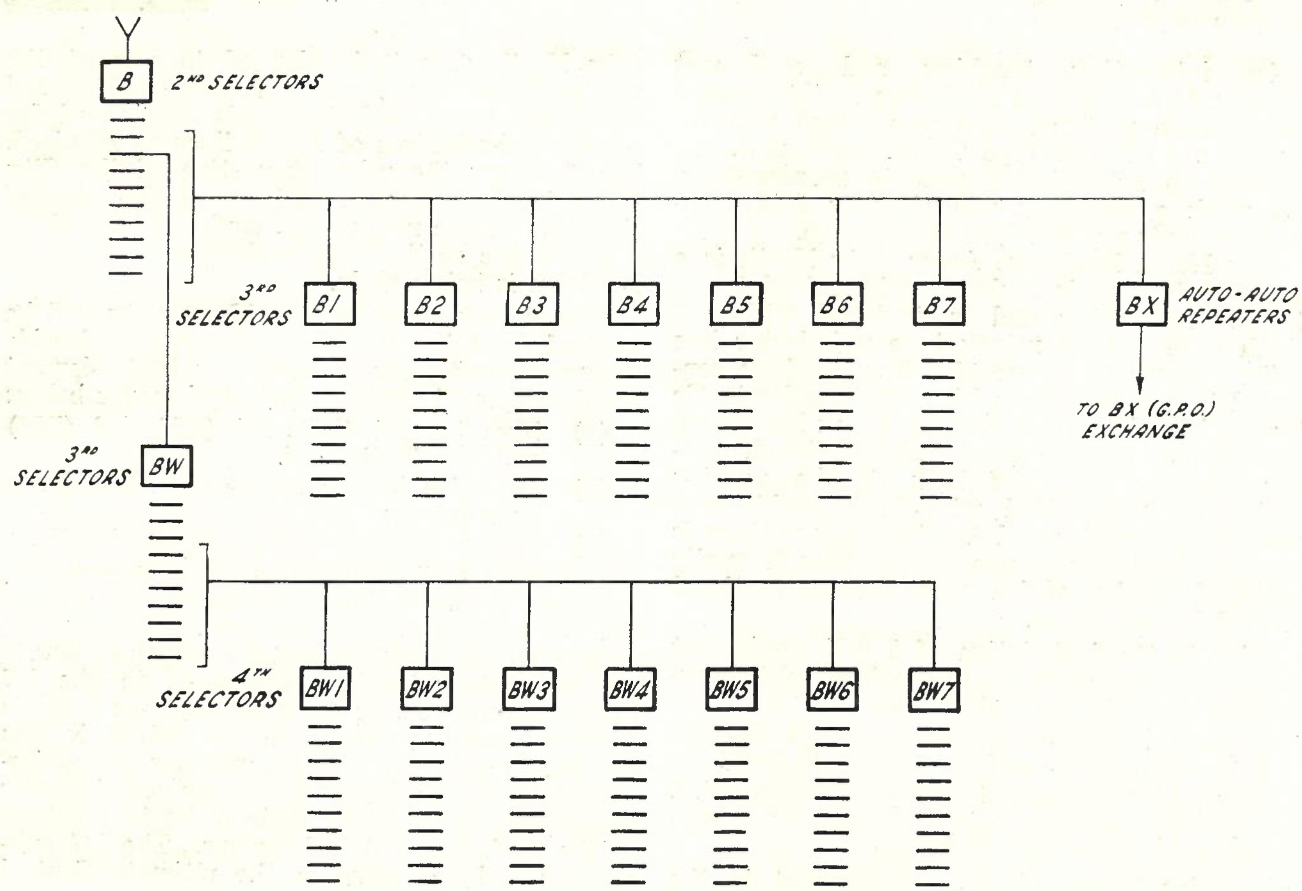


Fig. 1.—Portion of City North trunking scheme.

trunking which could be adopted. These are as follow:—

(a) Continue with the existing arrangement and provide trunks from the "fish back" assemblies in simple groups of 10.

(b) Introduce a system of grading on the "fish back" assemblies using "up and down" multiples between banks to common the outlets. If a grading is to be extended beyond one trunk board, multiples between trunk boards would be necessary.

(c) Adapt T.D.F. equipment as used in 2000 type exchanges.

The grading under either (b) or (c) provides a 22% saving (232) in third selectors over alternative (a) for the extension of the BW group required initially and, of course, greater savings would be made both in third selectors and later in junction hunters as the rearrangement plan is developed. Although alternative (a) involved the least work (as the "fish backs" are already in place) the inefficiency of the arrangement, especially when junction groups to other B exchanges came to be established, was a severe disadvantage. With alternative (b) no additional floor space was needed and much less cable would be used than with (c). However, this method was very cumbersome and it would have been difficult to have kept the trunk board assemblies free from faults owing to the heavy concentration of wiring and cabling. Furthermore, both alternatives to method (c) would require work on the "fish back" asemblies, which would have had a serious effect on the equipment and wiring, much of which was over 20 years old. Alternative (c) was adopted as it permitted the grading of the second selector outlets to be carried out on T.D.F. racks designed for the purpose and for which floor space was available. Also, once a level was put through the T.D.F. the relative "fish back" assemblies became connection points only and would not be interfered with in any future alterations to meet traffic variations.

Installation and Cabling Arrangements: Space was found for the T.D.F. racks on the floor above the second selector trunk boards and adjacent to the subscribers' register racks, thus providing for a short and convenient cable run. The register racks were 10 ft. 6 inch. high, so that continuity of the overhead construction was maintained. The T.D.F. layout was designed in such a way that additional T.D.F. racks to take the successive B levels required for the new B exchanges could be installed as register racks were recovered in the planned reduction of the City North Exchange to 10,000 lines capacity. In the initial installation, T.D.F. racks for BX, BW and BU only were provided.

Access to the second selector levels concerned

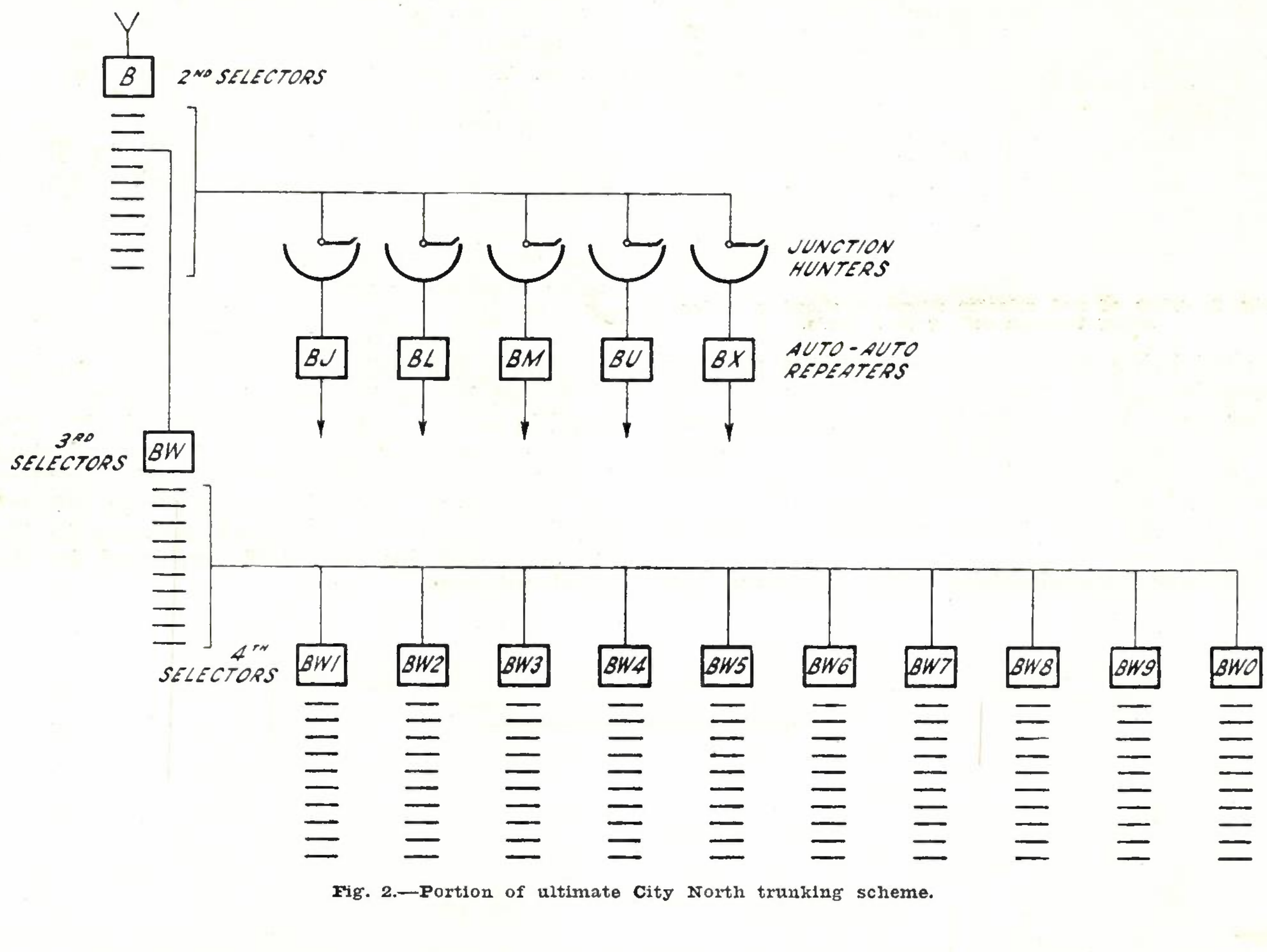


Fig. 2.—Portion of ultimate City North trunking scheme.

was obtained by inserting "fish back" strips cabled direct to the T.D.F. racks in the assemblies and later withdrawing the old "fish backs" which were cabled direct to third selectors, then dismantling associated slip and multiple cables between trunk boards.

The existing runways above the second selector trunk boards were already heavily loaded (see Fig. 3) and it was necessary to construct a third runway level above them. This new runway was made 6 inches wider than those below it, and this allowed space for the new cables to drop through the bottom of the new and pass the sides of the existing runways to take up their final positions on the "fish back" assemblies. Supports for this runway were fixed to the top horizontal angle iron of the trunk boards and were designed to align with the vertical angle iron trunk board supports and give the appearance of continuous construction. A good arrangement of cables at the T.D.F's was possible by designing the runways in the form of the letter "S." By this means, the cable sections in the area occupied by the "S" runways taper off as the run progresses and "cross overs" are avoided. Provision is made for ultimate cables serving all B levels. As the BU group

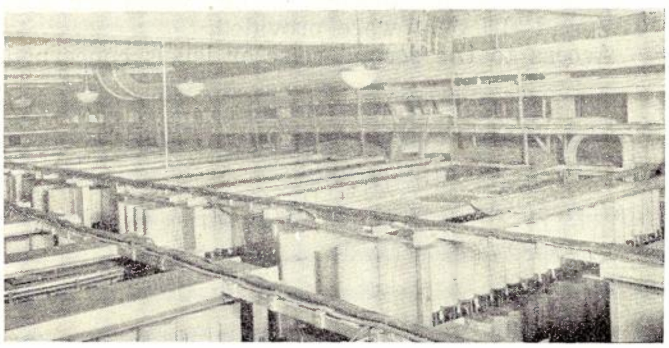


Fig. 3.—View of 2nd selector runways, showing cables rising through ceiling to T.D.F.'s.

was not being established initially in a separate exchange and as the BW third selectors were being used temporarily to serve BU numbers, arrangements were made to strap the two levels on the T.D.F. racks by using temporary cables suspended under the T.D.F. runways.

A close-up view of the cabling is shown in Fig. 4.

Cut-Over Organisation: The cut-over was complicated by the fact that it was necessary to give service to the B7 subscribers on either the existing BW or BX groups or on the new BU group immediately the B7 level was taken for the use of the BU group. Very careful organisation was necessary when the BU, BW and BX outlets from the second selectors were transferred from "fish back" trunking to the T.D.F. gradings. Each operation was set out on a schedule and schematic drawings were made indicating the existing and proposed arrangements. A clear conception was thus obtained by all the staff concerned of the work to be done and the order in which it was to be carried out.

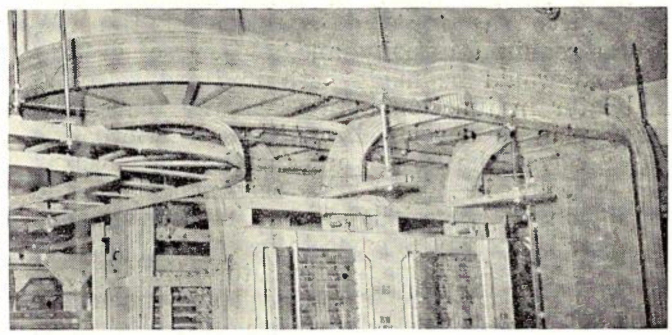


Fig. 4.—View of runways and cables above the T.D.F.'s.

The transfer was made during the weekend when the traffic was light and a proportion of outlets could be "busied" without degrading the service. Two technicians were stationed at each of the 11 second selector trunk boards and by working from top to bottom transferred each bank in turn from direct "feeds" to T.D.F. "feeds." The second selectors on the banks under operation were "busied" during this period by a special staff who arranged for incoming switches to be "busied" at the distant exchange as well as for the outlets from the local first selectors to be "busied." As the "feeds" from each bank were transferred to the T.D.F., arrangements were made for outlets to be provided through the T.D.F. before the second selectors were replaced in service on these banks. As the T.D.F.'s were on the floor above the second selectors strict general supervision of the whole operation was necessary. The change-over was effected satisfactorily, due in no small measure to the care exercised by the staff concerned in the actual cut-over.

TELETYPE EQUIPMENT

R. D. Kerr

The period from 1933 to 1941 saw a steady increase in the machine telegraph services provided by the Post Office in the Commonwealth. This increase was very largely represented by Creed Model 7 Teleprinters which were used to provide leased private-wire printer services to subscribers, this form of service having been introduced in 1933. During the war-time period the demands of the Services and those Government Departments engaged actively in the war effort became so great that all teleprinters in the Commonwealth were used to meet their requirements. The year 1941 found the Post Office with ever-increasing commitments and no supply of machines, for it had become apparent that the demand for teleprinters in Britain and North Africa was completely absorbing Creed's production. These circumstances led to the introduction of a new Start-Stop Page Printer, the Model 15 Printer (Teletypewriter) of the Teletype Corporation of Chicago, U.S.A., an order for 100 units being placed with this Company.

The entry of the U.S.A. into the war delayed the delivery of these machines and they were not received until the last quarter of 1942, but in the meantime the U.S. Army came to Australia and with it a considerable amount of teletype equipment which the Post Office Engineering Branch was asked to instal and maintain in co-operation with a limited number of U.S. Signal Corps technicians. A substantial amount of work was involved, as new types of circuits were necessary because the electrical arrangements of the teletypes differed considerably from those of the teleprinter. It also called for the training of personnel for the maintenance of the new and complex series of machines, a task complicated by the exigencies of providing service under the pressure and constant flux of war-time conditions.

The experience gained with these U.S. Army machines facilitated the introduction of the Department's own machines when these were delivered. From that time forward there has been a steady stream of teletype equipment flowing into the country, the increase in the Department's Start-Stop machines, particularly during the war-time period, being graphically shown in Fig. 1. Whilst this growth was brought about by the extensive Service requirements which the Post Office had to meet on the mainland, it is interesting to note that the post-war period has seen the absorption of all the additional machines in the provision of more extensive leased service requirements, and in the mechanisation of the Departmentally operated public telegraph service. It is also significant that 62% of the Department's machine telegraph plant is in use in subscribers' offices, whilst only 38% (including Multiplex equipment) is installed in Departmental offices. Judging by known commitments, both private-wire and Departmental, the present rate of development will be sustained for several years to come.

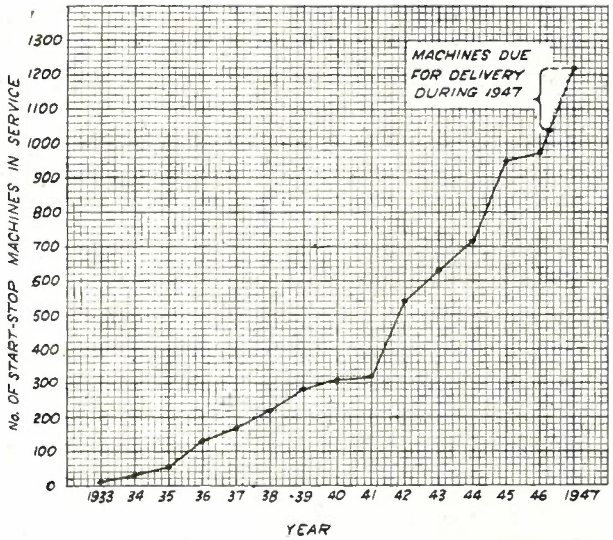


Fig. 1.—Increase in start-stop machines.

The Teletype Corporation's Model 15 Sending-Receiving Page Printer represents the great bulk of the new Start-Stop equipment, but in addition the following lesser-known types of equipment have been purchased:—

(a) Model 19 Set, comprising the Model 15 Page Printer, Model 15 Keyboard Perforator Transmitter and Model 14 Tape Transmitter Distributor.

(b) Model 14 Reperforator.

(c) Model 14 Typing Reperforator.

(d) Model 14 Keyboard Perforator.

(e) Model REP.6A/RED.8A Regenerative Repeater.

This equipment represents only that used to provide actual service, but to maintain service a variety of distortion testing equipment has been purchased. It is proposed to describe this equipment in a later issue of the Journal. The prominent features of the Model 15 Printer are shown in Fig. 2. In service the whole machine is enclosed in a black wrinkle-enamelled metal cover with the keyboard protruding and the platen visible through a shatter-proof glass window. The machine consists of four main units which may be dissociated readily for maintenance. The electrical connections between units are made through spring jacks. The units are:—

(a) Main Base Casting, comprising the mounting for the other component units, the wiring between units, miscellaneous electrical equipment such as spark quench and radio suppressor components and the electrical connections to the external circuits.

(b) Motor Unit, comprising the driving motor and governor assembly. This is normally a 1/25th horse power 110 volt A.C. series motor with a centrifugal governor adjusted for a motor speed of 2,102 r.p.m.

(c) Typing Unit, comprising the receiving selecting mechanism, translating mechanism, typing mechanism, platen unit and the auxiliary function (line feed, carriage return, etc.) controls.

(d) Keyboard Transmitter Unit, comprising the key levers and sending distributor mechanism. This unit is not required for a "receiving only" printer in which case the opening in the front of the cover is filled with a suitable plate.

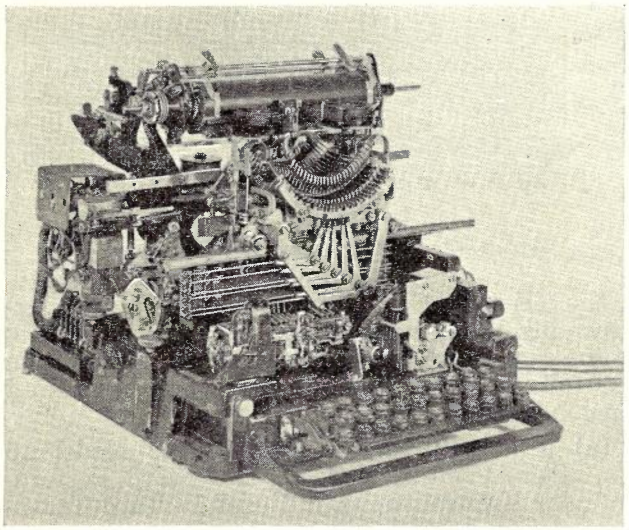


Fig. 2.—Model 15 printer.

The signalling connection to the printer is made to a single non-polarised electro magnet whose armature is normally operated to "mark" and is retracted by a suitable spring to "space" when no current flows in the magnet windings. The normal marking current is 60 mA in the magnet windings. The idle circuit condition is marking and the first spacing impulse (start signal) received releases the receiving selector cam cylinder which rotates, the succeeding train of five code impulses being analysed and converted to five mechanical impulses. The stop signal (marking) then stops the selector cam cylinder until the start signal of the succeeding character is received, this cycle of operation being characteristic of Start-Stop machines. The five mechanical impulses are used to control the position of five vanes in front of the machine, the motions of the vanes being transmitted through bell cranks to a group of five notched code bars on the type basket. Each of the 26 type bars is associated with a pull bar and the motions of the five code bars provide (in the usual manner) for the selection of one of these pull bars. The selected pull bar is engaged with a pull bar bail which functions on the receipt of each character. The motion of this bail is transmitted through the pull bar to its associated type bar, which in turn prints the character.

The most novel feature of the printing operation is that the platen is stationary and the type basket moves across the face of the platen with the printing of each character. This mode of operation has complicated the design of the machine but has obviated the very real difficulties in earlier page printers of keeping continuous alignment of the paper on the platen as it feeds up and moves across the printer. Another result is that since the printer does not have to be twice the width of the platen (i.e., to permit the platen to move its full length longitudinally) the machine is rather narrower and more compact.

The normal functions of letter space, line feed, carriage return, figures and letters shift and bell signal are provided, but in addition there are special "motor stop" and "send-receive-break" functions. The "motor stop" function is arranged so that an operator typing "figures" and "H" stops the motors of his own and all other machines on the circuit. Any station, by depressing the "break" key, opens the line circuit, and thus starts the motors of all machines connected to the circuit, including that of the home machine.

The "send-receive-break" function is so arranged that on receipt of a spacing signal, of at least two characters length, the keyboards on all machines on the circuit are short-circuited. Thus a receiving station, by depressing the "break" key to open the line circuit, may cause the "send-receive-break" function of a sending machine to operate to the "receive" position, stopping transmission. The "send-receive-break" switch must be manually restored to the upper (send) position before transmission may recommence. These functions are incorporated in one control lever which protrudes from the front left hand side of the cover, the uppermost position of the lever being the send position, the intermediate position the receive only, and the lower position the break (line open) signal.

The selecting mechanism is of interest as an orientation device is provided which, unlike the previous machine equipment used in this country, is completely mechanical in operation. The actual "instants of selection" (i.e., the period in each of the five code impulses during which the selecting mechanism of the machine determines whether the impulse is marking or spacing) are arranged by suitable cutting of the selector cams so that they represent only some 20% of the duration of a code impulse. This corresponds to the halving of the receive segments with respect to the send segments in a Murray Multiplex installation but, of course, in the teletype it gives the effect of receive segments of only 1/5th the length of the send segments. The shortening of the receive segments is necessary to give the receive selecting mechanism a tolerance of either lengthening or shortening of the transmitted impulses as they are transmitted over the line. The most desirable place for the instants of selection is normally in the centres of their respective code impulses (undistorted) since the machine will then have the greatest tolerance of either advancement or retardation of the signal transitions. If the instants of selection were of infinitesimal duration and at the centres of the code impulses, it is apparent that the transitions at the beginning and end of an impulse could be displaced by as much as 50% without incorrect selection occurring, or alternatively, the machine may be said to have a margin of ± 50%. Since the teletype's instants of selection are some 20% of the duration of a code impulse the margin is reduced from this theoretical maximum figure to some ± 40% and due to the complex electro-mechanical functions of the selecting mechanism may be reduced, with some forms of distortion, to only ± 35%. These figures are minimum limits for a machine in optimum adjustment and under service conditions, due to wear and variations of adjustment, may be reduced until inability to tolerate normal circuit distortions necessitates the machine's overhaul. The relation of the instants of selection with respect to the code impulses may be varied ("oriented") and the reduction in the extent of the permissible variation for distorted signals as compared with the extent for perfect signals gives a measure of the distortion of the signal impulses.

The keyboard transmitter of the Model 15 Teletype is mechanically very similar to that of the Model 12 Teletype which has been in use in the Commonwealth for several years. The Model 15 keyboard transmitter is arranged to transmit 7.42 unit code impulses consisting of a unit start signal, 5 unit code impulses, and a 1.42 unit stop signal, a lengthened stop signal being desirable when regenerative repeaters are used with Start-Stop systems. The transmitter shaft is normally geared to revolve at 368 r.p.m. so that the code impulses transmitted are of approximately 22 milliseconds' duration (31 milliseconds for stop impulses) and a maximum speed of 368 characters per minute, or approximately 60 words per minute, may be obtained.

It should be noted that the Model 7 Teleprinter is normally arranged to transmit code impulses of 20 milliseconds duration, a maximum of 428.6 characters per minute (Model 7C, 7 unit) or 400 characters per minute (Model 7B, 7.5 unit) so that the teletype speed must be increased for inter-operation with teleprinter.

The code for each character and the allocation of secondary characters and functions are shown in Table 1, whilst the corresponding characters in the teleprinter Model 7 code (International No. 2 Keyboard) are shown for comparison. It should be appreciated that, whilst the Post Office normally uses the International No. 2 Keyboard as a standard for Start-Stop machines, the teletypes purchased were, because of war-time exigencies, supplied with U.S. Army-Navy standard communications keyboards.

TABLE 1

Line Signals Code Impulses 1-5	Character Lower Case TPR & T Type	Character Upper Case T Type	Character Upper Case TPR
MMSSS	A	—	—
MSSMM	B	?	?
SMMMS	C	:	:
MSSMS	D	$	Who are you?
MSSSS	E	3	3
MSMMS	F	!	%
SMSMM	G	&	@
SSMSM	H	STOP	£
SMMSS	I	8	8
MMSMS	J	'	BELL
MMMMS	K	(	(
SMSSM	L	)	)
SSMMM	M	.	.
SSMMS	N	,	,
SSSMM	O	9	9
SMMSM	P	0	0
MMMSM	Q	1	1
SMSMS	R	4	4
MSMSS	S	BELL	'
SSSSM	T	5	5
MMMSS	U	7	7
SMMMM	V	;	=
MMSSM	W	2	2
MSMMM	X	/	/
MSMSM	Y	6	6
MSSSM	Z	"	+
SMSSS	Line Feed.		
SSMSS	Space.		
SSSMS	Carriage Return.		
MMSMM	Figure Shift.		
MMMMM	Letter Shift.		
SSSSS	Blank (Not used on TPR).		

M—Indicates Marking Code Impulse.
S—Indicates Spacing Code Impulse.

Although all purchases have been nominally of Model 15 Page Printers there are considerable variations in detail in the printers received. The original deliveries consisted of commercial Model 15 Page Printers with main base units wired to provide for direct magnet operation in the line or relayed operation of the magnet from the contacts of a Western Electric Type 255-A polarised telegraph relay which could be plugged into a socket on the main base of the printer. In the latter case, the direct current to operate the magnet and provide a spacing bias to one winding of the W.E.255A relay was supplied by a type

REC.10 Selenium rectifier converting 105-125 volts A.C., 50-60 cycles power to 120 volts D.C. with a maximum output of 200 mA. A limited number of commercial Model 15 Printers obtained from the U.S. Foreign Liquidations Commission in Australia have a later rectifier, REC.29, which is suitable for connection to 95-125 or 190-250 volts A.C., 25-40 or 50-60 cycles power supplies, and in addition to the 120 volts D.C. 200 mA output provides 115 volts A.C. (150 watts approximately) for the printer motor.

Later purchases were made through the Department of Army as the common purchasing agent for all Services and the Post Office in Australia, and the machines received were U.S. Signal Corps Field Teletypewriters Model TG7B. This unit consists of a Model 15 Printer fitted on rubber mountings to a stout wooden carrying chest, which may be used as a table for the machine. A smaller chest is provided to carry the typing unit separately and to serve as the operator's seat in field installations. The wooden chests are unnecessary for the Department's service and have been stripped from the machines. The main base unit of the TG7B is not provided with a socket and wiring for the W.E. 255A polarised relay, the intention being that the TG7B Printer should always be operated in the field in conjunction with a separate line relay unit and rectifier. These units have not been supplied with the majority of machines received by the Department, and in consequence direct magnet operation of the printer in the 60 mA single current line has been generally employed for all types, the W.E.255A relays and REC.10 rectifiers of the original delivery being diverted to general telegraph use. The TG7B Printer also includes a 3 position switch fitted to the side of the machine which adapts the 115 volts A.C. 50-60 cycles series governed motor to 40 cycle or 25 cycle and D.C. power supplies.

Since all the motors supplied have been of the 115 volts series governed type it has been necessary to provide 230/115 volts A.C. transformers at most locations. Where two or more machines are installed these are generally supplied from a large common transformer.

The Model 19 Teletype Set illustrated in Fig. 3 has been designed for use at stations with a large out-going traffic load (e.g., master transmitting stations of press distribution networks) and provision is made for tape transmission. The base, motor and typing units are those of the Model 15 Printer, but the Model 15 Keyboard Perforator Transmitter Unit, which is associated with these units in lieu of the normal Model 15 Keyboard Transmitter, provides for the following alternative facilities:—

(a) Direct keyboard transmission, the operation of the keys directly controlling the transmitting contacts.

(b) Simultaneous direct keyboard transmission and perforation of a tape similar to that used in a Murray Multiplex installation.

(c) Perforation of a tape only. In this case a letter-counting device is provided which lights a lamp after some 60 characters have been typed, representing the number of characters to a line across a normal page width. The counter is reset and the lamp extinguished on depression of the "carriage return" key.

These three functions are controlled by a three-position lever protruding through the front

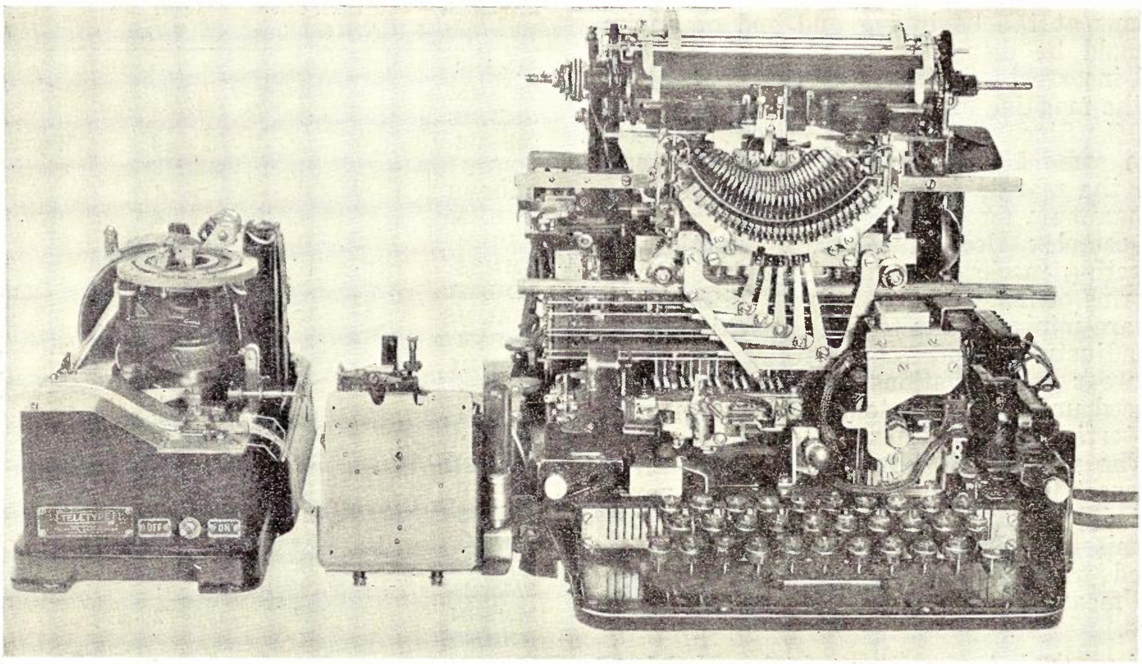


Fig. 3.—Model 19 set.

right hand side of the cover, the upper, intermediate and lower positions corresponding to conditions of (a), (b) and (c) above.

The remaining unit of the Model 19 Set is the Model 14 Tape Transmitter Distributor placed at the left hand side of the printer so that the tape, after passing through the perforating attachment on this side of the keyboard unit, may be passed through the transmitter distributor.

The transmitter distributor unit consists of a tape transmitter with a series governed motor unit driving brushes over a small plateau and providing a cadence signal to step the perforated tape through the transmitter. The five tape needles of the transmitter are arranged to test the code perforations in the tape as in Murray Multiplex installations, the contacts of the transmitter connecting to five segments of the plateau. Two additional segments of the plateau provide start-stop code impulses with each revolution of the brushes. Controls are provided to stop the distributor and tape at will by the operator or when the loop of tape between the perforator and transmitter becomes taut. The distributor brushes normally revolve at 368 r.p.m. and send 7.42 unit characters to line so that the actual signalling speeds of tape transmitter distributor and conventional keyboard transmitter are identical.

It should be noted that in operating the keyboard transmitter the typist cannot exceed the maximum speed of the machine and will frequently fall below this. With the keyboard perforator a typist may operate the keyboard at any speed within the mechanically practicable limit (probably over 100 words per minute) and since the transmitter distributor is only sending at 60 w.p.m. a loop of slack tape may accumulate. However, the other traffic handling duties of an operator and the human element make it necessary for him to stop typing, or decrease speed occasionally, and during this period the slack tape will pass through the transmitter. This feature of tape transmission, together with the fact that previously prepared tapes may be transmitted at maximum speed on part-time services, thus obtaining the maximum use of the channel, make the Model 19 Set particularly suitable for the rapid disposal of outward traffic.

The sending and receiving sides of the set are electrically dissociated so that it may readily be "split" and employed as a duplex machine using perforated tape for transmission from the send side and page printing for receiving.

The Model 14 Reperforator is arranged to receive signals from a line circuit and to perforate a tape in accordance with the characters received. This tape is identical in form with that prepared on the keyboard unit of the Model 19 Set and may, therefore, be retransmitted to another line through a Model 14 Tape Transmitter Distributor. The Model 14 Reperforator may thus be used to relay messages from one line to another at some central station without manual repetition and where engineering or traffic-handling considerations make direct connection of the lines concerned undesirable. This method of repetition is known as "tape relaying."

The reperforator has an individual 115 volts A.C. 50-60 cycle motor which drives the selecting mechanism and controls the perforating functions. The selecting mechanism is identical with that of the Model 15 Printer, but the five mechanical impulses of the selecting mechanism control the five code punches of the punch-block assembly instead of the translating and printing mechanisms as in the printer.

Whilst experience showed that tape relaying on the reperforating units was very useful, its full potentialities could not be realised since, even with skilled operators, reading the perforations in a tape was a slow process, and thus handling any large amount of tape became very difficult. To overcome this disability a new machine, the Model 14 Typing Reperforator (Fig. 4) has been developed. This machine reperforates tape from line signals and types the message on the tape simultaneously, permitting the typed tape to be read quickly and handled expeditiously.

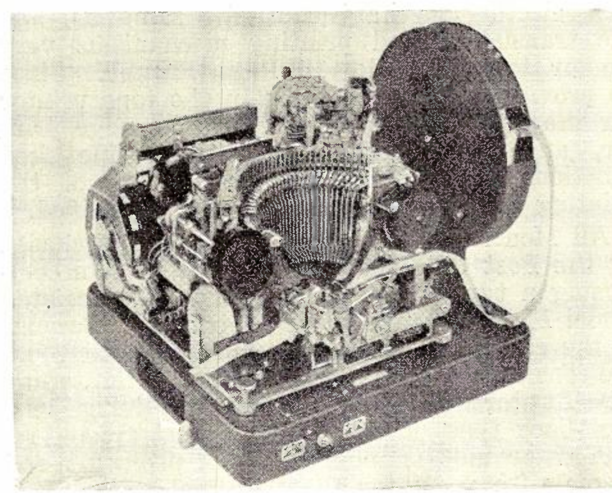


Fig. 4.—Receiving-only (low base) typing reperforator.

These functions have been effected on the one tape by arranging for an incomplete or "Chadless" perforation. In this process a U-shaped hole is punched in the tape, the punching or "chad" remaining attached to the tape by the solid material at the open portion of the U. This also functions as a hinge as the "chad" is bent up from the tape to clear the punched hole. Since there is no complete punching, the term "chadless" will be appreciated, as will the fact that the printing is not obliterated by holes in the tape since it is substantially complete. A sample tape of this sort is shown in Fig. 5, from which it will be seen that the tape is perforated cross-wise in the usual manner with five code perforations and a smaller feed hole for each character. The lower-case characters (letters) are typed on one edge of the tape whilst the upper-case characters (figures) are typed on the other side of the feed holes. The tape may be transmitted through a Model 14 Tape Transmitter to line in the conventional manner.

The Model 14 Typing Reperforator has been based on the Teletype Corporation's Model 14 Tape Printer, the essential changes being the addition of the punch block assembly and link mechanisms which transfer the motions of five conventional code bars of the printer to the five code punches of the punch block. The unit has the usual 115 volts A.C. 50-60 cycle series governed motor whilst

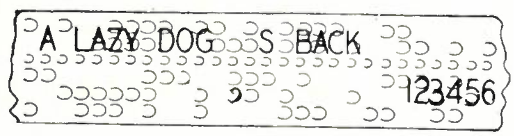


Fig. 5.—"Chadless" tape.

the selecting mechanism is the same as, and the translating and printing mechanisms very similar to, the Model 15 Page Printer. Since no provision has to be made in the tape printer for the large platen assembly of the page printer, and the carriage return and line feed functions are not required, the design of the printing mechanism is considerably simplified.

All Model 14 Typing Reperforators purchased by the Post Office have been units in sets comprising a typing reperforator and an associated Model 14 Tape Transmitter Distributor. Because of the exigencies of war-time procurement there are considerable variations in detail in the typing reperforators. Some are of the receiving only, high-base type, in which the actual typing reperforator unit is mounted on a pressed metal frame with room for the tape reel and a W.E. 255A polarised relay below the actual unit. Others are of the receiving only, low-base type, in which the typing reperforator unit is mounted on a low aluminium alloy base casting with provision for a tape reel at the side of the machine. Others are of the sending-receiving low base type having a similar base unit and tape reel to the receiving only low base machines but, in addition, a keyboard transmitter is mounted on the base unit and driven from the typing reperforator unit motor. Both of the latter types have provision for a special "tape out" alarm bell which rings when the tape reel is almost expended, whilst the sending-receiving machine has a letter counter and associated "end-of-line warning" lamp so that the tape machine may be used in conjunction with page printing machines if needed.

Whilst tape relaying has been used in Australia only to a limited extent, it is interesting to note its recent application abroad. The U.S. Signal Corps used, during the war, a number of installations in large centres in which all traffic was handled through typing reperforators, thus completely eliminating manual retransmissions at these centres with their large numbers of operators, delays and possibility of error. The A.T. & T. Co. has provided some large American organisations with tape relaying systems in which all cross connection is made by automatic telephone switches, the automatic switching being controlled by certain code perforations in tapes. It should be appreciated that tape relaying has immediate advantages over direct switching of line to line in telegraph work as it gives direct relaying from simplex to duplex circuits and avoids the very complex telegraph transmission problems of large telegraph switchboards. The retransmitted signals from the tape relay centre are substantially distortionless, irrespective of the distortion of the originating circuit (within, of course, the limits of the reperforating machine margin).

A limited quantity of Model 14 Keyboard Reperforators has been obtained from the U.S. Foreign Liquidations Commission. This machine is a power magnet operated keyboard perforating

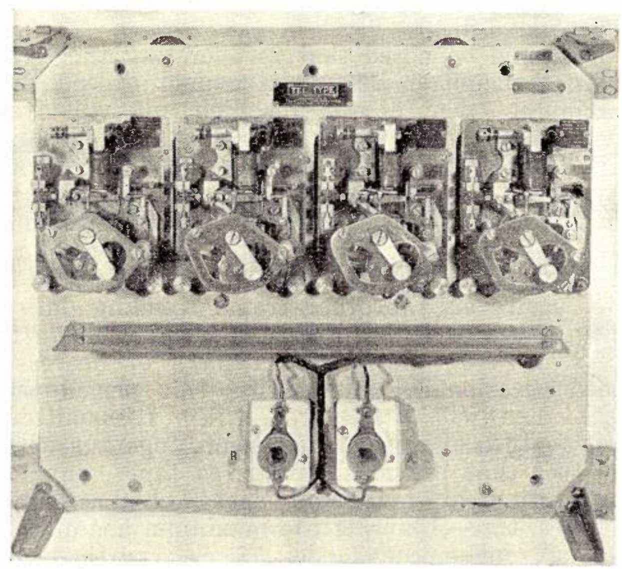


Fig. 6.—REP. 6A regenerative repeater panel.

unit of conventional design and is used to prepare tape for transmission through a tape transmitter to the line circuit.

The quantities of Model REP.6A regenerative repeater panels and associated Model RED.8A regenerator units have been purchased for use on very long multi-link teletype circuits. Teletype signals transmitted over long circuits become distorted. Ordinary telegraph repeaters relay all or part of this distortion from one link in the circuit to the next, the distortion in the sections being cumulative overall. If the overall distortion exceeds the limit determined by the margin of the receiving machine it will fail to operate correctly. To overcome this, regenerative repeaters are inserted in the circuit. The regenerative repeater receives any signal sufficiently perfect to operate a receiving teletype, analyses it and retransmits it in the distortionless condition to the next link in the circuit. The regenerator unit is mechanically similar to the selecting mechanism of the printer, but instead of controlling a printing mechanism the selecting mechanism controls the retransmitting contacts. As illustrated in Fig. 6 there are four RED.8A regenerator units mounted on each REP.6A regenerative repeater panel and driven by a common governed motor on the panel. The panel is arranged for mounting on a normal long line equipment rack together with the associated relays on an adjacent panel (not illustrated). Generally, two regenerator units are required for each circuit, one in the A-B and the other in the B-A directions. The complete panel will therefore normally provide for two complete circuits, the only connection between the individual regenerator units being the common driving motor and lay shaft.

The distortion normally experienced on long distance circuits is such that three carrier telegraph channels in tandem are considered to represent the safe limit for reliable teletype working under Australian conditions, and beyond this limit regenerative repeaters are necessary for direct working. The recent extensive provision of direct long distance carrier telegraph systems, such as the Melbourne-Brisbane and Sydney-Adelaide, which eliminate the previously used two link circuits Melbourne-Sydney-Brisbane or Sydney-Melbourne-Adelaide, has reduced the immediate need for regenerative repeaters, and in consequence these units are only coming into service slowly. However, it is anticipated that the development of switching systems at present under way will result in an increased need for the regenerative repeaters as part of the solution

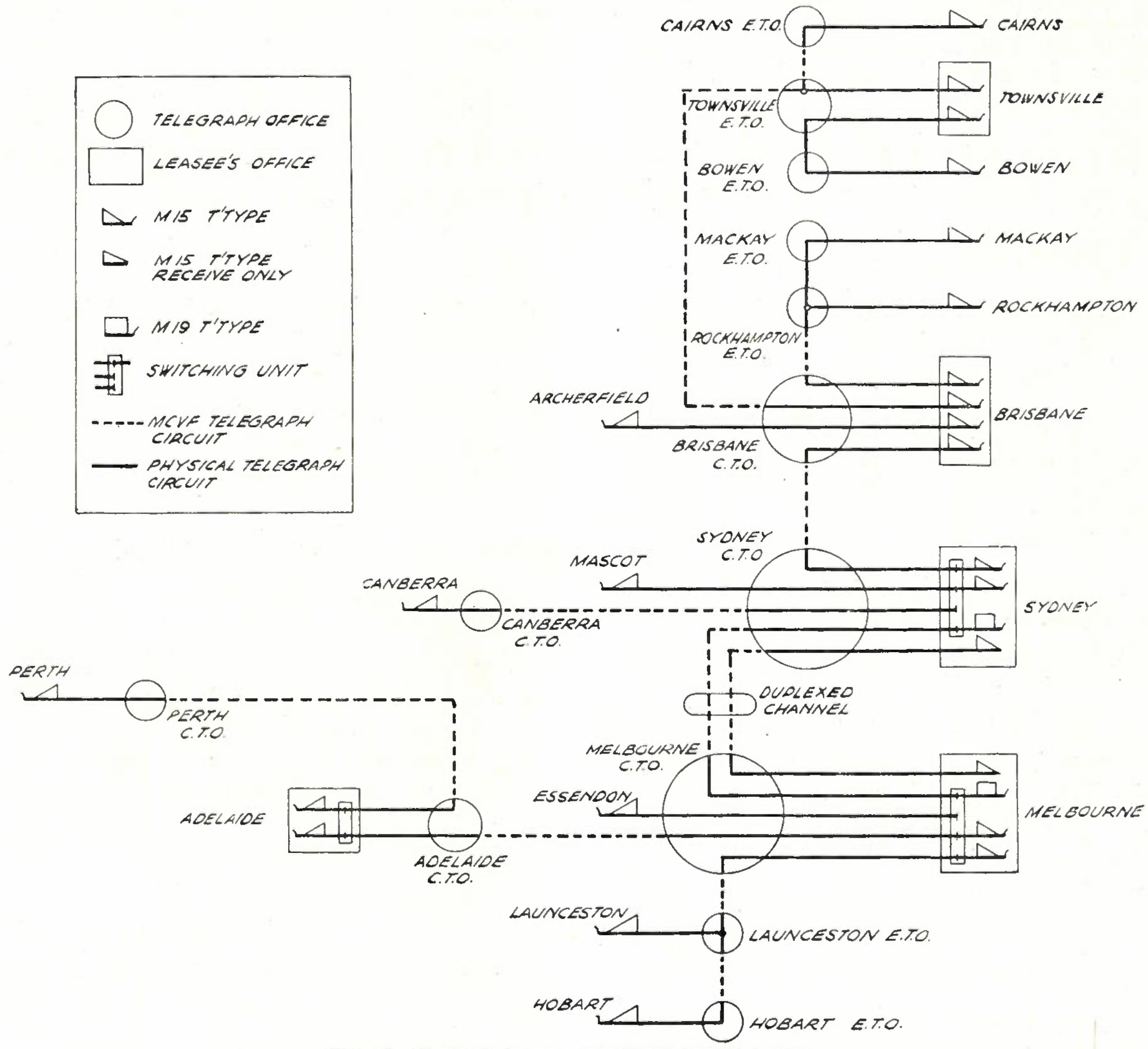


Fig. 7.—Typical leased teletypewriter network.

of the difficult transmission problems of extensive switching schemes.

It will be appreciated that each of the different types of teletype equipment described above provides a special facility, and that they may be used in various combinations to meet the particular requirements of any service. The circuit layout in Fig. 7 is typical of the extensive leased teletypewriter networks which are now being provided for large commercial and Governmental undertakings. The Department has also used the flexibility of the Start-Stop printer in handling its own traffic, as instanced by the special circuits, of a similar extent to those shown in Fig. 7, which were set up to handle press traffic in connection with the recent Test Cricket Matches. There is no doubt that more extensive and comprehensive networks of start-stop apparatus will be required and that the solution of the particular traffic handling problems of the individual user will be found in the employment of these various types of equipment to provide a complete and efficient service.

CENTRALISED TESTING SERVICES AND MAINTENANCE CONTROL IN THE ADELAIDE METROPOLITAN NETWORK

J. L. Harwood

General: In the years 1927-30, during the conversion of the Adelaide suburban telephone network to automatic working, four branch exchanges with L and M prefixes were established, viz., West Adelaide, Henley, Prospect and Woodville. All outgoing traffic from these exchanges was routed through one Tandem Exchange, but each handled its own testing services and controlled the sub-station maintenance staff accordingly. However, it was soon apparent that a more efficient and economical method of handling this aspect of the service could be arranged by concentrating the control at a centralised location and, to this end, the complaints handling and faults testing associated with the L and M branch exchanges were transferred to the Tandem Exchange. Under this arrangement each branch exchange was left only miscellaneous testing, such as routine testing of subscribers' services, cable breakdowns, etc., for which an allowance of 25% of the total testing was made in the exchange loading.

A notable feature of this scheme was the great flexibility obtained in directing the substation maintenance staff to the best advantage for the clearance of faults with a minimum of delay.

In recent years the installation of several small exchanges in the L and M group, namely Modbury, Gepps Cross, Edwardstown, and the development of the existing exchanges, has given further opportunity to prove the increased efficiency of the centralised testing and maintenance control scheme.

During 1944, it was decided to add two more exchanges to the group handled by the Tandem Exchange, and Glenelg and Brighton Exchanges were relieved of their complaints and testing services accordingly. The results proved highly satisfactory, as the reduction of the overload on the Exchange Maintenance staff at Glenelg was greater than the consequent increase in the loading of the Tandem staff. This was due to the elimination of much of the ineffective time spent on comparatively small Test Desks (e.g., those serving less than 3,000 subscribers).

It was then decided to transfer the Port Adelaide and Semaphore Complaints and Testing services to Tandem, therby adding another 1900 lines, whose average calling rate is 1,950 per annum for Port Adelaide and 1,000 per annum for Semaphore subscribers. The transfer of these exchanges to the Centralised scheme was effected at the time of issue of the 1945 Directory, and

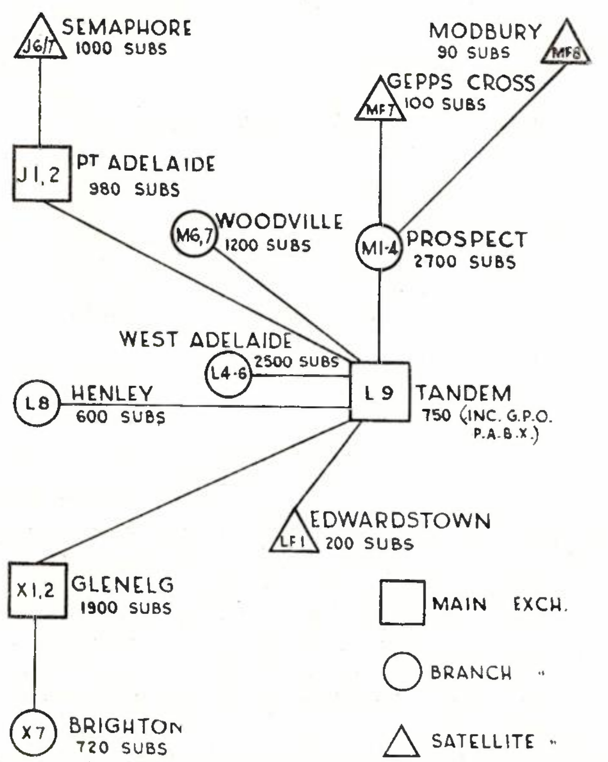


Fig. 1.—Adelaide exchanges included under the centralised maintenance control scheme.

the total number of lines now served by the Tandem Exchange Test Desk is nearly 13,000. Fig. 1 shows the sector of the network concerned.

The Test Desk (see Fig. 2) is a four position desk equipped with three testing positions and one complaints position. The filing sections are situated between the testing positions. The desk is normally staffed by two testing officers who receive the incoming complaints, test subscribers' lines and generally direct the activities of the subscribers' maintenance staff. When traffic demands, however, the third testing position and the complaints position are also staffed, the latter handling all incoming complaints and carrying out Public Telephone "Out-of-Order" observations. Sub-station maintenance staffs, directed by the testing officers, consist of 7 Technicians, two Senior Technicians (P.A.B.X's) and four Line Tracers, all of whom maintain subscribers' apparatus and lines in 12 automatic exchange areas.

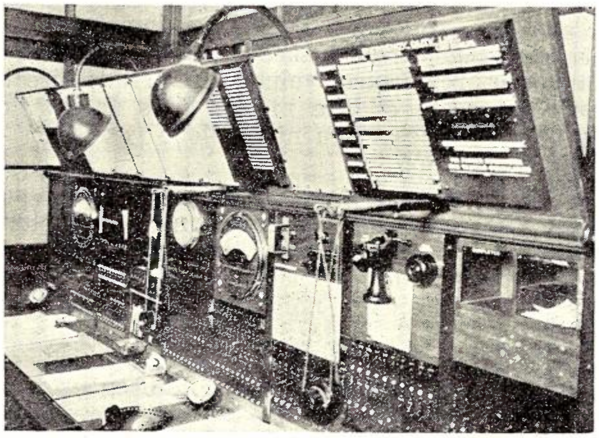


Fig. 2(a).—Tandem Exchange test desk showing two positions.

The outstanding features of the system are described hereunder:—

Master Card Records: Copies of telephone orders affecting all of the exchanges controlled under this scheme are sent to the Tandem Exchange, and Master Card Records are made as the installation staff completes the work. Each of the exchanges keeps records of its own subscribers' services on the usual "Branch Exchange Record of Subscribers' Services." P.B.X. maintenance records, dry cell records, etc., are the responsibility of the Supervising Technician of the Exchange, to which the Fault Technician serving the areas concerned is attached. The routine examinations and tests of P.B.X., Public Telephones, etc., are therefore controlled by the Supervising Technician at each individual Exchange.

The problem of housing the Master Cards for some 13,000 subscribers' services, covering nearly 16,000 stations, was solved by the installation of a nest of 30 steel drawers mounted on a turntable. This is placed directly facing the filing section between testing positions 2 and 3, so that two testing officers have direct access to the cards by rotating the nest through an angle of 90 degrees. The ultimate capacity of the cabinet is over 20,000 master cards.

Test Desk Facilities: In order to handle efficiently such a large number of subscribers' services many special facilities have been installed to cover all phases of testing. The facilities include: —

(a) The usual testing circuit for conductor resistance, insulation resistance, leakage, foreign battery, impulse count, speed and weight, P.G. release (local and remote), howler circuit and transmission test (25 and 40 db. pads).

(b) Lines to all other test desks in the metropolitan area, and order wire circuits to various desks in Adelaide trunk and Central exchanges.

(c) Public Telephone Out-of-Order observation circuits to all of the larger exchanges in the controlled group.

(d) Inspector's trunk circuits for direct tests from outside staffs.

(e) Incoming complaints and associated extension circuits.

(f) Extension of Complaints from Unley and Norwood Test Desks when those exchanges are not staffed for short periods.

(g) Test distributor trunk circuits to provide access to all of the L, M, J, and X Exchanges and all E and F type P.A.B.X's.

(h) Extension of alarm circuits from these Exchanges and the necessary means of identifying alarms occurring during unstaffed periods.

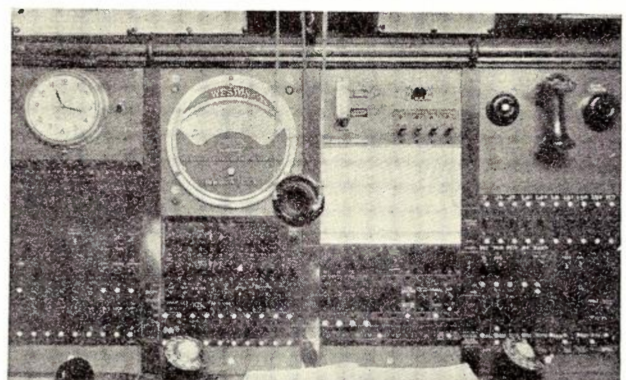


Fig. 2(b).—Close-up of main testing position.

(j) Loud speaker call circuit from the test desk to the Tandem Exchange switchroom to direct fault technicians to faulty circuits, etc.

(k) Loud speaker inter-communication circuit to branch exchanges to enable the branch exchange staffs to be called and addressed rapidly.

(l) Tone feed circuit to provide a tone of 800 cycles per second (1 mW in 600 ohms) on any final selector test number for switch and junction transmission tests.

(m) A volume indicator for the purpose of testing the transmission efficiency of subscribers' telephones.

During the latter part of the war, the main A.R.P. warning control, together with certain testing facilities, was also connected to the Tandem Test Desk.

Fault Procedure: Subscribers in the L, M, J, and X Exchange areas (Fig. 1) dial LOO when reporting complaints. The complaints officer records the complaint in the complaints register and enters the details on the prescribed fault docket (EM.3). While the subscriber is waiting, the master card is obtained, and the line is tested immediately. If a genuine fault exists, the fault docket is attached to the master card and placed in the "Suspense" pigeonhole. As soon as possible, the Fault Technician in the area concerned is given the details of the fault and proceeds to the subscriber's premises. When the O.K. test has been given, the fault is written off both in the register and on the EM.3.

Faults on Public Telephones in the Central area are passed from the Central manual test desk to the Tandem desk as these services are all connected to the L9 thousand group of the Tandem Exchange.

From the Port Adelaide, Glenelg, West Adelaide, Henley and Prospect exchanges, direct access may be obtained to the test desk testing circuit by dialling a special code, depending on the Exchange area concerned, thus enabling the test desk staff to test direct to the subscriber's telephone without the necessity of reverting the call via the test distributor.

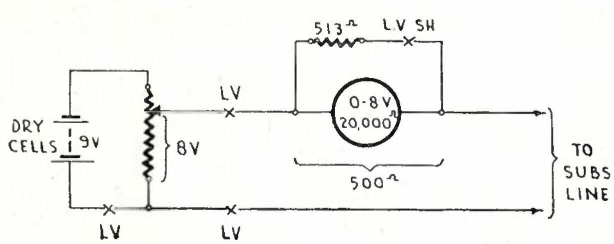


Fig. 3.—Circuit conditions for conductor resistance tests.

Special Circuits: A brief description of some of the special circuits used is given hereunder:—

1. **Conductor Resistance Test Circuit** (Fig. 3): 6 dry cells are used in conjunction with a 100 ohm potentiometer to provide a testing potential of 8 volts. The voltmeter with an internal resistance of 20,000 ohms on the 8 volt scale, has an effective resistance of 500 ohms when the shunt is connected. The advantages of this arrangement are:—

(a) A "non-earthed" testing battery is used.

(b) The maximum testing potential is only 8 volts. This relatively low potential has been chosen to minimise the possibility of breaking down intermittent faults during testing.

(c) The low internal resistance of the meter with its shunt allows the upper two thirds of the scale to be used for loop resistances under 1,000 ohms. The spreading of the scale in this way has resulted in greater accuracy in conductor resistance measurements, particularly in the remote exchange areas.

(d) The use of a dry cell battery obviates the maintenance difficulties associated with an 8 volt secondary battery, and gives very stable results. The potentiometer needs adjustment only once or twice each week.

Conductor resistance values are read directly from the scale of the meter, thus facilitating the accurate measurements of loop resistance of subscribers' lines.

2. **Transmission testing of subscribers' services:** The Transmission Measuring Set (Volume Indicator) has been installed to provide for transmission tests from subscribers' telephones by the use of the standard noise generator described in Vol. 4, No. 2, Page 86. The range of the instrument is from —20 db. to +2 db. (ref. one mW in 600 ohms) and means have been provided to test receivers by using the noise generator against the earpiece, in which case the range is extended to read levels as low as —45 db. It is very important that the transmitter current be cut off when making receiver tests, otherwise the transmitter will be sensitive to the noise generator and the test will be of no value. The transmission test set is operated from the exchange 50 volt negative and 50 volt positive batteries.

3. **Remote P.G. release circuit (Fig. 4):** No standard means is provided for the release of "permanents" over the normal test distributor circuit to distant exchanges. A method of doing this was found which depends upon a positive battery pulse sent from the test distributor "operating" circuit of the test desk at the controlling exchange to the test distributor at the terminal exchange. The A relay of the latter is not affected, but D releases and PGR operates. PGR relay introduces the boosting pulse to force the release of the switch held by the fault condition and, in the case of an "intermediate" exchange, transmits a positive battery pulse to the "terminal" exchange. After release occurs and the positive battery pulse is disconnected, D operates before PGR releases and ensures that the K relay of the subscriber's line circuit is operated from the test distributor and test final circuits. The D relay of the test distributor in the "intermediate" exchange is made slow releasing so that it will hold during dialling, otherwise it would affect the impulse repetition to the satellite exchange. Relays PGR, A and B are mounted adjacent to the test distributors, accessible from the Tandem exchange. The method of forcing the release of the "permanent" is similar to the standard arrangement shown on Drawing C.558, with the difference

that a 3 volt negative booster battery is used in some exchanges, while in others it has been found possible to dispense with it entirely. A 6 volt dry cell booster battery is unsuitable, for the reason that with the increasing use of 50/50 A relays and their associated barretters, "PG's" cannot be released on Repeaters and Discriminating Selector Repeaters so equipped, as the reverse current flowing in the negative winding is approximately 60 milliamps, thus causing a re-operation by the reverse flux in one winding. With the 200/200 A relay this does not occur as the reverse current with 6 volts is only 30 milliamps in the negative winding.

4. **Lines Between Desks** (Fig. 5): To minimise the number of cable pairs required for special circuits an omnibus "Line between desks" circuit was developed for use between Tandem, Port Adelaide and Semaphore exchanges, over a 2-wire circuit. It enables any one of the three exchanges to call either of the other two individually. A guard lamp at the unwanted exchange test desk indicates that the line is in use between the other two exchanges. The circuit functions as follows:—

(a) To call Port Adelaide (from Tandem or Semaphore) an earth operates relay A via the A wire at Port Adelaide. A lights the calling lamp and operates the night alarm, and when Port Adelaide exchange answers, relay C lights the guard lamp and extinguishes the calling lamp. At the unwanted exchange relays A and B operate and complete the circuit for the guard lamp.

(b) To call Semaphore: As for Port Adelaide except that the B wire is earthed and relay B is operated to light the calling lamp.

(c) To call Tandem from either Port Adelaide or Semaphore, an earth is placed on both legs via a high impedance (R/O) and relays A and B operate at Tandem. The call lamp circuits are completed and light on all positions. When the call is answered, the guard lamp circuits are completed and the call lamps extinguished. In the case of a call between Port Adelaide and Semaphore only, an earth would have been applied, first to one wire and then to the other, and would normally have called the Tandem exchange. To prevent this, the operation of only one of the relays A or B at Tandem exchange will operate relay C and also charge the 25 μF condenser QA. to 50 volts. At the operation of the other relay when the distant exchange answers, relay D will operate on the discharge of

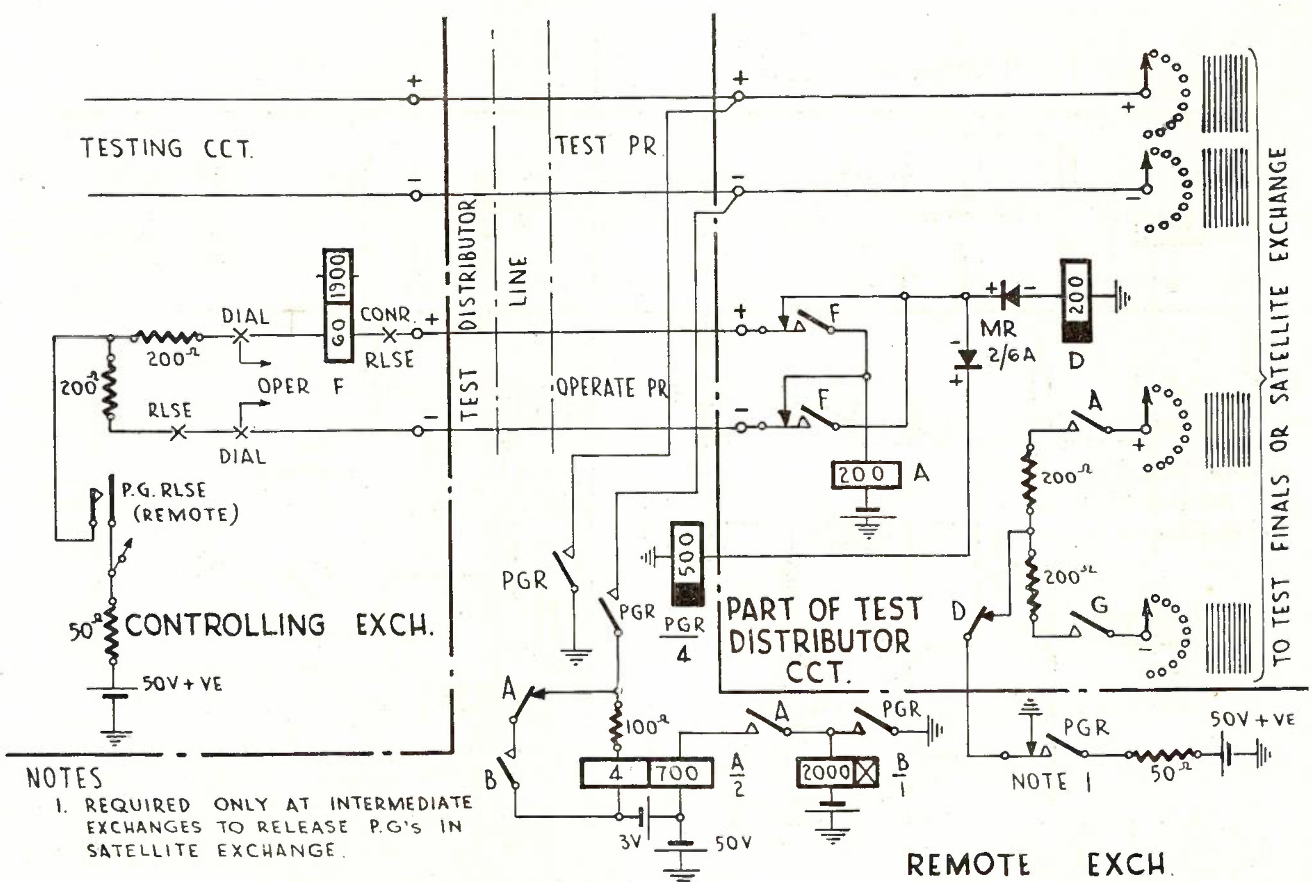


Fig. 4.—Remotely controlled P.G. release CCT.

the condenser, and lock until both A and B have released. Only the guard lamps glow on the Tandem desk when a call is in progress between the two remote exchanges. Hence the only way in which Tandem can be called is to apply the earth to both A and B wires almost simultaneously in which case the condenser cannot be charged sufficiently and D remains unoperated throughout the duration of the call.

5. **Public Telephone Out-of-Order Observation Circuits** (Fig. 6): As frequent reports are received from Public Telephone users, special observation circuits are used to enable the Tandem exchange testing staff to monitor calls from this source. It will be appreciated that the fault incidence of these instruments is extremely high, and any means of reducing the number of ineffective faults or "F.O.K's" is of value. Fault statistics show that the average Public Telephone requires approximately 30 times the attention given to the ordinary subscriber's instrument.

The observation circuits serving the J and X exchanges (Fig. 1) are provided on a 2-wire basis, while those serving the L and M branch exchanges utilise three wires. The same equipment is used at the Tandem exchange for either type. The circuit functions as follows:—

When the Public Telephone user lifts the receiver, relay A operates at the distant exchange and places an earth via two 3,000 ohm resistances and a high impedance (R/O) on each leg of the line in the case of the 2-wire circuit, while for the 3-wire circuit the 3rd wire is earthed. This operates relay L at Tandem and lights the call lamps on testing positions 2 and 3. The call lamps, which function also as guard lamps (at lower brilliance), are six-volt metal filament lamps connected in series. When the call is answered, the guard relay G is operated and holds in series with both lamps which remain at a dull glow. The call is observed for satisfactory progress and the key is then restored.

A key is provided in the main exchanges to switch the 2-wire circuits through to satellite exchanges for Public Telephone observations.

6. **Direct Access to Test Trunks:** Direct testing circuits are provided from West Adelaide, Henley, Prospect, Woodville, Port Adelaide and Glenelg exchanges via a special third or fourth selector level. Direct connection to the test desk from the subscriber's telephone can be set up without the necessity of the test desk officer reverting the call through the test distributor.

7. **Loud Speaker Inter-communication circuit:** This circuit has been installed between Tandem and the Port Adelaide and Semaphore exchanges

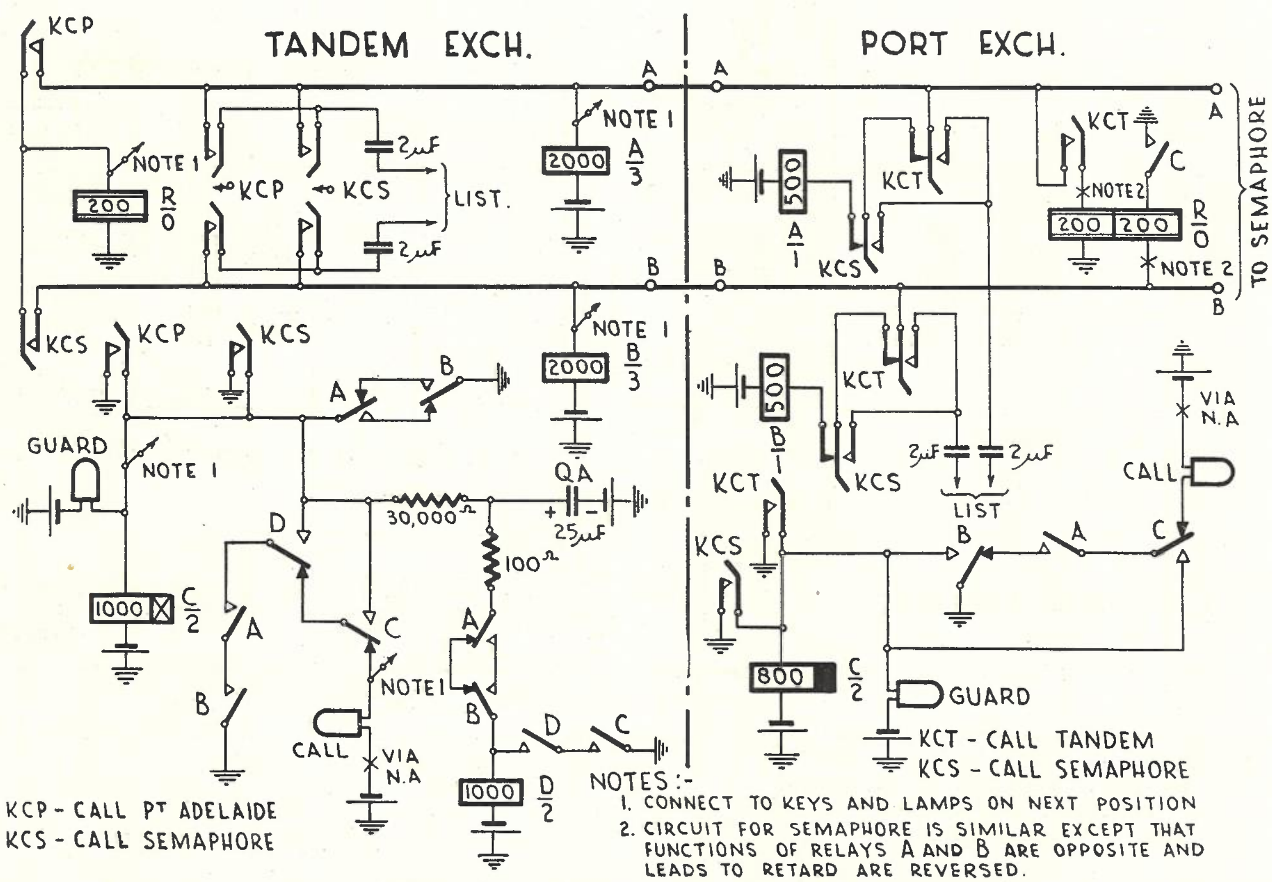


Fig. 5.—B/W line between desks with selective calling facilities.

and will be extended to other exchanges shortly. It enables Tandem to call Port Adelaide or Semaphore individually on loud speakers in the respective exchange switchrooms. The distant exchange staff can answer the call from almost any position in the switchroom merely by speaking loudly. The conversation is controlled by the Tandem testing officer by means of a "Press-to-Talk" key, which reverses the amplifier and connects the loud speaker in the distant exchange.

The advantages of such a system are:—

(a) Calls can be made direct to the exchange concerned rapidly, and many faults can be traced while the faulty condition remains.

(b) It is not necessary for the officer in the distant exchange to move to the test desk or telephone to answer. This is of advantage as attention to the main frame, repeater rack or other equipment may be required during the course of the conversation.

Conclusion: The foregoing gives an indication of the degree of efficiency which has been achieved by the centralised control of subscribers' maintenance services in the Adelaide network. With the complete conversion of the Central Exchange area to automatic working, it is anticipated that the centralised control of Complaints services will be further extended and linked closely with the centralised Testing services.

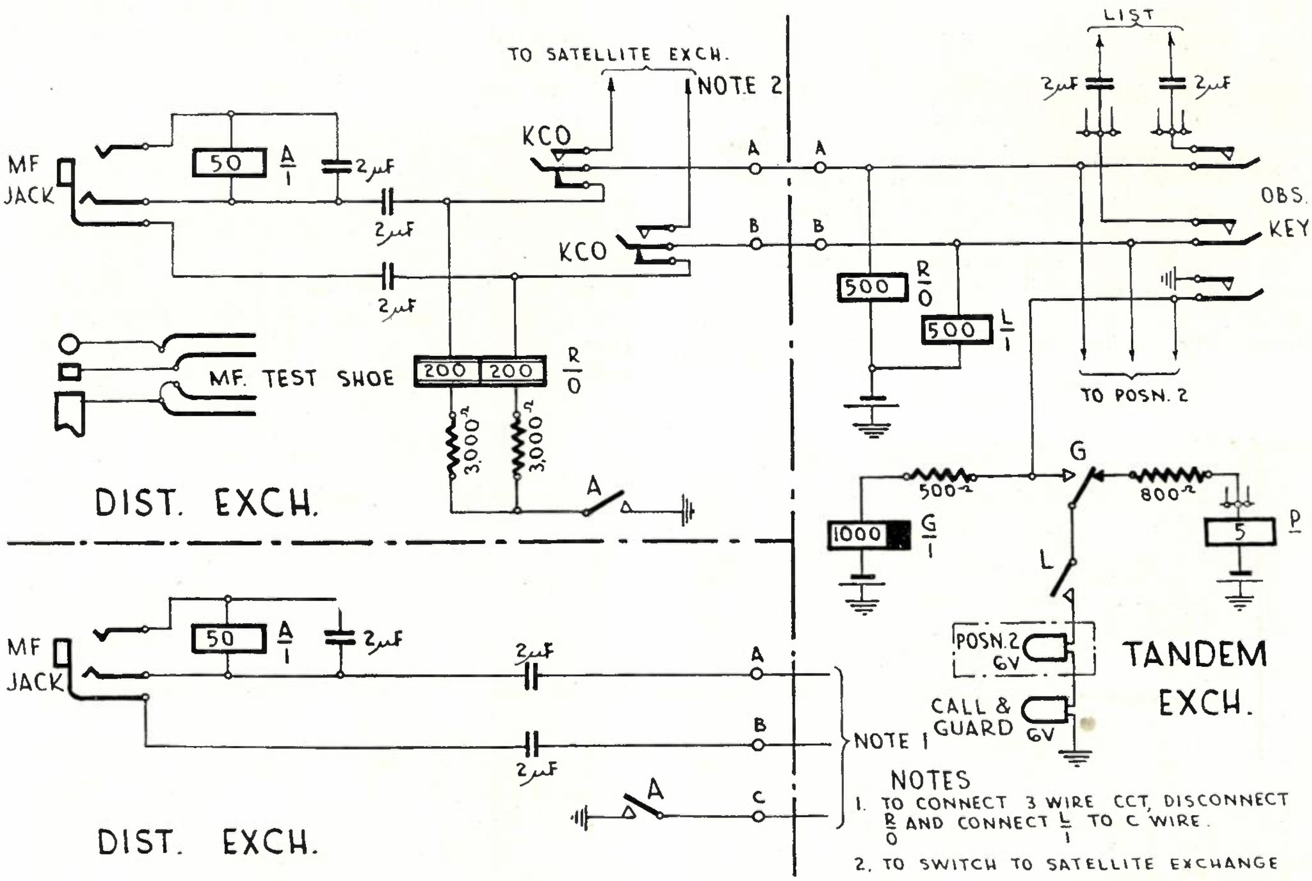


Fig. 6.—Public telephone out-of-order observation CCT.

SEDAN TYPE ACCOMMODATION OF 30 CWT. TRUCK

E. W. Corless

Over the past few years considerable attention has been paid by the Department to improving conditions for line staff required to travel on and work from 30-cwt. trucks with tray bodies. The present standard equipment for such trucks consists of folding seats built into the tray, with a canvas canopy fitted to a removable iron framework. Ladder racks are also fitted fore and aft of the tray to accommodate ladders, pikes, pipes, etc.

Fig. 1.—General view of modified cabin truck.

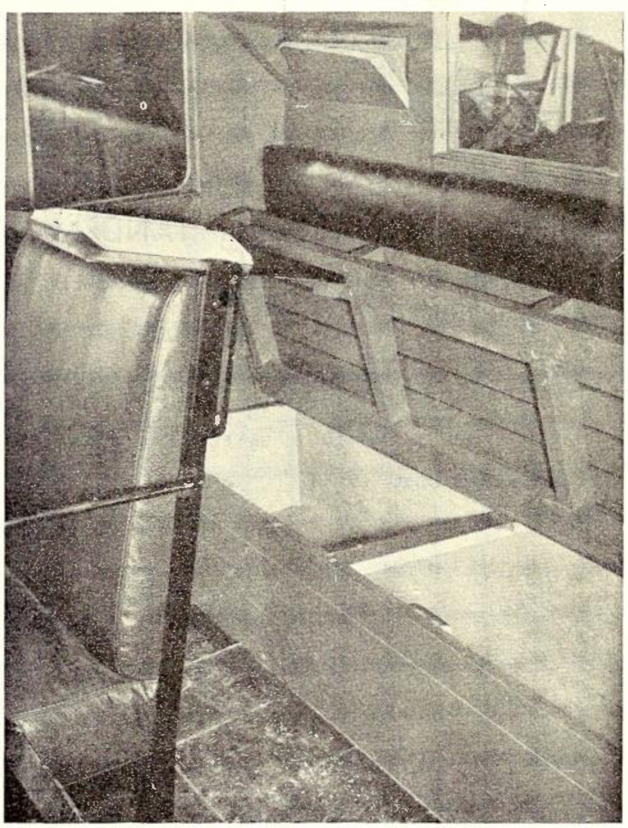


Fig. 2.—Interior of cabin showing writing table, etc.

A new method of providing accommodation on existing trucks has been tried out recently, and from preliminary tests and costs it appears possible that it may in many instances replace the existing type. This new unit, which is shown in Fig. 1, consists of a modified cabin giving accommodation for six passengers and driver on two seats inside the cabin. The driver's seat is, for safety purposes, separated from the remainder of the front seat by an arm rest. A section of the front seat used by two passengers is made to fold forward to give easy entrance to the rear seat. This rear seat accommodates four passengers, and is of similar construction to the seats now provided on the tray of the truck. The seat and the back are upholstered.

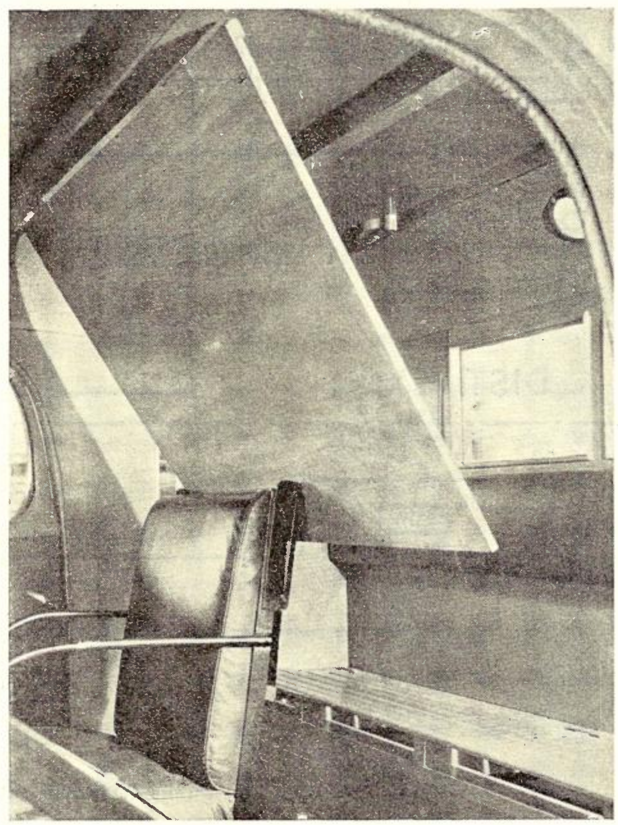


Fig. 3.—Interior of cabin showing plan table.

Other features of the cabin are:—

(a) A folding table mounted on the back of the driver's seat for use of the party leader when preparing reports, etc. This table unfolds into a convenient position for use by a person sitting in the rear seat. (See Fig. 2.)

(b) Accommodation for working report books, etc., in special pouches inside the cabin. (See Fig. 2.)

(c) A folding plan table which will accommodate a large-size drawing, and which when not in use folds against the ceiling of the cabin. (See Fig. 3.)

(d) An interior light, to facilitate use of plan table and writing desk at night time if it

Fig. 4.—Rear view of truck.

is necessary to use vehicles on fault work. (See Fig. 3.)

(e) Accommodation for Linemen's lunches and personal belongings underneath the rear seat. (See Fig. 2.)

(f) Accommodation in a separate locked enclosure for the tools attached to the truck. This space is underneath the rear seat.

(g) Facilities for driver to see behind when reversing the vehicle. This is important from a safety point of view.

The tray of the truck is fitted with a long locked enclosure between the main chassis members. It opens at the rear, and accommodates shovels, crowbars, etc. As the cabin is less than the full width of the tray, it is convenient to carry pipes or pole pikes on the edge of the tray, if necessary.

There is accommodation for ropes, chains, etc., in cupboards mounted underneath the tray on each side at the rear of the vehicle. These cupboards can be seen in Fig. 4.

The ladder racks on this vehicle can be mounted lower than on the present standard vehicle because it is not necessary for clearance to be left over a canopy. As will be seen in Fig. 4, it is easy for a man standing at the rear of the truck to remove a ladder from this vehicle or to strap the ladder in place. This feature saves climbing on to the truck, and simplifies the problem of garaging the vehicle.

It is expected that the unit described above will meet with the approval of operators who are required to use it, and the Department in turn should benefit from the fact that its staff will be more comfortably accommodated.

Reference: "Automotive Equipment and Construction Apparatus in Telephone Company Service." Bell Telephone Quarterly, July, 1939.

INFORMATION SECTION

RESISTANCE No. 112 (DRAWINGS C.E.390 AND C.E.392)

A new type of spool has been developed in this Department's Circuit Laboratory for wire wound resistors used with 6 volt lamps as current limiting resistances in 50 volt circuits. The complete unit which is shown in Fig. 1 is known as Coil Resistance No. 112 and has been designed especially for mounting on strips containing 10 standard lamp sockets (Type 19A) in the spare position adjacent to each lamp. The resistance is fixed in position by means of one screw. Three connecting tags are provided on the spool.

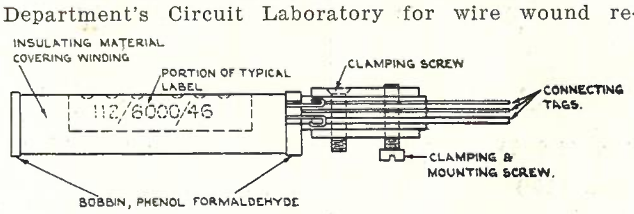


Fig. 1.—Coil resistance 112.

In cases where it is necessary to mount the resistors in strips of 20 a mounting strip type 112 is used. This strip is generally similar to the standard lamp socket mounting strip except that the front face consists of a brass plate with black finish. Fig. 2 shows the

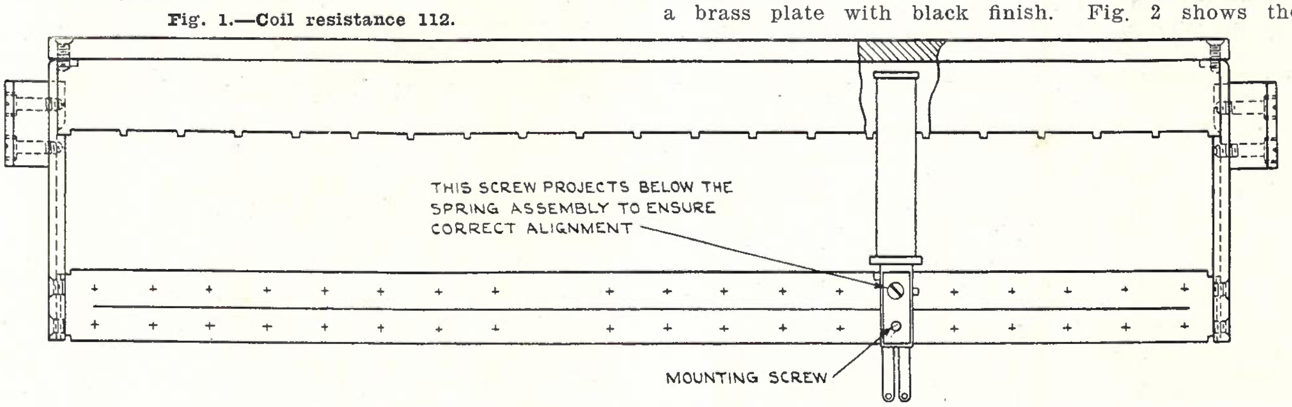


Fig. 2.—Mounting strip type 112, with one resistor in position.

general assembly with one Coil Resistance No. 112 in position. When the resistors are mounted in this manner the strip can be used as a blank spacing strip or for designations.

Considerable saving in wiring and cabling can be effected by the use of this resistance, especially in the case of multiple switchboards where many multiple appearances of the lamps are required. The resistance will be used on the standard floor pattern P.B.X. described in Vol. 5, No. 2, thus dispensing with the framework and cable forms in the top section of the switchboard.

The rating of the Coil Resistance No. 112 is 2 watts and, in this respect, it is equivalent to the standard Coil Resistance No. 12.—J.S.S.

SYMBOLS

The Symbols Commission of the C.C.I.F. recently considered several proposals concerning letter and graphical symbols. It was stated that, in all countries, there has been a tendency towards the use of Roman instead of Greek letters for some symbols. This is due mainly to the practical reason that Roman letters are provided on typewriters. It is understood that the Commission has proposed a standard list of letters for universal usage, and these symbols will be recommended for international adoption.

Pending the adoption of the proposed symbols, it will be necessary to continue with the use of those symbols previously accepted in general practice. The following lists of symbols and abbreviations will be used in future articles in the Journal until other information is published:—

Abbreviations for Terms

Term	Symbol
Admittance	Y
Attenuation Constant	α
Capacity	C
Conductance	G
Current	I
Current, Alternating	A.C.
Current, Direct	D.C.
Cycle	c
Cycles per second	c/s
Kilocycles per second	kc/s
Dielectric Constant	k
Efficiency	η
Electromotive Force	E
Frequency	f
Frequency, Angular $2\pi f$	ω
Gravity, Acceleration due to	g
Impedance	Z
Inductance, Mutual	M
Inductance, Self	L
Length	l
Magnetic Field	H
Magnetic Flux	Φ
Magnetic Flux Density	B
Magnetisation, Intensity of	J
Magnetomotive Force	F
Mass	m
Permeability	μ
Phase Displacement	ϕ
Potential Difference, Electric	V
Power	P
Quantity of electricity	Q
Reactance	X
Reluctance	S
Resistance	R
Resistivity	ρ
Root Mean Square	R.M.S.
Susceptibility	K
Time	t
Time, Period of	T
Turns, Number of	n
Wavelength	λ
Wavelength Constant	β

Abbreviations for Names of Electrical Units—Employed Only After Numerical Values

Name of Unit	Abbreviation	Name of Unit	Abbreviation
Ampere	A	Watt	W
Volt	V	Farad	F
Ohm	Ω	Henry	H
Decibel	db	Watt-hour	Wh
Coulomb	C	Volt-ampere	VA
Joule	J	Ampere-hour	Ah

Prefixes for Multiples and Sub-Multiples

Prefix	Abbreviation	Example
Milli $(\frac{1}{1,000})$	m	mA = milliampere
Micro $(\frac{1}{10^6})$	μ	μF = microfarad
Pico $(\frac{1}{10^{12}})$	p or $\mu\mu$	$\mu\mu$F = micro-microfarad
Kilo (1,000)	k	kW = kilowatt
Mega (10^6)	M	MΩ = megohm

—A.A.P.

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 give information which a candidate should have to enable him to give answers which would secure high marks.

EXAMINATION No. 2643—ENGINEER, TELEGRAPH EQUIPMENT— GROUP 1

R. D. Kerr.

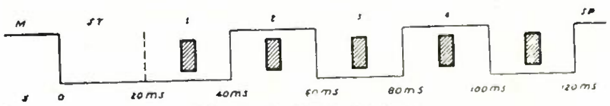
Q. 1.—(a) What is the effect at the receiving teleprinter of a difference in speed between teleprinters at the ends of a circuit? Show clearly why there is a limit to the allowable difference in speed and give an idea of its magnitude.

(b) How many signal elements are transmitted for each character and state the respective lengths of the signal elements? Assuming a speed of 432 r.p.m., give the duration in milliseconds of a signal element of the teleprinter.

A.—(a) The effect of a difference in speed between sending and receiving teleprinter motors is to reduce the effective margin of the receiving teleprinter, i.e., reduce its effective tolerance of distortion of the signals in the telegraph circuit. The loss of margin is approximately 6% for each 1% error in speed. Beyond the finite limit of this tolerance of speed errors the receiving teleprinter fails to record the signals correctly.

Since the effect of speed errors is cumulative over each start-stop character, the displacement of the sent signal transitions with respect to the selection intervals of the receiving teleprinter will be greatest on the fifth code element, and errors in printing generally show first as "extras" or "drop-outs" of the fifth code element.

Fig. 1 shows an undistorted train of signals corresponding to letter R.



Group 1, Q. 1, Fig. 1.

Each element of the signal train is 20 milliseconds long at teleprinter speed.

The selection intervals of the receiving teleprinter are not more than 30% of a signal element (i.e., 6 millisecs. long), and are placed at the middle of the signal element. These are shown graphically as the shaded portions of Fig. 1. The commencement of the fifth selection interval should occur 107 millisecs. after the start transition, and its completion 113 millisecs. after the start transition.

Should the fifth selection interval be advanced by increase in speed of the receiving machine so that its commencement coincides with the preceding M to S transition (end of the 4th signal element), this will be the limit beyond which error is likely to occur, due to "extra" fifths.

In this case the fifth selection interval would commence 100 milliseconds after the start transition. The percentage speed error fast would be given by—

$$(107-100)/107 \times 100\% = 6.5\%.$$

Similarly, the limiting slow speed will be given when the completion of the fifth selection interval coincides with the commencement of the stop signal, i.e., 120 millisecs. after the start signal. The percentage speed error slow would be given by—

$$(120-113)/113 \times 100\% = 6.2\%.$$

(b) The 7C teleprinter transmits for each character sent a start signal of 1 unit duration, 5 code elements each of 1 unit duration, a stop signal of 1 unit duration, the total character being 7 unit pulses long.

The 7B teleprinter transmits start and code pulses each one unit long, but the stop signal is 1.5 units long, the total character being 7.5 units long.

With a transmitter shaft speed of 432 r.p.m., the number of pulses sent to line per minute is 432×7,

or $(432 \times 7)/60$ per second,

i.e., duration of unit pulse is $(60 \times 1000)/(432 \times 7)$ millisecs $= 19.9$ milliseconds.

Q. 2.—Define the terms "bias distortion," "characteristic distortion" and "fortuitous distortion," and state how distortion of each type can occur in (a) a direct current telegraph circuit, and (b) a channel of a voice frequency telegraph system. The signal distortion on a certain telegraph circuit is 10 per cent. at 50 bauds. Explain fully what is the meaning of this statement.

A.—(i) Bias distortion is the lengthening of marking signals and the corresponding shortening of spacing signals (or vice versa) during their transmission through a circuit. The lengthening of marking signals is known as marking bias and the lengthening of spacing signals as spacing bias. Bias distortion can be observed by the sending of neutral reversals when, if bias is present, adjustments can be made until the received signals are neutral.

Bias distortion can occur in any circuit due to assymmetrical adjustment of the transmitting contacts, receiving relay or electromagnet, or to inequality of the marking and spacing batteries when double current signalling is employed.

(i) (a) In a single current D.C. telegraph circuit bias distortion can occur due to changes in the amplitude of the received signal. In such a circuit the restoring force applied to the receiving relay or electromagnet (e.g., by a steady current through one of the windings) should be such that the output signals are unbiassed. Owing to the shape of the received signal waves, a given restoring force will only result in unbiassed output with a suitable amplitude of the received signal. Any change in amplitude which may result from changing conditions in the line will therefore result in bias distortion at the receiver.

(b) In a V.F. channel the same fundamental connection exists between the amplitude of the received carrier signals and the bias of the signal output as in the single current D.C. circuit. The effects are, however, mitigated by the automatic compensation for changes in signal amplitude which is afforded by the type of amplifier detector used on V.F. channels.

(ii) Characteristic distortion is that distortion arising from the inherent electrical characteristics of the transmission circuit, including the normal sending and receiving terminations of the circuit, and is the distortion occurring consistently with any given series or combination of signal elements. It is therefore the distortion which would be measured at the output of the receiving relay, this relay being in perfect order, when perfect signals are applied at the sending end, the circuit being completely free of bias and with no interference from any other circuit, channel or external disturbing source.

(a) In a D.C. telegraph circuit characteristic distortion is mainly due to the distributed capacitance of the line, and occurs when the time required for the received current to build up to its full value is longer than the duration of the shortest signal element.

(b) In V.F. telegraph channels the line has a negligible effect on the characteristic distortion, the build-up time of the signals being determined by the channel filters. Characteristic distortion therefore occurs when the speed of signalling is increased to a point where the duration of the shortest signal element is less than the build-up time of the filters. With the standard 18-channel V.F. telegraph system this speed is in the neighbourhood of 70 bauds.

A further cause of characteristic distortion on a V.F. channel is the automatic gain control arrangement in the amplifier-detector. If a train of signals having a preponderance of spacing (no-tone) elements is sent over the channel, the gain tends to rise during the no-tone periods and is not fully restored to the correct value during the tone signals. Thus, at the end of a long no-tone period the gain is higher and the space-to-mark changeover tends to take place early. The effect is not noticeable to any extent with normal signals, but is quite marked when, for example, a continuous train of signals having six elements spacing and one element marking is transmitted. Although in this case the distortion appears as a bias, it is not true bias distortion, as it disappears if neutral reversals are transmitted.

(iii) Fortuitous distortion is that distortion which arises from random influences upon the apparatus or circuit. It can arise from mechanical faults in transmitting and receiving apparatus, a typical instance being the presence of magnetic particles in the air gap of a relay. It can also arise—

(a) In D.C. telegraph circuits, from electromagnetic and electrostatic interference from other telegraph circuits carried on adjacent wires in a cable. On overhead lines interference can also arise from atmospheric electrical disturbances or induction from electric power lines.

(b) In V.F. channels, from interference from other channels in the same system not completely suppressed by the channel filters, and from effects of second order intermodulation products resulting from the transmission of the V.F. signals through non-linear components in the line circuit. Interference with a V.F. system can also arise due to crosstalk from neighbouring telephone circuits or other V.F. systems and from noise in the line arising from some external source.

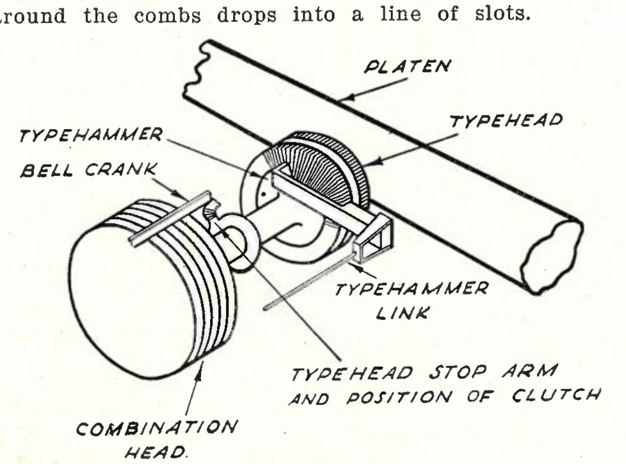
The statement that the signal distortion on a circuit is 10% at 50 bauds means that, during the period for which the signals were observed, and while signalling at 50 bauds, the maximum relative displacements from their true positions of any two transitions (mark to space or space to mark) was 10 per cent. of the unit signal.

At 50 bauds the unit signal is $^1/_{50}$ second or 20 milliseconds. The error of timing observed was therefore 2 milliseconds, being the sum of the forward displacement of the earliest and the backward displacement of the latest signals over the period of test.

Q. 3.—Describe with the aid of sketches the action of the printing mechanism of the teleprinter. Explain the sequence of operations from the reception of the train of signal impulses to the printing of the desired character.

A.—The start signal of a character causes the receive clutch to couple the driving motor to the receive cam cylinder. The operation of the receive relay armature, following the code signals of the character, moves the striker blade guide up to mark and down to space. When the striker blade guide is up, the striker blade engages the comb setting pin. When the striker blade guide is down, the striker blade moves below the comb setting pin. The start signal causes the traversing link to move the comb setting pin across the five comb setting fingers, and as the pin is in line with each finger the striker blade moves in, engaging the pin for each marking element and moving below it for each spacing element.

The pin pushes the comb setting finger in for marking elements, and the fingers remain unchanged in position for spacing elements. The comb setting fingers lifting lever lifts all the fingers after the five code elements have been analysed. Those fingers, pushed in by the striker pin, engage the comb setting levers of their respective combs, and their elevation turns the combs through a slight angle. The fingers which have not been engaged by the striker pin, when lifted, clear their respective comb setting levers, and these combs remain unchanged in position. The arrangement of the slots in the peripheries of the combs is such that one of 57 bell cranks arranged around the combs drops into a line of slots.



Group 1, Q. 3, Fig. 1.

Fig. 1 shows the main parts of the printing mechanism of a teleprinter, which comprise the typehead, type head clutch and type hammer. It also shows the relative positions of the platen and of the combination head.

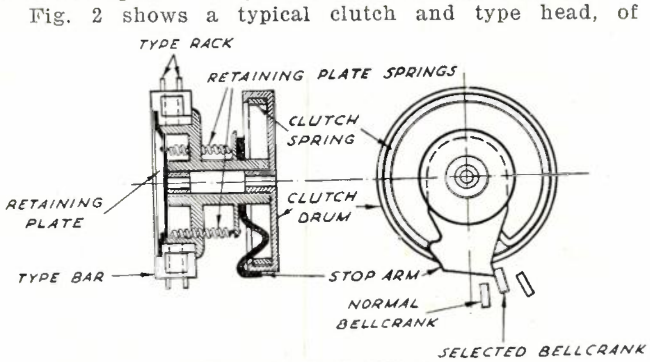
The functions performed by the various parts of the printing mechanism are briefly as follow:—

The type head consists of a circular rack which accommodates the type bars bearing the various characters, and to print any character the type head must be turned until the appropriate type bar is opposite the typing position on the paper platen. In this position the type bar is ready to be struck by the type hammer. The function of the clutch is to drive the type head to the required position and then disengage the drive. The sequence and timing of the operations are controlled by the receiving cams. The clutch comprises an outer drum, or driving member, rotating continuously on the type head spindle, which passes through the centre of the combination head, and a driven member, which is attached to the type head rack and is provided with a stop arm.

When a signal combination has been received, representing a character to be printed, the selecting mechanism sets up the required combination on the comb setting fingers. At this instant the type hammer operates to print the character previously selected, and immediately afterwards the bell crank latches on the combination head are raised and the circular comb discs are reset to their normal positions. As the bell crank latches are raised, that corresponding to the character just printed is moved out of engagement with the type head stop arm, referred to above. This allows the clutch to drive the type head until again, after the comb setting levers have set the combs for the next combination, the stop arm is arrested by the depressed bell crank latch appropriate to the character to be printed, causing the clutch to slip and hold the type head in position until the type bar is pushed forward by the type hammer. The type hammer is driven by a lever from one of the receiving cam tracks.

The No. 7 type teleprinters employ ribbon inking, in the same way as typewriters, and a ribbon jumper is provided to withdraw the ribbon from the line of characters between successive printing operations, so that the operator may read what is being printed.

Fig. 2 shows a typical clutch and type head, of



Group 1, Q. 3, Fig. 2.

which a number of slightly varying types are in use. The type bars are held in the rack by a spring retaining plate, so that they may be moved forward by the type hammer. The type head is driven by the clutch spring, which engages with the stop arm.

GROUP 2

Q. 1.—(a) State what line condition limits the speed or distance of direct telegraph working and explain how the use of repeaters extends the range.

(b) What is a regenerative repeater and under what circumstances would its use be advisable?

A.—(a) The following conditions limit the speed or distance of direct telegraph working:—

(i) The leakage of aerial lines under unfavourable line conditions makes it impossible to get sufficient current over the line to operate the receiving device effectively without using excessively high voltages and currents.

(ii) The resistance of cable lines makes it impossible to get sufficient current over the line to operate the receiving device effectively without using excessively high signalling voltages and currents.

(iii) The resistance and capacity of a line limit the maximum signalling speed obtainable from it. The maximum signalling speed is given empirically by the formula—

$S = A/KR$

where S is speed in words per minute

A is a constant depending on the type of line

K is total capacity of line

R is total resistance of line.

Should the line be divided and a repeater inserted, the speed of the overall circuit would be limited by the maximum speed over the longest section.

Where the repeater is the mid-point, the new speed per section becomes—

$S_1 = A/(K/2) \times (R/2) = 4\ A/KR = 4\ S.$

Thus the insertion of the repeater in the middle of the circuit enables the maximum speed overall to be theoretically quadrupled. Actually, there are cumulative distortions over the sections and distortions introduced by the imperfections of the repeaters (particularly in duplex balance) which reduce the practical gain.

In this way a very long circuit which could not be worked directly at machine speed may be divided by a repeater and effective working at machine speed obtained.

(b) A regenerative repeater, which would be designed for a particular type of machine system, consists essentially of a normal machine receive selecting mechanism which has a similar tolerance of received signal distortion to the normal terminal receiving selecting mechanism. The regenerative repeater receive selecting mechanism, instead of controlling a printing mechanism, controls a retransmitting mechanism, the code impulses retransmitted being controlled by those received by the selecting mechanism.

Ordinary relay repeaters strengthen the current for the next line section, reduce the KR of each section, and thus increase the effective speed of operation overall and minimize the detrimental effects of induction from other wires.

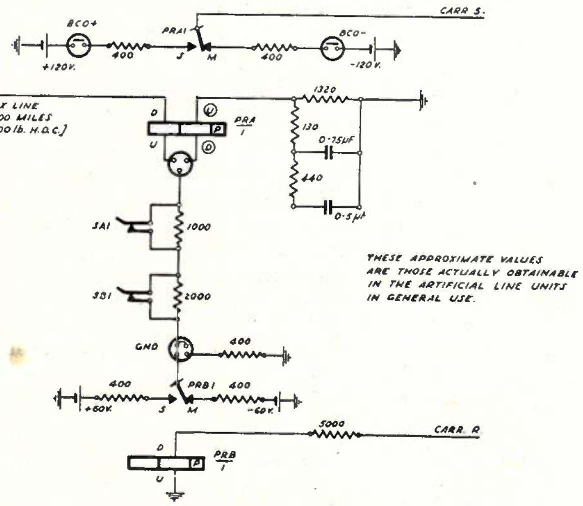
However, the repeaters do not correct any variations in the length of the signals, so that where a circuit is long and contains many such repeaters, it is not possible to maintain the speed of operation attainable over short sections due to the cumulative distortion of several line sections and repeaters.

The regenerative repeater not only strengthens the current for the next line section, but corrects any distortion of the received signals, so that repeated signals will be as perfect as signals originally sent from the transmitting terminal station.

Q. 2.—It is desired to connect a duplexed physical line 300 miles long and 200 lb. H.D.C. to a telegraph carrier channel. Describe, with the aid of a sketch, the circuit of a suitable repeater for the purpose and explain the operation. Show inserted in a sketch the approximate numerical values for the components in the artificial line box for satisfactory duplex operation over the line mentioned.

A.—The duplex physical line to V.F. telegraph channel repeater is similar to a terminal duplex set. Actually, in modern installations the same panel unit is used for both purposes.

The circuit of the unit is shown in Fig. 1. Connection is made from the duplex line relay tongue to the Carrier Send Circuit.



Group 2, Q. 2, Fig. 1.

The Carrier Receive Circuit drives the receive relay, which functions as a pole changer, its contacts sending negative battery to mark and positive battery to space into the split of the duplex line relay. The same circuit conditions apply in the duplex repeater as the duplex unit, i.e.—

(i) Carrier marking, negative battery in duplex split with mark at terminal end gives duplex repeater line relay marking.

(ii) Carrier spacing, positive battery in duplex split with mark at terminal end gives duplex repeater line relay marking.

(iii) Carrier marking, negative battery in duplex split with space at terminal end gives duplex repeater line relay spacing.

(iv) Carrier spacing, positive battery on duplex split with space at terminal end gives duplex repeater line relay spacing.

The keys SA/1 and SB/1 are provided to cut the 1000 ohm and 2000 ohm resistance in or out of the circuit to the split of the duplex line relay. These resistances are provided to limit the current in short lines.

EXAMINATION No. 2643—ENGINEER, TELEPHONE EQUIPMENT

W. King.

Q. 1.—(a) The traffic offered in the busy hour to a group of five switches arranged in a full availability group is 1.0 traffic unit. What grade of service is given?

(b) During the busy hour, at a moment taken at random, the number of switches engaged in the group of five switches referred to in (a) above is noted. Determine the most likely number of switches which will be engaged at the time notation is made and state the probability that the number of switches engaged will not coincide with the particular value shown by your calculations.

A.—(a) Assuming pure chance traffic, the grade of service is given by Erlang's formula—

$$B = \frac{A^N/N!}{1 + A + A^2/2! + \ldots\ldots A^N/N!}$$

where B = grade of service or calls lost
N = number of switches in the group
A = traffic offered in T.U.'s.

$$\text{Thus } B = \frac{1^5/5!}{1 + 1 + 1^2/2! + 1^3/3! + 1^4/4! + 1^5/5!}$$

$$= \frac{1/120}{1 + 1 + 1/2 + 1/6 + 1/24 + 1/120}$$

$$= \frac{1}{120 + 120 + 60 + 20 + 5 + 1}$$

$$= 1/326 = 0.003 \text{ approx.}$$

(b) The probability that X switches in a group of N will be found engaged at any instant taken at random is given by the formula—

$$P = \frac{A^x/X!}{1 + A + A^2/2! + \ldots\ldots\ldots + A^n/N!}$$

Let P0, P1, P2 be the probability that 0, 1, 2, etc., switches will be found engaged—

Then P0 + P1 + P2 + P3 + P4 + P5 = 1

P0 = 120/326 = 0.368
P1 = 120/326 = 0.368
P2 = (120/326) × 1/2 = 0.184
P3 = (120/326) × 1/6 = 0.061
P4 = (120/326) × 1/24 = 0.015
P5 = (120/326) × 1/120 = 0.003

The most probable number of switches engaged at any random instant is 0 and 1, which are equally probable. The probability that the number engaged will not be zero is 1 — 0.368 = 0.632.

Q. 2.—Discuss the advantages and disadvantages of 100 outlet compared with 200 outlet group selectors of the 2000 type, giving special attention to economic and impulsing considerations. State the functions of the individual relays fitted to each of these two types of selector switch.

A.—All earlier types of group selectors were provided with 100 outlets, 10 per level, and this limited the trunk group to a succeeding grade of switches to 10 trunks. With 200 outlet group selectors, 20 trunks per level are available to the succeeding group, and consequently more efficient trunk groups are provided. By this means, a saving of approximately 20 per cent. of switches in the succeeding rank is effected. Offset against this, however, is the extra cost of the additional 200 contact bank which must be provided for 200 outlet group selectors, plus the additional cost of the 200 outlet switch due to the provision of an additional test relay per switch. However, an overall economy is effected by the use of 200 outlet group selectors, and it is now standard practice to provide this type of switch in all modern exchanges.

Regarding impulsing conditions, these are similar for both types of switch, as the vertical stepping only is under the control of the dial.

The function of the individual relays fitted to group selectors is as follows:—

Relay "A" (Impulsing Relay):

(i) Operates over subscriber's loop.

(ii) Controls the operation of the guard relay "B."

(iii) Provides a balanced dial tone for calling subscribers.

(iv) Impulses under the control of the subscriber's dial and controls the operation of the vertical magnet.

(v) Returns a balanced busy tone to calling subscriber should all trunks on the level tested be busy.

Relay "B" (Guard Relay):

(i) Operates under the control of relay "A" and returns a guarding earth on the private to hold the subscriber's K relay and the switching relays of preceding switches.

(ii) Busies the selector to other incoming calls.

(iii) Due to its slow release, maintains the guarding condition during impulsing and switching.

Relay "C" (Switching Relay):

(i) Operates under the control of "B" relay and remains operated during vertical impulsing.

(ii) Completes the operation of the testing relay H, or in the case of 200 outlet switches, relays HA and HB.

(iii) Releases after vertical impulses and completes the rotary magnet circuit.

(iv) When a free trunk is found, reoperates and switches the subscriber through to the switch ahead.

Relay "H" Testing Relay (100 outlet selectors):

(i) This relay is held operated until the switch cuts in on a level.

(ii) When the rotary interrupter springs open during each rotary step, the holding of H relay is dependent upon the conditions of the private contacts tested. Earth connected to busy contacts holds the relay operated via the test winding, and the switch will continue to step. When a free trunk is found the relay will restore and allow the switching relay "C" to reoperate and switch the call through.

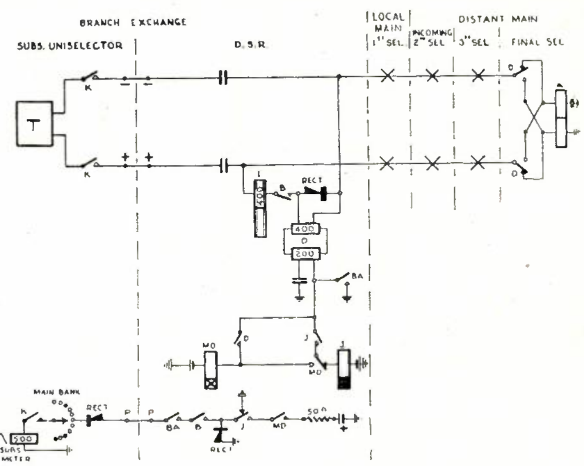
(iii) After switching, relay H reoperates and holds to earth returned on the release trunk from the switch ahead.

Relays HA and HB (Testing relays; 200 outlet selectors):

In the case of 200 outlet selectors, two testing relays are provided, one to test the upper and the other the lower 10 bank contacts of the private bank. The functions of these relays are similar to those of H relay in the 100 outlet switch; both relays will remain operated when testing busy contacts, but either or both will restore when a free trunk is found. This allows the switching relay "C" to reoperate and switch the call through. It is necessary for the negative, positive and release trunks to be switched through to the wipers corresponding with the free trunks. Therefore one relay must remain operated and, in the event of both trunks testing free, a circuit is provided for the reoperation of relay HA. Earth returned on the release trunk from the switch ahead will hold relay HA or HB operated while the call is in progress.

Q. 3.—A subscriber connected to a branch exchange originates a call which is routed through a main exchange to a subscriber connected to another main exchange. Describe how the call is metered and give a diagram of the circuit elements involved when metering takes place. Assume that each of the exchanges through which the call is routed is of the 2000 type.

A.—The circuit conditions are indicated in Fig. 1. As the call is originated by a branch exchange subscriber it would be switched via a D.S.R. or repeater in the branch to a 1st selector in the local main. From a level of this switch the call would be routed via a junction to an incoming 2nd selector in the distant main. The call would then pass via 3rd selectors and a final selector to the called subscriber. The metering of the call is controlled by a reversal of battery from the final selector, as follows:—



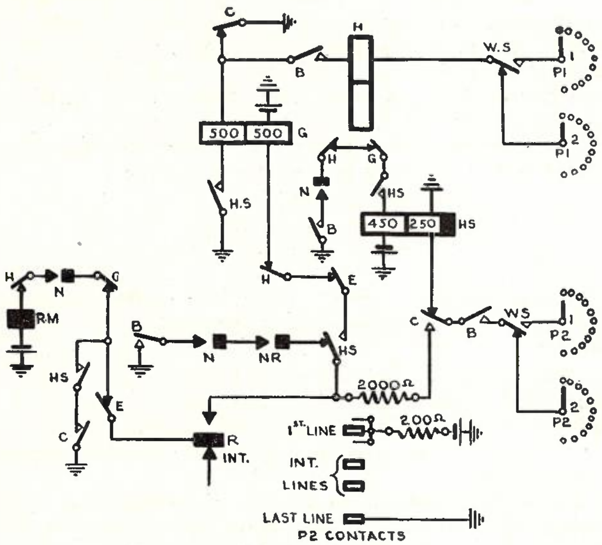
Q. 3, Fig. 1.

When the called subscriber answers, relay D in the final selector operates, and a reversal of battery from the "A" relay takes place; this allows the polarized relay D in the D.S.R. to operate. The metering circuit in the D.S.R. has already been prepared by the operation of relays B, BA and J. The operation of the polarized relay D in the D.S.R. completes the circuit of relay MD, and the operation of this relay completes the positive battery metering circuit to the calling subscriber's meter; at the same time the holding circuit of relay J is opened, but as J is a slow-release relay, the positive battery pulse to the meter is maintained during the slow release of J relay (approx. 300 m.s.), thus the meter operates once and restores, and cannot again operate as the operating circuit of relay J in the D.S.R. is opened. The rectifier in the uniselector trunk is provided to prevent the operation of the meter from negative battery, while the rectifier earth connected to the D.S.R. private is provided to hold the subscriber's K relay operated and maintain the connection should a failure occur in the positive battery circuit.

Q. 4.—What facilities, in addition to those afforded by ordinary final selectors, are provided for in final selectors installed in a 2000 type automatic exchange to deal with traffic to private branch exchanges having not more than 10 exchange lines in each case? With the aid of a simplified circuit diagram, describe the special circuit arrangements which provide these facilities.

A.—On P.B.X. type final selectors extra facilities are provided to enable full rotary search to take place over all lines in a group. Each line in the group is tested in turn and if busy the switch rotates automatically to the next line. This continues until a free line is found or until the last line of the group is reached. If the last line is busy the engaged signal will be returned to the calling subscriber. To enable this to be done an extra bank contact is provided for each line, termed a P2 contact, and two additional relays, HS and G, are provided in each P.B.X. type final selector. The special circuit arrangements are as indicated in Fig. 1, and the operation is as follows:—

Battery via 200 ohm is connected to the P2 bank contact of the first line of each group; intermediate



Q. 4, Fig. 1.

lines have no potential connected, while the P2 contact of the last line of a group is connected to earth.

When the final selector reaches the first line of a group, relay HS operates on its 250 ohm winding to battery via the P2 contact and locks on its 450 ohm winding to earth at B. If the first line is free, relay H will operate via the P1 wiper and the call will be switched through in the usual manner. If, however, the first line is busy, relay H will not operate, and when relay C reoperates the rotary magnet steps the switch to the next contact. The operation of the rotary interrupter springs allows relay G to operate, and this opens the circuit to the rotary magnet, the rotary interrupter springs return to normal and open the circuit of G relay, which in turn releases. This interaction between relay G and the rotary magnet continues, and the switch rotates until a free line is found, when relays H and G will operate in series and cut the drive.

If all lines in a group are busy, earth on the last P2 private will operate relay G, the circuit of HS will be opened, and this relay will restore after the slow-release period and busy tone will be returned to the calling subscriber.

Q. 5.—Enumerate the facilities afforded by the relay set provided at the main automatic exchange of the 2000 type on circuits outgoing to a manual operator at a phonogram position. What are the essential features for a queueing system designed for association with a group of manual phonogram operating positions?

A.—The facilities afforded by the relay set provided on phonogram circuits should be similar to those provided by an automatic to manual relay set or repeater; however, as the charge for the call is included in the phonogram rate, there is no necessity to meter a call against the calling subscriber, therefore reversal or metering facilities need not be included in the phonogram relay set. The facilities provided should be as follow:—

(i) Hold the switches in the local exchange and complete chain relay contacts.

(ii) Provide a guarding earth on the trunk incoming to the relay set so that it tests busy to other incoming calls.

(iii) Provide transmission battery to the calling line.

(iv) Complete an operating circuit for the phonogram line circuit.

(v) Release the connection when the calling loop is removed.

The essential features for a queueing system designed for a group of phonogram operating positions are:—

(i) A systematic grouping of calls should be arranged, as phonogram operators working inward traffic type the phonograms as they are received. As it is necessary to use different forms for different types of traffic, it is important that the type of call offering should be known by the phonogram operator. The calls should be arranged, therefore, in three separate queueing systems, as follows—

(a) calls from subscribers;
(b) calls from direct lines or Post Offices;
(c) calls from the Trunk Exchange.

(ii) The system should be arranged so that any call may be answered on any staffed position, and each operator should be provided with three calling lamps and keys, one for each type of call.

(iii) Calls for all operating positions should be controlled on the Traffic Control Cabinet, and provision should be made on this cabinet to restrict incoming traffic of any particular class to any operator's position.

(iv) In all queueing systems it is necessary to arrange that queue positions which were occupied by calls which have been abandoned are not subsequently taken by new calls in incorrect priority.

Q. 6.—What do you understand by the term "common control equipment"? Compare the merits of using (a) subscribers' uniselectors, and (b) line finders for connecting subscribers' lines to first selectors. What advantage justifies the use of secondary finders in a line finder system?

A.—The term "common control equipment" refers to the equipment in an automatic exchange of the line finder type which controls the assignment of a first selector or equivalent switch, such as a repeater or D.S.R. in a branch exchange, to a calling subscriber. The common control equipment includes primary and secondary line finders, with their associated start and control relay sets, and allotters.

The merits of using subscribers' uniselectors as against line finders is determined by the economics of the alternative schemes for any particular exchange.

For comparatively low calling rate exchanges, where the number of primary finders required for a group of 200 lines would not exceed 25 per group, with approximately half the primary finders directly connected and the remaining half indirectly connected via secondary finders to first selectors or equivalent switches, the provision of finders as against a uniselector per line would be justified, and a saving in the total cost of the exchange equipment would result. However, it is difficult to distribute the traffic evenly over the various finder groups, and unless most of the lines are of a very even calling rate congestion in one or more groups can very easily occur, even with secondary working.

For this reason, uniselectors are favoured for exchanges where a mixed traffic of high calling rate and lower calling rate lines is anticipated.

It will be appreciated that for city or other high calling rate exchanges, uniselectors would prove economical as compared with line finders, apart from the flexibility of the uniselector per line system. With uniselectors of the homing type, grading can be introduced and the trunking can be arranged to cater for each group of lines independently, thereby providing for the traffic offering in the particular group.

The use of secondary finders enables partial secondary working to be introduced. This increases the flexibility of the finder systems by making provision for a common group of trunks which may be used to carry the peak traffic from any primary finder group. By this means, the total number of 1st selectors or equivalent switches required can be considerably reduced.

EXAMINATION No. 2633—TECHNICIAN—TELEPHONE INSTALLATION AND MAINTENANCE

A. N. Birrell

Q. 1.—(a) The resistance of the moving coil of a D.C. meter is 10 ohms and a full scale deflection of the needle occurs when a current of 10 milliamperes is flowing through the coil. The scale is marked into 50 equal divisions and during a test when the instrument was energised by the application of an E.M.F. the needle moved 20 divisions. What value of voltage is thus represented?

(b) Draw circuit diagrams showing how this instrument could be adapted for use as:—

(i) A voltmeter. (Range 0-50 volts.)

(ii) A milliameter. (Range 0-50 ma.)

Calculate the value of the external resistance required in each case.

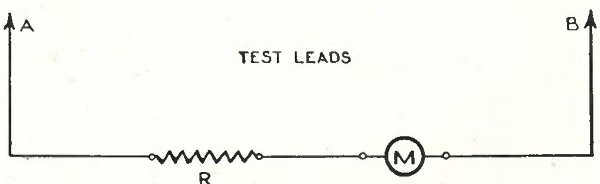
A.—(a) In a moving coil meter, the deflection of the needle is proportional to the current flowing. Hence the current when the needle moves 20 divisions

$= 10 \times 20/50 = 4$ m.a.

By Ohm's Law, the E.M.F. applied to the terminals of the instrument is

$E = I.R. = .004 \times 10 = .04$ volts.

(b) (i) For use as a voltmeter (range 0-50 volts) the instrument would be placed in series with a relatively large resistance.



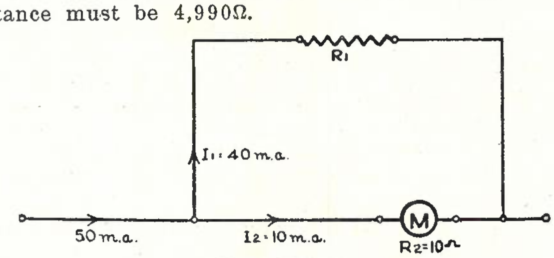
Q. 1, Fig. 1.

It is required that when the potential difference between points A and B is 50 volts the needle will show the full-scale deflection, i.e., 10 m.a. current will flow through the meter.

By Ohm's Law, the total resistance of the external resistance and the instrument

$= E/I = 50 \times 1000/10 = 5{,}000\Omega$

Since the meter resistance is 10Ω, the external resistance must be 4,990Ω.



Q. 1, Fig. 2.

(ii) A milliameter is connected in series with the circuit in which current is being measured. For reading 0-50 m.a. the instrument would be shunted by a resistance of such a value that when 50 m.a. is flowing in the circuit 10 m.a. will pass through the meter coil and 40 m.a. via the shunt resistance.

Now the voltage drop across the meter will be the same as the voltage drop across the shunt, i.e.:

$$I_1 R_1 = I_2 R_2$$
$$\therefore .04 \times R_1 = .01 \times 10$$
$$R_1 = 2.5\ \Omega$$

Q. 2.—(a) Explain briefly how the principle of mutual induction is applied in the operation of a transformer.

(b) The primary winding of a single phase power transformer having a turns ratio primary to secondary of 10 to 1 is connected to a 240 volt commercial A.C. supply. What voltage would you expect at the secondary terminals?

A.—(a) If two coils are placed in the neighbourhood of one another and a current is passed through the first coil, part of the flux produced in that coil will cut the second coil. Should the current in the first coil be varied, the flux will change and an E.M.F. will be induced in the second coil. At any instant the secondary voltage is equal to the coefficient of mutual induction multiplied by the rate of change of the primary current.

In the transformer, an alternating current in the primary winding establishes an alternating magnetic field which in cutting the secondary winding causes an alternating E.M.F. to be induced therein.

(b) The voltage ratio is equal to the turns ratio:—

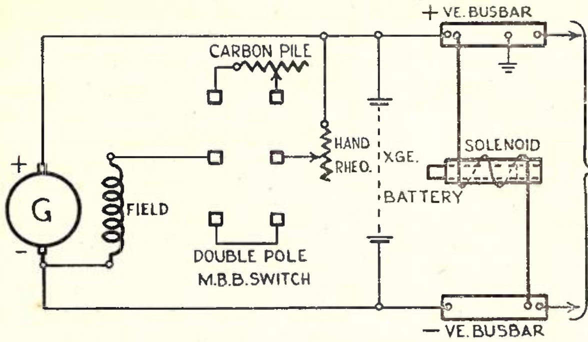
$$\text{i.e., } E_p/E_s = N_p/N_s$$
$$\therefore 240/E_s = 10/1$$
$$E_s = 240/10 = 24 \text{ volts.}$$

On load the secondary voltage would be slightly less than 24 volts due mainly to resistance losses in the coils and hysteresis losses in the iron core.

Q. 3.—In an exchange having a floating battery power supply system the generator is equipped with an automatic voltage regulator of the carbon pile type. With the aid of a schematic diagram showing typical connections, explain the method of operation of the voltage regulator in controlling the generator output.

A.—The output voltage of the shunt field type of generator used for battery charging is controlled by varying the field excitation. This can be arranged by connecting a rheostat in series with the field winding. Automatic voltage regulation is possible if the rheostat or an additional variable resistance is placed under the control of a device which responds to the variation in voltage across the exchange busbars.

As shown in the sketch, the carbon pile type regulator consists of two basic units, the variable resistance carbon pile connected in series with the hand-operated field rheostat and the solenoid element connected directly across the exchange busbars. When the exchange voltage rises, the moving core is drawn further into the solenoid field. The movement is transmitted through a system of levers to the carbon pile and results in an increase in its overall resistance with a consequent reduction in generator field strength and terminal voltage. On the other hand, a fall in the busbar voltage causes a decrease in the resistance of the carbon pile and hence a higher generated voltage due to the increased field strength. A dashpot is con-



Q. 3, Fig. 1.

nected to the lever system to prevent hunting.

The exchange power circuit is arranged so that by throwing a switch, manual control is available as an alternative to automatic voltage control. To safeguard the generator should the regulator cease to function correctly, part of the resistance of the hand rheostat should be left in circuit whenever the automatic voltage regulator is in use.

Q. 4.—List the functions of the following items of equipment in a 2,000 type automatic exchange:—

(a) First local group selector;

(b) Relay set (auto-auto repeater).

A.—(a) The functions of a 1st local group selector in a 2,000 type exchange are:—

(i) to return dialling tone to the calling party when ready to receive impulses.

(ii) to step the wipers vertically under the control of the calling party's dial.

(iii) at the end of the first train of impulses to step the wipers into the level and automatically hunt for and seize the first free outlet in the level.

(iv) to prevent interference with circuits over which the wipers pass.

(v) to guard the seized circuit from intrusion.

(vi) to extend the calling party's line to the next switch.

(vii) to connect "busy" tone to the calling party's line should all outlets in the level be engaged.

(viii) to extend an earth to the overflow meter when all outlets in the level are engaged.

(ix) to release on completion of the call and to prevent interference with circuits over which the wipers pass while restoring to normal.

(b) The functions of a relay set (A-A Repeater) in a 2,000 type exchange are:—

(i) to return the guarding and holding earth to the preceding switches.

(ii) to repeat the impulses from the calling party over the two-wire junction to the distant exchange.

(iii) to provide a transmission bridge which feeds current to the calling subscriber.

(iv) to connect positive battery to the private wire for a short period for the purpose of metering the call when the current flowing over the junction is reversed.

(v) to reverse the battery feed to the calling line for supervisory and public telephone fee collecting purposes when junction current is reversed.

(vi) when the calling subscriber's loop is removed, to open the junction line to the distant exchange, to disconnect the holding earth from the private wire and to restore all relays to normal.

Q. 5.—Name three methods of registering calls in automatic exchanges and describe one of these briefly with the aid of a schematic circuit.

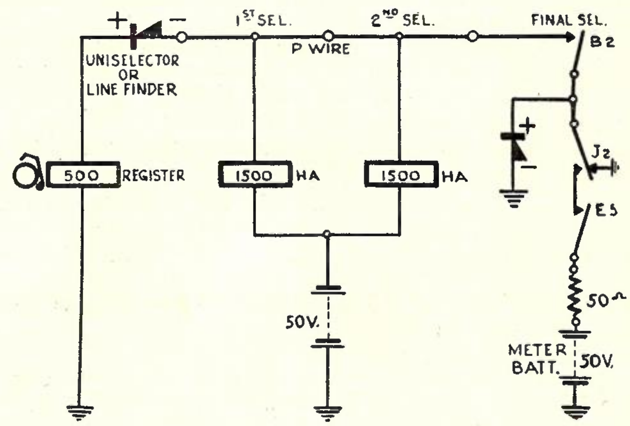
A.—Three methods of metering calls in automatic exchanges are:—

(i) Reverse battery.

(ii) Booster battery.

(iii) Positive battery.

Details of positive battery metering.—The metal rectifier in the P wire of the uniselector or line finder is so connected that negative battery from relays connected to the P wire will not operate



Q. 5. Fig. 1.

the meter. When the called subscriber is being rung relays B and J are operated. When the called subscriber answers, relay E operates and opens the circuit to relay J which is slow to release. Contacts of relays E, J and B are closed and positive battery is applied through the rectifier to the meter which operates. Relay J releases approximately 300 milliseconds after the operation of relay E and the meter restores to normal. The metal rectifier in the final selector circuit maintains the earth on the P wire during the change-over period of contacts J2 and also prevents the release of the connection should the metering battery be disconnected.

ERRATA

In Q. 7(c), page 191, of the February, 1947, issue, read $\sqrt{3}$ instead of 3 in line 4. As stated in the question, the voltage between phases (line voltage) is 400 V r.m.s.; therefore E = 400 V and transposing the formula for I—

$$I = P/(\sqrt{3}\ E \cos \theta)$$

$$I = (16 \times 10^5)/(9 \times \sqrt{3} \times 400 \times 0.85)$$

$$I = 302 \text{ amps.}$$

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