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The

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THE DESIGN OF AN AUTOMATIC TRUNK LINE SWITCHING PLAN FOR AUSTRALIA

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Introduction

The extensive use which has been made in Australia of direct dialling over trunk lines into local automatic networks has shown that better service can be given, and more efficient use of trunk line plant can be obtained by the elimination of the incoming operator from the process of setting up and control of trunk calls. Single operator control of trunk calls can be extended very considerably by the provision of automatic trunk switching facilities, and any call between two manual exchanges can be completed by not more than two operators instead of three or more. For these reasons, and because it is not practicable to provide a trunk line service commensurable with modern standards on the basis of manual switching, it was decided that the time had arrived to commence the provision of an automatic trunk line service. Looked at in one sense, an automatic trunk network is simply a local automatic network on a grand scale, and it is true that a very close parallel exists between the factors which now dictate the provision of an automatic trunk network and those which, many years ago, decided in favour of local automatic networks. The parallel cannot be stretched too far, because the trunk network has varied problems peculiar to itself, and some of these were surveyed in a previous article (1). At the outset there is a choice to be made of the type of network which will be adopted, and in arriving at a decision it is necessary to consider the existing manual network, the transmission plan and long line equipment, the numbering scheme, the switching and signalling equipment likely to be available, and the practicability of the economic provision of a basically no-delay trunk service. These various factors have been considered, and the purpose of this article is to give an outline of the design features of the automatic trunk switching plan which has emerged as being suitable for the conditions in Australia.

The Objective

Before proceeding further, it should, perhaps, be made clear that whilst the principal objective at this stage is one-operator control of trunk calls, this must be ultimately replaced by a service which provides for a large percentage of calls to be completed by the subscriber dialling the distant number without the aid of an operator. Possibly very long distance calls will always need the assistance of an operator, but this may be more for reasons of accounting and economics than for any technical difficulty in providing the service. It is worth noting that 70-80 per cent. of the trunk traffic originating or terminating in some of the large metropolitan centres is to or from places within 100 miles radius of those centres, and much of this could be handled on a subscriber dialling basis. Indeed, short distance trunk calls between automatic areas up to about 40 miles apart are no longer an economic proposition on a one-operator per call basis, and subscriber dialling of these calls with time and distance metering is an urgent necessity.

Subscriber dialling of trunk calls has been an established fact for many years overseas, especially in some European countries, and there is now a fairly extensive literature on the subject. A recent article (2) giving detailed results of the subscriber dialling service between Zurich and Basle, in Switzerland, a distance of about 50 miles, is of particular interest, as it shows that better overall and busy-hour efficiency is obtained from trunk line plant with subscriber dialling, than was previously obtained from the operator dialling service. All this points to the need for early action to place a number of centres in Australia on a subscriber dialling basis, for not only would it be more economical and provide a better service, but it would also relieve the growing problem of providing sufficient building space for the accommodation of operating staff.

Difficulties to be Overcome

One of the major hurdles in the way of meeting even the more immediate objective is the large number of existing manual exchanges, notwithstanding the fact that over 61 per cent. of subscribers are connected to automatic exchanges at present, and given the necessary trunk switching and signalling facilities all trunk traffic incoming to these subscribers could be dialled-in on a one operator per call basis. The ratio of traffic incoming to the large automatic areas is about 6 : 4 of the outgoing traffic, which mostly requires two operators at present. The latest statistics for which complete returns are available are those for June, 1950, and these are as follow:

	Subscribers Connected		
	Metro.	Country	Total
Automatic	451,711	32,841	484,552
Manual	32,176	276,349	308,525
Totals	483,887	309,190	793,077
	Exchanges		
Automatic	192	284	476
Manual	53	6,191	6,244
Totals	245	6,475	6,720

The total increase in subscribers during 1950 was 91,087, of which 58,185 were in metropolitan areas and 32,902 in country areas. Of the large number of manual exchanges in the country, about 4,300 serve 20 subscribers or less, so that individually these do not present any difficulty to conversion to automatic working by small Rural Automatic Exchanges (R.A.X's), or by 10-line Subsidiary Automatic Units (S.A.Us.) connected to the larger R.A.Xs. or to any automatic exchange. Within the next year or two it is expected that the country automatic exchanges will be increased by about 600 R.A.Xs. of up to 200 lines capacity each, and possibly by the conversion of about 20 or so of the larger manual exchanges with capacities ranging from about 1000 lines to 3000 lines each. In the future it is hoped that the present endeavours in this direction will result in R.A.Xs. being grouped around large parent exchanges, preferably automatic, so that it will be easy to provide for inter-dialling between all the R.A.Xs. in the area as well as between the R.A.X. and the parent exchange subscribers. In addition, the trunk switching facilities at the parent exchange would permit all incoming trunk calls to be dialled directly into the area. The following out of such a plan over a period of years would result in a very great reduction in the amount of trunk traffic handled by operators, and especially by more than one operator.

The next big obstacle which has to be overcome if the objective is to be substantially met, is the economic provision of trunk channels on a no-delay basis. For the early stages it will be shown later that where single operator control applies, some trunk channels may be planned on a definite delay basis. Up to the present time an enormous amount of time and effort has been expended on the major trunk routes by the erection of new aerial wires, on re-transposing and re-spacing existing wires, and on re-spacing poles, in order to make the routes suitable for the operation of multi-channel carrier systems. Underground trunk cables are now being installed and more will be laid in the next few years, to replace the heavily loaded open wire trunk routes. This work will release labour and materials which can be concentrated on building up other open wire routes. It will also allow blocks of new channels to be readily added to the cable routes by the installation of terminal and repeater equipment only. The installation of radio links, of which several are already in operation, should also ease the problem of channel provision. Apart from this, the use of a separate channel for each individual telephone conversation is undoubtedly very inefficient, and the application of modern communication theory (3) may result in equipment being available within a few years which would multiply individual telephone channels by means of one of the various possible time sharing methods. It is probably not too optimistic to assume that the long-standing problem of channel provision and use will be solved very effectively by the wide application of new techniques. If so, much of the substance of this article, which is concerned with the application of traffic theory to obtain efficient use of individual channels, will be out-moded, and the related problem may be the determination of how many separate connections can be carried by a common channel or group of channels for maximum efficiency.

Basic Design of the Automatic Trunk Network.

The economic justification for an automatic trunk system is usually derived from the greater traffic carrying capacity of large groups of lines relative to smaller groups. If the average traffic carrying capacity of trunk lines with manual service and delays is 0.7 traffic units (T.U.), then the same average traffic per trunk can be carried by a group of 25 trunks with no delays (grade of service, 1 lost call in 50), as is shown in Fig. 1, curve A. If the manual network comprises a large number of small groups of direct lines as is usually the case, the many small groups are collected into a few large groups and full intercommunication between all the places previously served by the system is obtained by introducing automatic trunk switches at convenient points in the system. This is possible because the switching time is negligible, whereas a manual switching operation introduces considerable delays.

In Fig. 1, curve A, the group efficiency increases to a maximum at about 100 lines, but the rate of increase is very gradual over 50 lines and, in fact, is only 0.0709 T.U. per trunk better at

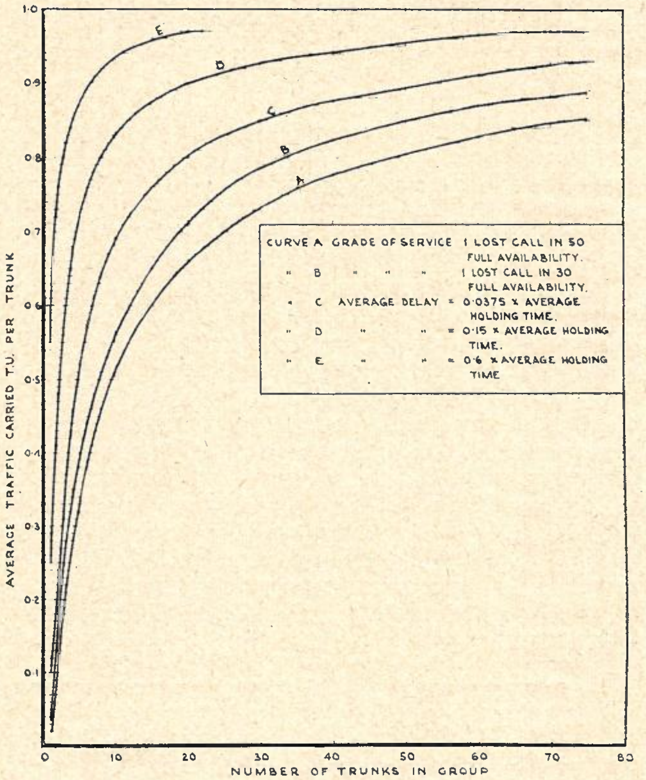

Fig. 1.—Traffic Capacity Curves.

100 lines than 50 lines. For this grade of service, therefore, groups of 40-50 lines are as large as need to be aimed at in practical design.

In Germany (4) very great savings in lines and trunk route mileage have been obtained by the conversion of mesh networks developed for manual switching to the star type networks made possible with automatic switching. In one instance, savings of 26 per cent. in the number of lines and 50 per cent. in route mileage were reported. Similar results are not possible in Australia because the mesh type network is fortunately not fully developed, and, moreover, the distribution of population is less uniform. Since the mesh type network is thus shown to be fundamentally uneconomic, however, there are actually very real savings to be made in money, materials, and effort, by adopting a policy of automatic trunk switching at this stage of development. There can be no doubt that the complete mesh networks would not have been developed in other countries if the art of communication had been sufficiently advanced at the appropriate time. Whilst the economics of trunk network design are important, of at least equal importance is the grade of trunk line service offered, and if a substantially no-delay service becomes a practicable proposition in this country through the provision of automatic trunk switching facilities, and if this is obtained at no greater cost than would otherwise have been incurred, then this in itself would be a worthwhile achievement.

Although the largest groups of lines can be formed by a completely star type network, investigation has shown that this design is not suitable for general adoption in Australia owing to its effect on the transmission plan and the cutting up of carrier systems which would result. These difficulties were discussed in the previous article (1) already mentioned. The star network can be modified by the provision of direct lines in relatively small groups to many places, but, in order to obtain adequate traffic capacity from the small groups an alternative path must be provided to each place via one or more automatic switching centres. For a no-delay service the alternative path must comprise a large group of lines in order to obtain an overall traffic efficiency equivalent or very nearly equivalent to the star network. The arrangements are such that the direct lines are tested first, and if all are busy the overflow traffic is diverted automatically to the alternative path which, in turn, is tested for a free line. This arrangement is shown in Fig. 2, in which the direct route is between switching centres M and S, and the alternative route is via switching centre. When a free line is found from M to P on the alternative route, an extra routing digit is added automatically in order to steer the call to the group from P to S. If a free

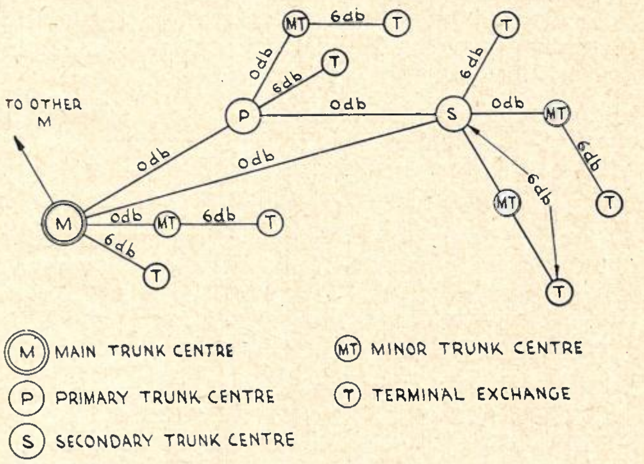

Fig. 2.—Basic Element of Trunk Network showing Switching Centres and Allocation of Transmission Loss.

line is not found when the alternative route is tested, the call may be diverted to busy tone or to manual positions as desired. Other arrangements may apply if the full no-delay service is not in operation as will be mentioned later.

This alternative routing scheme has been adopted as the basis of the design of the automatic trunk line switching plan for Australia. This type of network not only provides good traffic efficiency and economy, but also a measure of protection against complete breakdown of communication, more especially where the direct lines follow a different route geographically to the indirect or alternative lines.

The Switching Plan

Having decided the basic design of the network, a plan can be prepared along the lines of Fig. 2 to show how all the various interconnections can be established between all the trunk exchanges in the system and, where the traffic is known or can be estimated, the number of trunk lines required. It is convenient to adopt a nomenclature to describe the switching centres at the various levels or planes, and the following have been adopted as being suitable for all purposes:—

Main Trunk Centre. This is a centre of major switching importance within a State and, in general, corresponds to the Capital City of the State. In certain cases additional exchanges may also be classified as Main Trunk Centres.

Primary Trunk Centre. This is a centre of major trunk switching importance within a large district, and has direct trunks to a Main Trunk Centre. It performs switching functions within the district and to other districts, and is the switching point for all traffic between the district and the Main Trunk Centre, except in cases of Secondary Trunk Centres, which are of sufficient importance to warrant direct trunks to the Main Trunk Centre. In these cases the Primary Trunk Centre switches traffic for the Secondary Trunk Centre only when the direct trunks between the Secondary and the Main are fully occupied.

Secondary Trunk Centre. This type of centre switches traffic for Minor Trunk Centres and/or Terminal Exchanges, and has direct trunks to a centre or centres of higher switching order.

Minor Trunk Centre. This is a centre of minor switching importance and, in general, switches only for Terminal Exchanges. It is connected by direct trunks to the nearest suitable centre of higher switching order.

Terminal Exchange. This type of exchange does not perform any "through" trunk switching operation.

The manner in which the various trunk centres may be arranged in accordance with the definitions is shown in Fig. 2. In Tasmania the Capital City is Hobart, but the Main Trunk Centre in this case is Launceston, which is the approximate centre of gravity of the trunk network. In Queensland it is probable that both Rockhampton and Townsville will, at some future date, become Main Trunk Centres in addition to Brisbane. On the other hand, it is unlikely that the need will arise to directly interconnect all the present Main Trunk Centres. This will be readily appreciated from the relative locations of Perth and Brisbane, for instance, and all trunk calls between these centres will be switched at Melbourne as at present, or possibly at Adelaide, in order to obtain group efficiency on the Perth-Adelaide trunks. The centre for all international connections is Sydney which is, therefore, one of the main switching centres in the world telephone area (5).

Minimum and Maximum Size of Direct Routes.

In a previous paragraph it has been stated that direct routes having alternative routes will be relatively small. It has also been stated that a large group from the traffic viewpoint is 40-50 lines, as seen from Fig. 1, curve A. It remains, therefore, to examine what is meant by the relative smallness of a group. As shown in Fig. 1, for a grade of service of one lost call in 50, one trunk carries 0.0204 T.U. per trunk, two trunks carry 0.112 T.U. per trunk; and three trunks carry 0.2 T.U. per trunk. If groups as small as these are to be provided, they must carry an economic load which should be at least as high as obtained on the alternative route, that is 0.77 T.U. per trunk or higher. If one trunk is to carry 0.8 T.U. the proportional loss or overflow is 80 per cent. or 3.2 T.U., as is readily calculated from Erlang's loss formula:—

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

where B = Grade of service or proportional loss.
A = Average traffic offered in T.U.
N = Number of lines in the group.

When $N = 1$, $B = A/(1 + A)$, from which it is apparent that one trunk must be offered 4 T.U. in order that it may carry 0.8 T.U., and the proportional loss is $^4/_5$ or 80 per cent. as indicated above. In this case the overflow is too great to justify the provision of a direct trunk. In the case of two trunks, that is when $N = 2$, it is found that 4.8 T.U. must be offered to obtain an occupancy of 0.8 T.U. per trunk, and the proportional loss is approximately 67 per cent. which is also high. In the case of three trunks 5.5 T.U. must be offered, and the proportional loss is about 56 per cent. In these circumstances, and because large numbers of trunk channels are, and will continue to be, provided by means of 3-channel carrier systems, it has been decided that the minimum size of direct routes shall be 3 channels. A further reason for the selection of 3 channels as the minimum number for the provision of direct routes will be given later, when trunk service with delays is being discussed. The minimum of 3 channels does not, of course, apply to trunk groups which serve Terminal Exchanges in those cases where the total traffic can be carried by one or two channels.

Since a minimum has been specified the query may arise as to whether there is a maximum size of direct route that should not be exceeded in any circumstances. It need only be borne in mind that the purpose of the alternative routing scheme is to obtain increased traffic efficiency, and since the traffic capacity increases with the size of the group, there will be no traffic advantage in providing alternative routing facilities for groups of 40-50 channels. A case may arise where there may be some advantage to be gained by providing an alternative route for a group as large as 30 channels, but this could only be decided by a study of the particular case. The problem of deciding how many channels shall be provided on direct routes in particular cases will be discussed in a later section.

Grade of Service on Trunk Routes

The trunk route between the Main Trunk Centre M and the Primary Centre P in Fig. 2, is the alternative route for traffic to the Secondary Centre S, and, therefore, carries the overflow traffic from the direct route between M and S as well as for any other Secondary Centres similarly connected to the Main Centre M. In addition, the route also carries the normal direct traffic between M and P. This total traffic comprises not only traffic originating or terminating at the centres mentioned, but also automatic transit traffic from any centre in the complete trunk network. Whilst it would be uneconomic to provide for a very high grade of service, it is essential that any call shall have a reasonable chance of success at the first attempt. If too many calls fail to find a free line on the first attempt, repeated attempts will quickly lead to serious congestion. It is considered that 1 lost call in 50 is a reasonable standard for design purposes in view of the fact that tandem connections have to be catered for, and this grade of service has accordingly been adopted. In general, this grade of service will apply to all trunk routes in the system for which the channels are provided on a lost-call basis. The trunk network design must aim at providing as large groups as possible in the interests of traffic efficiency and economy, and in particular there must be a backbone of large groups to serve as alternative routes. Such routes would be those between M and P and between P and S in Fig 2.

Where the Terminal Exchanges are very small, the economic loading of channels using a grade of service of 1 in 50 is not possible unless the lines are very short. The grade of service adopted tentatively as standard for design purposes in these cases is 1 lost call in 30. The design curve is shown in Fig. 1, curve B. One of the assumptions made in the theory from which the formula used for the calculation of the points in curves A and B is derived, is that the number of sources is infinite. This assumption is made in order to render the mathematical treatment more tractable, but it happens that there is a negligible difference between the results obtained from using this assumption and the results obtained from assuming a finite number of sources, providing the number of sources (subscribers in this case) is about 200. On the assumption of an infinite number of sources, the origination of one call does not affect the probability that another call will originate, but where the number of sources is small this does not hold. The practical result of this is that if one trunk line is provided to a small Terminal Exchange serving, say 20 subscribers, and this line is engaged by a call, then the probability that the line will be required to serve a second call during the period it is engaged on the first call is less than assumed in the formula on which the trunk provision curves A and B are based. In addition, the overload capacity of small groups is greater than that of large groups, as can be established readily by inserting values for N and A in the Erlang loss formula. If N and A are both 1 the proportional loss is $\frac{1}{2}$ or 50 per cent. If A is increased by 100 per cent. to 2, the proportional loss is $^2/_3$, that is, the loss is 1.33 times greater. If N and A are both 3, the proportional loss is 34.6 per cent., but if A is increased by 100 per cent. to 6, the proportional loss is 59 per cent., or 1.695 times greater. In this example the small values of N and A were used to simplify the calculations, but the same principle applies throughout, and for large groups the increase in proportional loss is several times that of small groups for the same percentage increase in traffic. In these circumstances it appears that a satisfactory grade of service may be provided to small Terminal Exchanges included in the automatic trunk switching scheme with less trunks than the 1 in 30 curve would indicate, and it is hoped that sufficient data will be available shortly upon which to base an empirical trunk provision curve or table for these cases. In the meantime, the application of the standard grades of service given will facilitate forward planning by giving a reasonably accurate forecast of future requirements of trunk channels.

Channel Provision on Direct Routes.

Since the aim of the alternative routing scheme is to obtain traffic efficiency as near as possible to that which could be obtained with a completely star network, it is clear that the average traffic per trunk must be similar. It has already been shown that from the point of view of traffic efficiency a group need never exceed 50 lines, and from Fig. 1, curve A, it can be seen that the average traffic per trunk for a group of this size is about 0.805 T.U. This loading can be obtained on smaller groups only by allowing for a higher proportional loss. In the case of direct routes this "loss" is actually the overflow traffic which is carried by the alternative route, but is subject, of course, to the grade of service loss on this route. Fig. 3 has been prepared to show the proportional loss from groups of various numbers of channels and occupancies. From these curves the number of channels to be provided on any loading basis can be determined, as well as the amount of traffic which will be diverted to the alternative route. On the other hand, the number of channels may be estimated roughly from the total amount of traffic, and for a given

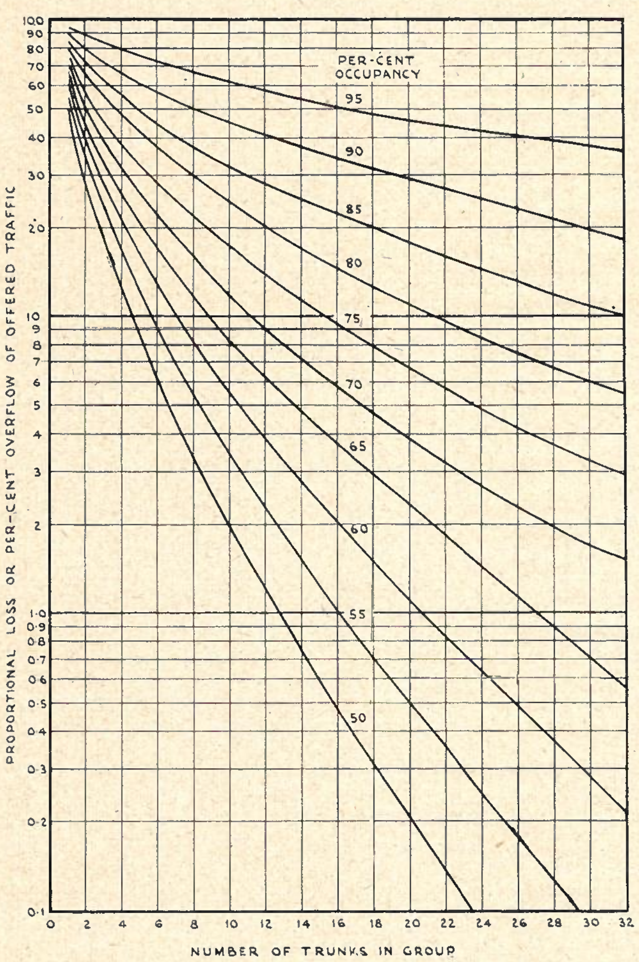

Fig. 3.—Proportional loss when average traffic per trunk is constant.

number of channels the overflow traffic for a selected loading can be determined. Suppose the total busy-hour traffic is 14 T.U. and a 12 channel carrier system is available. If the average traffic per channel is 0.85 T.U., 12 channels will carry 10.2 T.U., and from Fig. 3 it is found that the proportional loss from 12 channels, with average occupancy of 85 per cent., is 28 per cent. The traffic carried, namely 10.2 T.U., is, therefore, 72 per cent. of the traffic offered, which is 10.2/0.72 = 14.16 T.U., and this is close enough to the 14 T.U. busy-hour traffic for all practical purposes, so that the overflow traffic may be taken as 2 T.U.

As indicated in the previous paragraph, it is probable that the physical means available for channel provision will in many cases dictate the number of channels which will be provided on direct routes. Subject to efficient loading being obtained and a satisfactory alternative route being available, there is no special virtue in endeavouring to arrive at what appears to be the optimum economic arrangement in all cases. The characteristics of telephone traffic are dynamic, not static, and, therefore, provision for continual change must be made throughout the system, whether it be trunk lines, equipment, or operators. Because of this, the peak efficiency of any installation may not be reached for two years, or even more, after it is brought into service, and it is usual to design on this basis. The designer will be fortunate, however, in these days of rapid expansion in Australia, the trend of which is often difficult to predict, if the installed plant is adequate for the needs at the time of installation without change or addition to the original design.

For these reasons, and because it is outside the scope of this article, a detailed study of the economics of how much traffic shall be routed direct and how much indirectly, and therefore the channel provision on the direct and alternative routes, will not be attempted here. For general estimating purposes, Fig. 3 is likely to prove slow and inconvenient, and, therefore, subject always to the proviso of a satisfactory alternative route, the number of direct channels may be taken to be the same as the total busy-hour traffic in T.U. Fig. 4 has been prepared on this basis,

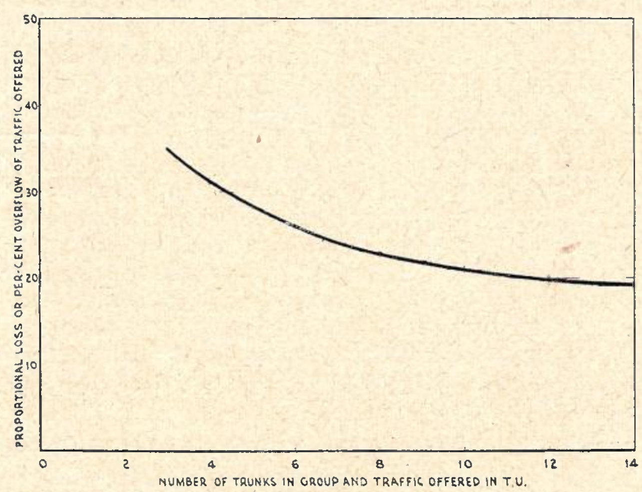

Fig. 4.—Proportional loss when traffic offered equals one T.U. per Trunk.

and the overflow traffic shown as the proportional loss can be ascertained for each amount of traffic and number of trunks. The minimum traffic loading of this curve is 0.65 T.U. per trunk for 3 channels, and whilst this is fairly low, the margin between this and an economic load of the order of 0.8 T.U. per trunk may be required in some cases to allow for rapid expansion. The traffic per trunk gradually increases, and at 12 trunks the load is 0.8 T.U. per trunk and the overflow 20 per cent., which corresponds to Fig.

3 for these parameters. The figure of 0.8 T.U. per trunk should in general be regarded as the minimum for design purposes as this will allow ample margin for development on the direct route.

In the case of the 12 channel group previously cited, it may be supposed that the traffic increases by 100 per cent. to 28 T.U. The traffic per trunk then increases to an average of 0.95 T.U., or 11.4 T.U. carried by the 12 channel group, whilst the overflow of approximately 60 per cent. or 16.6 T.U., as found from Fig. 3, is carried by the alternative route. When the overflow traffic reaches such a high proportion of the traffic offered, relief measures for the direct route should be well in hand because there is no margin for temporary overloads on the route, and, as previously pointed out, the overload capacity of the larger alternative route is not high and the grade of service will quickly deteriorate.

Determination of Traffic on Trunk Lines.

Before the channel requirements for the automatic trunk switching scheme can be calculated it is necessary to know the amount of traffic to be carried. Usually this will have to be estimated by using existing traffic as a basis. The assembly of trunk traffic data is the responsibility of the Telephone Branch, and is obtained from trunk call dockets on which each 3-minute period of paid time is normally indicated. Each 3-minute period is called a speech-period, and it has been the practice to provide a trunk channel for each 70 speech periods of daily load and to estimate development on the basis of 5 per cent. per annum simple interest. This method is concerned with the economic aspect of trunk provision, and not so much with the grade of service which is necessarily basically variable with number of channels in a group, although operating practices have tended to even up the waiting times. The speech-period load is the paid time or effective occupancy, but the total occupancy, which includes the ineffective time of setting up and clearing calls, is not known accurately at present. In addition, a proportion of calls terminate before the paid time is expired, whatever this may be in multiples of 3 minutes. In order to obtain these unknown factors, the Telephone Branch recently undertook an extensive series of observations, and it is hoped that sufficiently reliable data will be available shortly to enable traffic to be expressed in T.U.

Where only the speech-period load is available this is converted to busy-hour T.U. by using a factor of 60 per cent. for ineffective time, and a factor of $12\frac{1}{2}$ per cent. for the busy-hour concentration, so that it is only necessary to divide the total daily speech-period load by 100 to obtain busy-hour T.U. For example, a daily load of 70 speech-periods is equal to $(70 \times 3 \times 1.6)/(60 \times 8) = 0.7$ T.U. (busy-hour).

Increased Trunk Traffic with Improved Trunk Service.

Experience has shown that improvement in the trunk service obtained as a result of providing more trunk channels quickly attracts more custom, until a stage is reached where the delays are substantially the same as before. For this reason it is probably impossible, at the present time, to estimate with any degree of accuracy what the trunk calling rate would be if unrestricted by the present grade of service. The question then arises as to whether estimates of trunk traffic based upon present conditions should be multiplied by some factor, necessarily arbitrary at first, in order to provide for the expected increase of traffic when the automatic no-delay trunk service is introduced. This service is, however, inherently much more efficient than manual service with delay working. A reduction of 50 per cent. in the ineffective time has been recorded (1) upon the conversion of trunk lines to dialling and one operator per call. This was achieved in direct comparison with the back-to-back method of manual operation, so that even better results may be possible in comparison with ordinary manual operating methods. In view of the fairly large amount of dialling-in equipment already in service it might be thought that the figures for the percentage improvements gained by this equipment should now be well established. Except for the 2VF signalling system used in Victoria (6) however, much of the dialling equipment in use does not provide full supervisory facilities, so that comparisons are not directly applicable. In Victoria practically the whole trunk network was converted in 1940 at the time of the installation of the Melbourne Trunk Exchange (7) just at the beginning of the last war, and conditions and operating efficiencies changed so quickly that no useful comparisons are available of the traffic previously handled on the lines converted, and the amounts handled subsequqently. Much of the reason for this is that the traffic increased enormously, but the number of trunk channels remained static or nearly so, with the result that the consequent delays reacted upon the efficiency in general. Without traversing all the reasons, there is no doubt that more efficient use can be made of trunk channels when operators are relieved of the necessity of making reverted calls and other work inseparable from delay working, and this also provides a factor to cope with increased traffic resulting from improved service.

It has been noted previously that large savings in the number of trunk lines have been made in other countries as a result of the conversion to automatic working, which is proof that the traffic can be handled more efficiently. The increased traffic resulting from the improved service will, therefore, be largely absorbed by more efficient use of plant and the ability of operators to handle more calls, rather than by any need to make relative increases in the number of trunk channels. In an earlier section the problem of providing sufficient channels was discussed, but this refers just as much to present needs as to needs of the future. The present actual trunk provision is a very long way behind the estimated requirements, and to a very great extent this is due to the physical effort required to provide new channels on open wire routes that have reached saturation point, or which require reconstruction to fit them as bearer circuits for multi-channel cerrier systems. When channels cannot be provided in accordance with the estimates, waiting times increase and the difficulties of operating the service multiply.

If the trunk network or portion of it is designed and equipped for no-delay service, the need to meet trunk channel estimates is more urgent since the reversion to waiting times is not so easy, although, of course, it is not impossible. The emphasis of the previous section was on the ability to meet the estimates in the future rather than on any need for more channels than the present service requires. In concluding this section it is added, for the information of those who are not familiar with the standard loading co-efficients for operators, that the unit allowance for a delayed call is 14 units and for a call not delayed (not reverted) 9 units. This means that 55 per cent. more traffic can be handled by the same number of operators if calls are not delayed long enough to make it necessary to revert the call to the originating subscriber. This is one of the reasons why it is uneconomic to provide a delay service on the shorter routes.

Initial Applications of Automatic Trunk Switching with Delays

The provision of trunk service with waiting times or delays enables high occupancy to be obtained from trunk channels irrespective of the size of the group. The fact that this occupancy includes a large percentage of unpaid time, which is of the order of 60 per cent. at present is, of course, a measure of the inefficiency of the method when the waiting times become long. Highly efficient occupancy of trunk channels can, however, be obtained by introducing quite short delays into the trunk service. When these short delays are accepted as an integral part of the service, the name of "demand" service is applied in some countries to distinguish from no-delay or delay service. With demand service in operation, the calling subscriber may be held by the answering trunk operator for a minute or more whilst attempts are made to find a free line, but if one is not found in the prescribed period the caller is asked to hang up. The call docket is held in position, however, and as soon as a line becomes free the subscriber is recalled and the call completed. This method of operation is particularly effective where automatic call storing facilities are available, as in automatic trunk exchanges, since the operator sets up the call to the wanted line only once. The automatic equipment then takes over the task of watching for a line to become free and signals the operator immediately this occurs. When delay working is introduced on any route, due to the accumulation of too many call dockets on the demand positions, no attempt is made to complete a call for that route on demand. The call docket is simply filled in and sent to delay positions for completion.

It is quite practicable to use demand type of working in an automatic trunk switching scheme based upon one-operator control of trunk calls, especially in the early stages when it would be most useful. Any trunk group which is immediately accessible to an operator, either with automatic or manual selection, can be provided on a demand basis instead of upon a no-delay basis providing the group is not used or is not the only one available for automatic transit calls through the switching centre. If, for instance, an operator at exchange T connected to exchange M in Fig. 2 makes a call to exchange P, the channels from T to M can be provided on a demand basis. The group from M to P must be provided on a no-delay basis unless special arrangements are made for transit calls by providing for these calls a separate group from M to P, which is not accessible to the operators at M, but which is connected so that overflow calls also test the M to P group used by the operators. The latter group can then be provided on a demand basis. The transit call group in such a case would be designed to carry a small average traffic per trunk, say 0.5 T.U., for which value the overflow for a group of 4 trunks is only about 13 per cent. as is shown in Fig. 3. In the initial stages of the introduction of the automatic trunk switching plan, an arrangement as outlined can be used to avoid a manual switching point and at the same time obtain good overall occupancy of channels where the total traffic is not high enough to need large trunk groups. Since manual transit traffic is always difficult and results in low effective occupancy of lines, the provision of a separate transit group designed for low occupancy would not necessarily be less efficient than existing arrangements.

The traffic capacities possible with short delays are shown in Fig. 1 curves C, D and E, which have been prepared from C. D. Crommelin's delay probability formula (8) for constant holding times. From curve D, for instance, it is seen that an average occupancy of 0.8 T.U. per trunk can be obtained from a group of 8 trunks with an average delay of 0.9 minutes if the average duration or holding time of the trunk calls is 6 minutes.

When deciding the total number of channels to be provided between any two switching centres, the grade of service in both directions must be considered. In one direction a demand grade of service may apply, but in the other a no-delay grade of service. This will be arranged by a suitable provision of uni-directional and both-way lines. Groups of up to 5 lines will be provided by both-way lines only.

Reference to the delay curves in Fig. 1 shows the steep rise in traffic efficiency as the group size increases, and this provides the further reason mentioned earlier for the selection of 3 channels as the desirable minimum for a direct route to be established to a Secondary Switching Centre.

The Numbering Scheme

The only numbering scheme which is at present practicable for an automatic trunk network in Australia is the "open" or variable scheme, under which an exchange or a subscriber may have a different number depending upon the relative locations of the originating and terminating exchanges. This should not lead to any difficulty because the numbers within an area can be kept fairly uniform, and the main outlets to other areas can have the same selection digits for all the exchanges of the same order connected to the switching centre giving access to those outlets. The open numbering scheme has the advantage that it is completely flexible and does not control the method of connecting exchanges within the network, so that Terminal Exchanges or Switching Centres can have tie lines between them if this is the most economical arrangement as it will be in many cases.

A change or a partial change to the "closed" or non-variable numbering scheme may become necessary in the distant future after subscriber dialling of trunk calls becomes fairly extensive, but this is not at all certain. The closed system requires a considerable increase in equipment and, moreover, experience elsewhere (10) has shown that when a change was made from the closed to the open system, the subscribers found no special difficulty in dialling the variable part of subscriber's numbers. Perhaps, from the subscriber's viewpoint, the main disadvantage of the open numbering scheme is that the trunk network or national number cannot be placed on letter heads in addition to the local network number.

The numbering plan requires very careful consideration at the outset so that numbers can be allotted in accordance with the basic plan as the trunk switching scheme is implemented. The numbering of direct and alternative routes should be planned so that wherever possible the direct route and its alternative are in the same switch group, since this allows a more simple transference of a call from the direct to the alternative route when automatic alternative routing facilities are provided.

Equipment for Automatic Trunk Switching

The basic requirements for the purpose of automatic trunk switching with operator dialling are a selector or switch and a signalling system to control the selector and provide supervisory signals, such as answering and release signals. Other signals may be added such as a re-route signal from an intermediate transit switching centre when the called trunk group is engaged.

The selector standardised for trunk switching is the motor uniselector similar to that used in the Melbourne Trunk Exchange, although a later form is now being supplied which includes a number of refinements designed to simplify maintenance attention (11). This switch has also been standardised by the British Post Office for automatic trunk switching purposes. The signalling system used to control the switches and provide basic signals may be D.C. or its equivalent, or one of the various forms of A.C. signalling, but the system standardised for major uses is the 2 VF signalling system designed by Siemens Bros. and Co. Ltd., London. This system, which is also used by several other Administrations, has been designed to meet all the requirements of an automatic trunk switching system such as contemplated for Australia. An important feature in this respect is the employment of end-to-end signalling as this avoids repetition of impulses and other signals at intermediate switching centres.

Considerable quantities of standard trunk switching and signalling equipment have been purchased for several States and some deliveries have been made. It is expected that all Main Trunk Centres and some of the larger Primary Trunk Centres will eventually be equipped with automatic trunk exchanges. For use at the lesser switching centres the motor uniselectors are mounted in racks of 20 and 40, and the 2VF signalling equipment in completely self-contained racks of 5 and 10 lines for magneto exchanges, and 10 and 20 lines for C.B. exchanges of the sleeve control type.

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A SIMPLE V.F. DIALLING SYSTEM

L. A. Jones

General

During and since the recent war, the need for facilities to permit direct dialling between country manual exchanges and the metropolitan automatic network in Western Australia has become increasingly evident. While this requirement has been recognised in existing proposals for the installation of 2 V.F. equipment at a number of centres, delivery is still some time distant, and it was necessary to find a temporary solution.

A limited number of D.C. loop, composite or cailho dialling circuits has been in use for some years between country centres and Perth, but their provision has, for well-known reasons, not been extended. In addition, a few V.F. dialling channels of a type similar to that already described in this journal (1), were installed during the war; but, although fairly satisfactory service was obtained, it was found desirable, when considering the expansion of the scheme, to introduce a number of modifications. The equipment eventually installed has the merits of simplicity of manufacture, low initial and maintenance costs, and moderate size, and is, therefore, suitable for bridging the gap until standard apparatus is obtained. It has given satisfactory operation on a number of channels for more than a year, and additional systems are now being installed.

Facilities

The equipment is suitable for operation on either physical or carrier-derived speech circuits having normal transmission performance, but has so far been applied only to carrier channels. Because of the need for simplicity, no special arrangements have been made for supervision; to the country telephonist the trunk line appears identical with an automatic subscriber's line, and it is used accordingly.

For application to bothway trunks, facilities are provided for main trunk exchange telephonists to call country exchanges by dialling into special final selectors, with the result that a magneto ring reaches the distant switchboard. In this case an indication is given when the country exchange answers. Similar arrangements apply to the D.C. dialling lines still in use.

Operation

A block schematic diagram of the system is shown in Fig. 1.

Country to Perth Direction: On the insertion of a plug in the line jack on the country switchboard a burst of tone is sent to line and operates the V.F. receiver, which causes a first group selector to be seized before the telephonist commences dialling. At each break of the dial contacts a 66-millisecond V.F. impulse is transmitted, to be converted by the receiving apparatus into a standard D.C. impulse to operate the automatic switching equipment. Dial and other tones are repeated in turn to the country telephonist, and when the called subscriber or metropolitan manual exchange answers, conversation proceeds through the signalling equipment with an added loss of about 1db. On conclusion, withdrawal of the plug from the trunk jack causes a further V.F. burst to be transmitted, which has the effect of restoring all equipment to normal.

Perth to Country Direction: The trunk exchange telephonist dials into a final selector to obtain the desired trunk dialling line. If the line is busy it may be "camped" on, and seized as soon as it becomes free. A free line is fed with automatic ringing from the final selector, which is converted by the line equipment into a form suitable for operating V.F. ringers. When the country telephonist plugs up to answer, a V.F. burst is transmitted to complete the final selector loop and the call proceeds. On completion the release burst restores the dialling equipment to normal, while release of the final selector is under the control of the trunk exchange telephonist.

Description of Equipment

V.F. Oscillator: Signalling power at 2200 c/s, which frequency was found satisfactory in earlier equipment, is provided by the oscillator shown

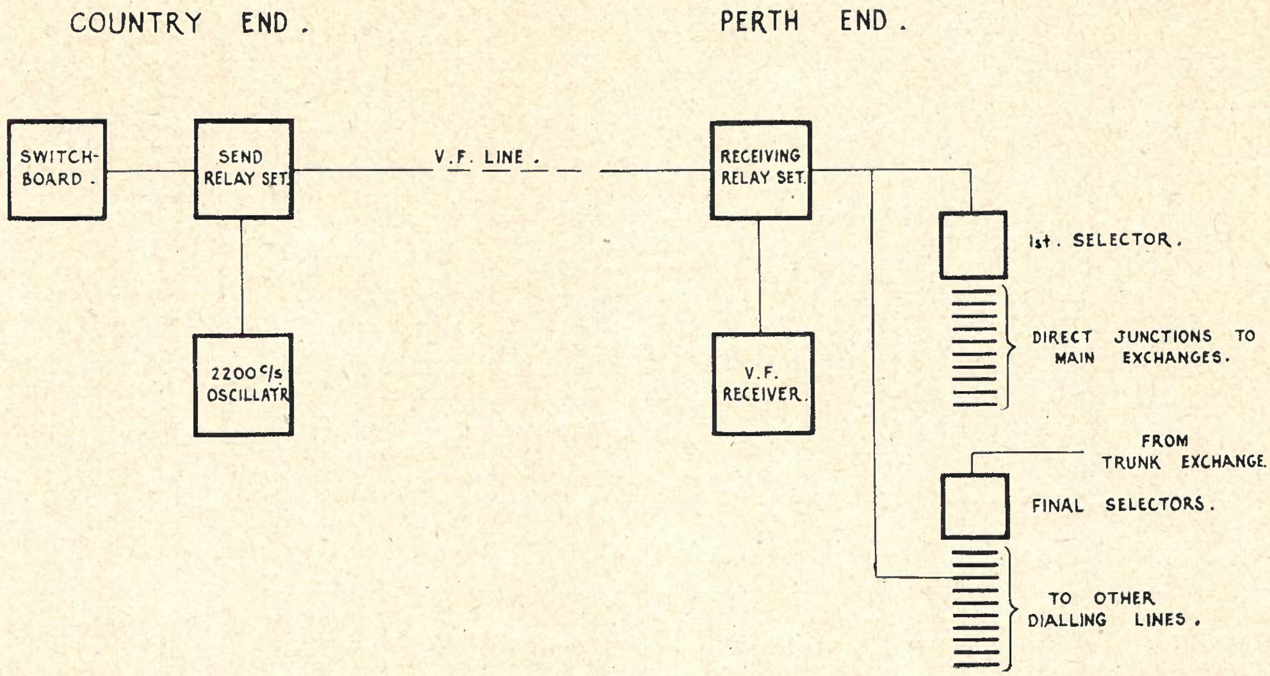

Fig. 1.—Block Schematic V.F. Dialling System.

schematically in Fig. 2. This is of the well-known inductive-feedback, resistance-stabilised type, and produces sufficient power to feed a number of dialling circuits. The components are mounted on a 19 in. by 5¼ in. panel, which is installed with the other long line equipment in the country office, and the 24V. and 130V. supplies furnish power to the electron tube, which consumes 0.3A at 24V. and about 5mA at 130V.

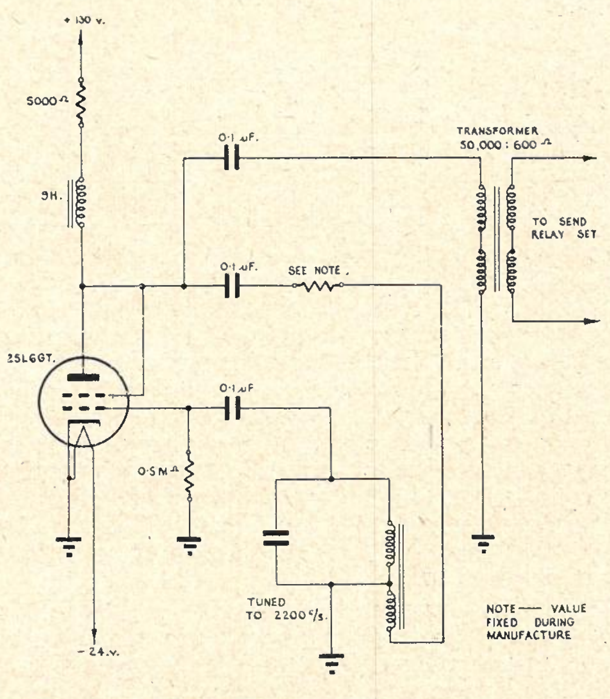

Fig. 2.—2200 c/s Oscillator.

Send Relay Set: The circuit of this equipment and of relevant parts of the switchboard appears in Fig. 3. Equipment for one or two lines is fitted on a 19 in. by 5¼ in. panel, and the 24V. supply is used to operate the relays. The functions of this panel are the transmission of seizing, dialling and releasing signals, and provision is also made for circuit testing by the technician. Operation of the "Test" key permits continuous 2200 c/s tone to be fed to line for level measurement or frequency check at either end of the V.F. channel; the other operated position of this key allows the technician to dial clear of the exchange for testing purposes.

V.F. Receiver: This was designed with the object of obtaining satisfactory performance while keeping the size small and manufacture simple. Reference to Fig. 4 shows that the number of components is small, and in practice the receiver is mounted wholly on a base of the size used for pre-2000 type group selectors, with standard jack mounting. This feature is of value for maintenance, as the receiver can readily be removed for attention and a spare substituted within a few seconds. Power requirements are 0.6A at 24V. and about 3mA (except during reception of signals) at 130V.

Although the receiver is normally bridged across the V.F. line, its input impedance is so high under all conditions that the resulting transmission loss and speech distortion are negligible, even should grid current flow in the electron tubes. The receiver consists of a voltage amplifier, a detector, and a guard circuit, requiring the use of three electron tubes. The 6J7G tube, V1, operates as an amplifier with a plate circuit parallel resonant at 2200 c/s and therefore rejects signals of

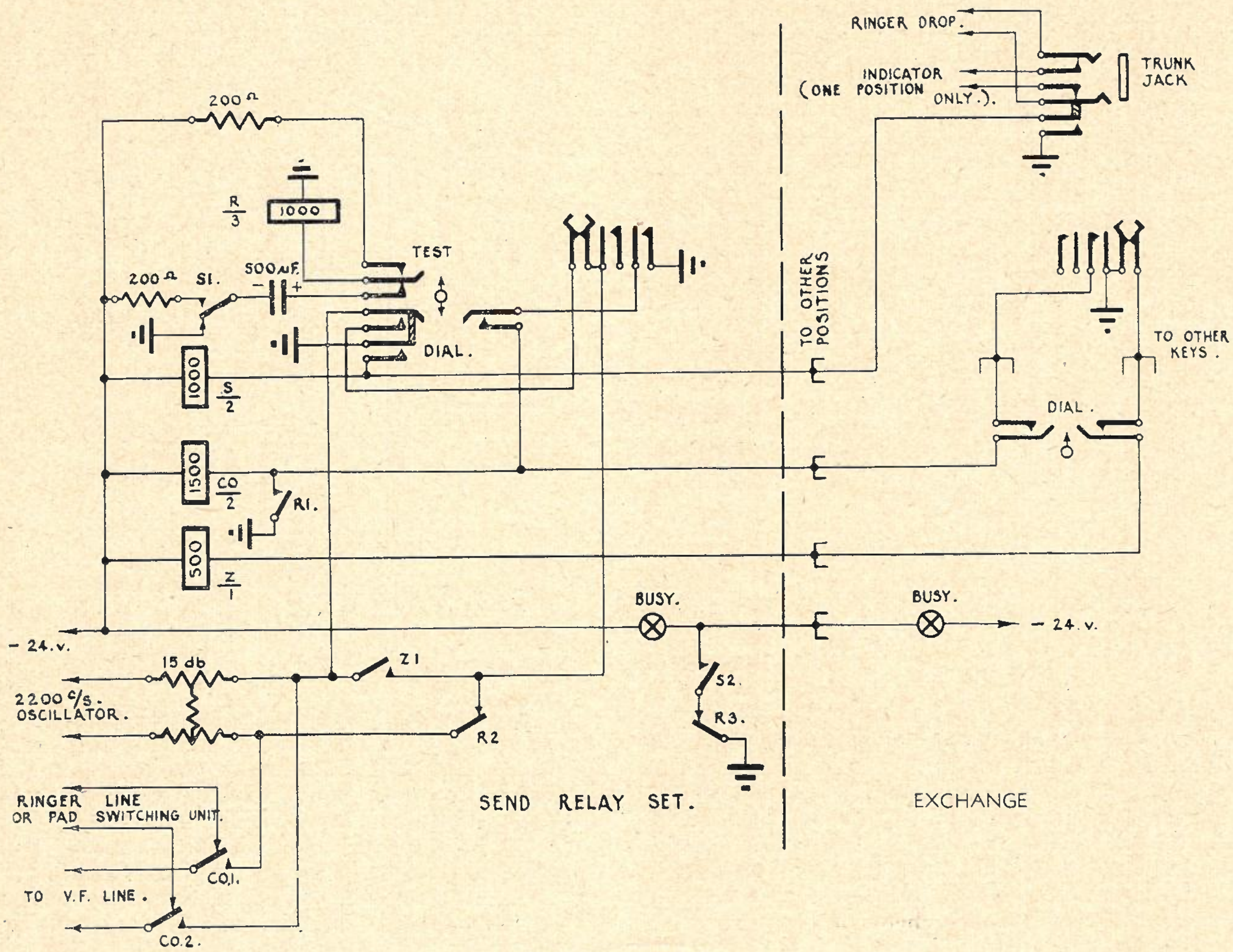

Fig. 3.—Country End.

frequencies much removed from this figure. This stage is supplied with 154V. on the anode, but only 24V. on the screen grid, with the following results:—

High voltage gain.

High anode A.C. resistance, in order to preserve a high tuned circuit "Q".

Low anode current, to avoid adversely affecting the inductance of the tuning coil L1.

The gain is greatly reduced by the application of a small negative potential to the control grid, thus facilitating the operation of the guard circuit.

The detector tube, V2, is supplied with 130V. to anode and screen grid, while the 24V. negative supply is connected to the control grid so that, under static conditions, anode current is substantially cut off. On the application of a 2200 c/s signal to the input circuit of the receiver an amplified voltage appears between grid and cathode of V2, causing a rise in anode current which, if sufficient, operates an external relay to convert the V.F. signals into D.C. impulses of the same duration. A capacitor between anode and earth filters out the V.F. ripple from the anode current.

An amplitude limiting arrangement is included in the detector circuit to prevent impulse distortion with change of input level, and to obviate the use of a gain control. When the level on the V.F. line exceeds –10dbm, grid current commences to flow in V2, resulting in the generating across the 1 megohm resistor of a negative voltage which remains practically constant because of the reservoir action of the 0.1 microfarad coupling capacitor. A further rise in input level increases the bias voltage so applied to V2, altering the working point so that anode current flows during a smaller angle of each cycle of input voltage. At the same time the tops of the anode current pulses are flattened because of the high grid-circuit impedance, and the result is that for all levels above –10dbm the average plate current remains fixed at about 40mA.

While the receiver is responsive only to a narrow band of frequencies about 2200 c/s, such components are frequently present in speech and might, therefore, have the effect of a clearing burst, if sufficiently sustained and cause calls to

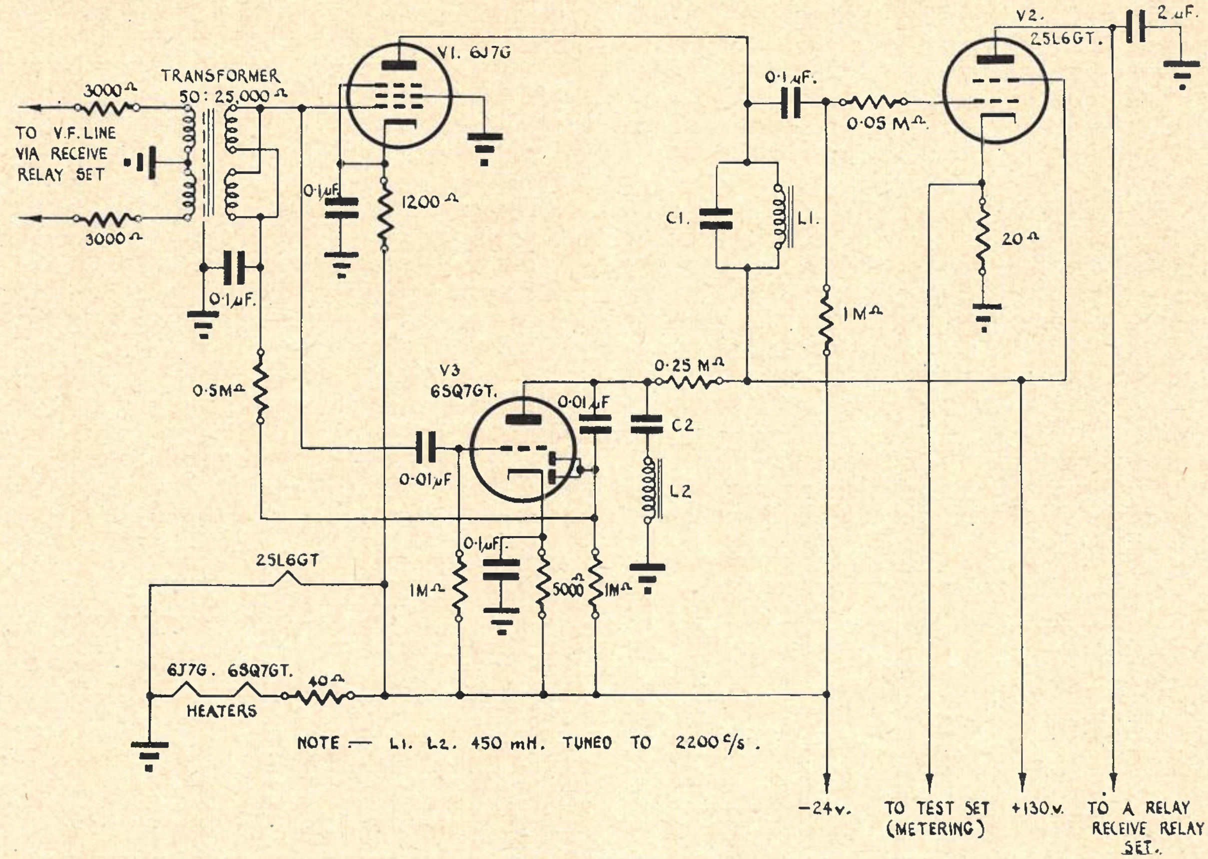

Fig. 4.—V.F. Receiver.

break down during conversation. To overcome this a guard circuit, consisting of a selective amplifier and a rectifier, has been incorporated. The triode section of V3 shares all input signals with V1 but, unlike it, has a series tuned circuit for its effective anode load. Input signals at 2200 c/s, therefore, produce no effect in the output circuit of V3. However, speech signals, even if they contain 2200 c/s components, will always include components at other frequencies, to which the impedance of the series tuned circuit will be relatively high, so that an amplified voltage will appear in the anode circuit. Rectification in the shunt diode circuit gives a negative D.C. voltage which, after filtration of the V.F. ripple, is applied to the control grid of V1, causing a reduction in gain which makes the voltage amplifier ineffective even at 2200 c/s. The sensitivity of the guard circuit is such that, while providing voice immunity, it does not permit normal line noise to put the receiver out of action.

A possible source of trouble in a receiver of this type is the production of harmonics in V1, which might result in a high voltage output at 2200 c/s due to a strong input signal at, say, 1100 c/s. The operation of the guard circuit, while reducing the

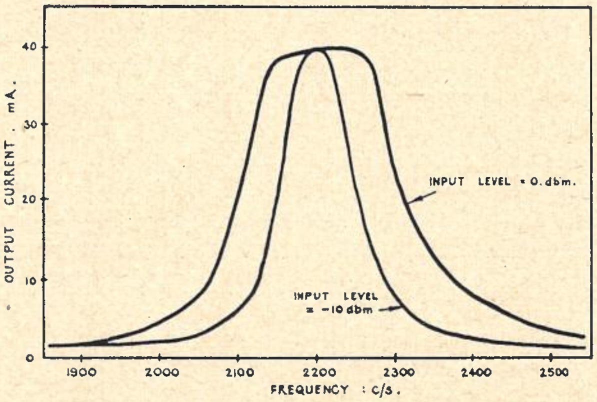

Fig. 5.—V.F. Receiver Selectivity.

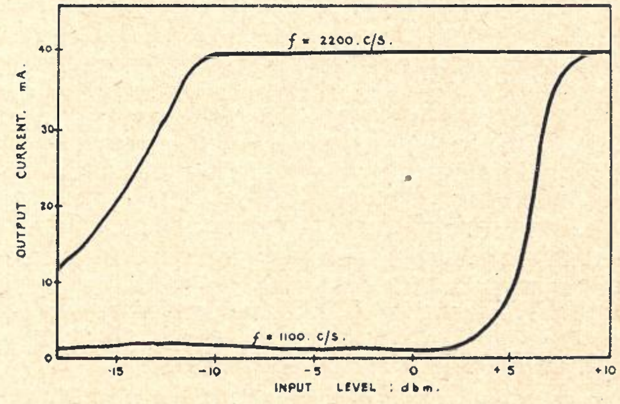

Fig. 6.—V.F. Receiver Sensitivity.

gain of V1, could increase its harmonic production because of the high grid bias voltage. Careful attention to the operating conditions of V1 eliminated this difficulty, as can be seen from Fig. 6, which illustrates the variation of detector anode current with input V.F. level at frequencies of 1100 and 2200 c/s.

The selectivity of the receiver for two input levels is shown in Fig. 5, the apparent reduction of selectivity at high levels being a result of the automatic limitation of output current to 40mA. Because the bandwidth to which the receiver responds is adequate to permit moderate variations in oscillator frequency and carrier synchronism, no critical adjustments of apparatus are necessary.

Receive Relay Set: The relays and other components necessary for repetition of speech and dialling signals between the trunk channel and the metropolitan network are mounted on a pre-2000 type relay set base, with the exception of the 4012A repeating coil and certain capacitors which are shelf-mounted. Like the receiver, this unit can be quickly exchanged with a spare in the event of a fault. Only seven relays are used, and the impulsing relay (A in Fig. 7) is a standard 3000 type with isthmus armature.

A further guard feature is provided in the release lag of the B relay, which is such that, even if the V.F. receiver should momentarily respond to speech and so cause the A relay to flick, interruption of calls is extremely unlikely.

Connected across the transmission circuit is a rectifier limiter, the purpose of which is to prevent impulse distortion which would occur if the high-amplitude transient pulses, developed in the D.C. side of the circuit during impulsing, should reach the V.F. receiver. During dialling, also, there is included in the transmission path a resistance network, the functions of which are:—

- Provide a termination to the V.F. line.
- Reduce the effects on the receiver of impedance variation as the call progresses through the automatic network during dialling.
- Isolate the receiver from the rectifier limiter.
- Further reduce the amplitude of transient pulses.

The resistance network causes a drop in the level of tones reaching the country telephonist, but not a serious one. This loss, moreover, reduces the possibility of the guard circuit operating on busy or N.U. tones and so preventing release.

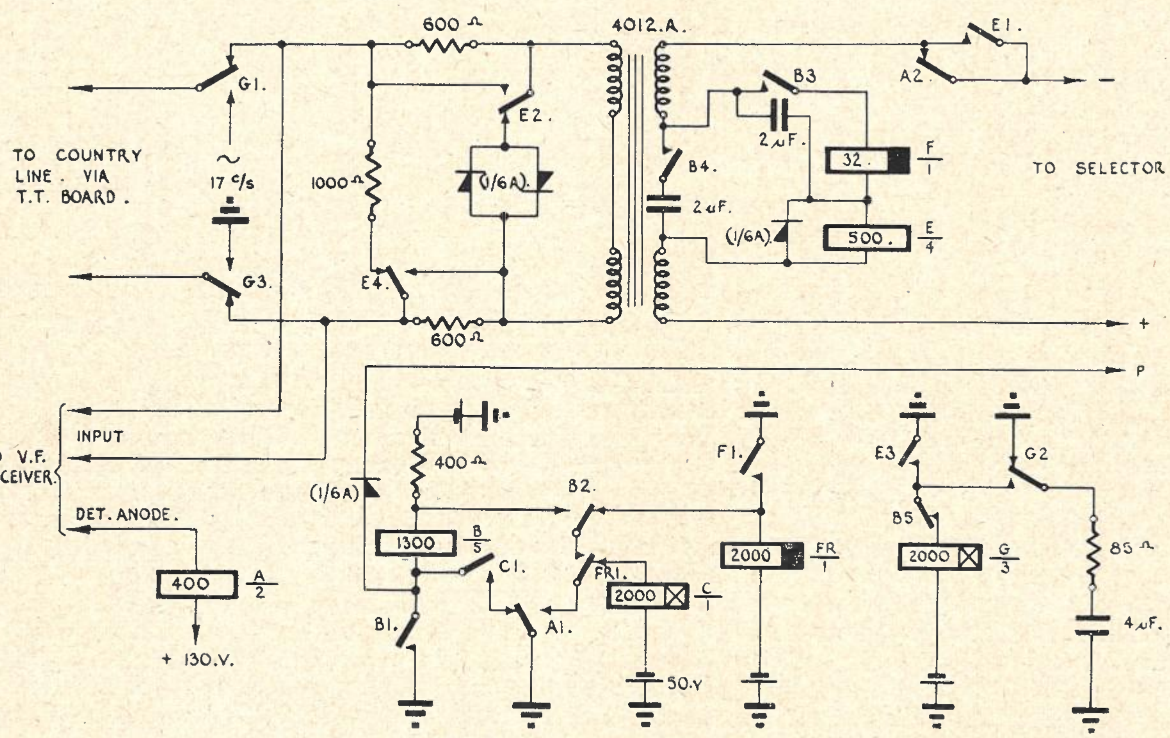

Fig. 7.—Receive Relay Set.

Detailed Circuit Operation: Country-Perth Direction

Country End: Referring to Fig. 3, the operation is as follows:—

Telephonist plugs into trunk jack. Extra springs close to operate S relay. Contact S1 allows the 500 microfarad capacitor to charge from 24V supply through relay R, which operates. Contact S2 prepares the busy lamp circuit which, however, is opened by contact R3.

Contact R1 operates CO relay; contacts CO1, CO2, switch 2200 c/s oscillator to line via 15 db pad. Contact R2 guards against mutilation of seizing burst by premature operation of dialling key.

After approximately 2 seconds, capacitor charging current falls to the point where relay R releases. The lamps now glow, indicating to calling telephonist that seizing burst has been transmitted, and to other positions that the circuit is busy.

Relay CO releases. Telephonist hears dial tone from Perth end and operates dialling key. Relay Z operates through dial impulse springs and key. Contact Z1 short-circuits output of pad.

Telephonist proceeds to dial. Relay CO operates through dial off-normal springs and key. Contact Z1 permits a V.F. burst to reach line for each break of dial impulse springs. After each digit relay CO restores to permit telephonist to hear tones from Perth.

On completion of dialling, key is restored and conversation proceeds when distant subscriber answers.

At conclusion of call, telephonist removes plug. Relay S releases and contact S2 opens lamp circuit. Capacitor discharges to earth through relay R which operates, and relay CO operates to send a further long V.F. burst until relay R again releases.

Perth End: Referring to Fig. 7, the corresponding operation at the Perth end is:—

Seizing burst from country reaches V.F. receiver via contacts G1 and G3 normal. Anode relay A operates. Contact A1 operates C relay, which has operating lag to prevent possible false seizure from noise on line.

At end of burst A relay releases, B relay operates through contacts A1 normal, C operates, and locks at contact B1, which also extends earth via rectifier to group selector to mark circuit busy. Contact B2 prepares release circuit of B relay, B3 completes D.C. loop to selector, B4 prepares transmission path, B5 opens G relay circuit.

Relay F operates and contact F1 completes FR relay circuit. Contact FR1 further prepares release circuit. Relay C releases.

At this stage dial tone from the selector passes to trunk line through 4012A transformer and resistance network.

Country telephonist dials. A relay operates in response to received impulses and contact A2 repeats them to the selector. Relays B, F, FR hold. Busy, N.U. or ringing tone is duly transmitted to line.

Called subscriber answers. E relay operates on reverse current and contact E1 shunts A2 to guard against possible interruption. Contacts E2, E4 disconnect resistance and rectifier networks and speech proceeds.

At conclusion A operates on release burst. Relay B is short-circuited by contacts A1, FR1, B2 and releases slowly.

As contact B3 restores, relays E and F release. FR relay is now held through contacts B2 normal, FR1, A1.

At end of burst A relay releases and FR relay releases last to prevent re-operation of C relay during burst.

The circuit is now ready for a fresh call.

Detailed Circuit Operation: Perth-Country Direction

Perth End: Trunk exchange telephonist dials into final selector, which feeds automatic ringing to receive relay set. Relay E operates and contact E3 operates relay G. Contacts G1, G3 connect

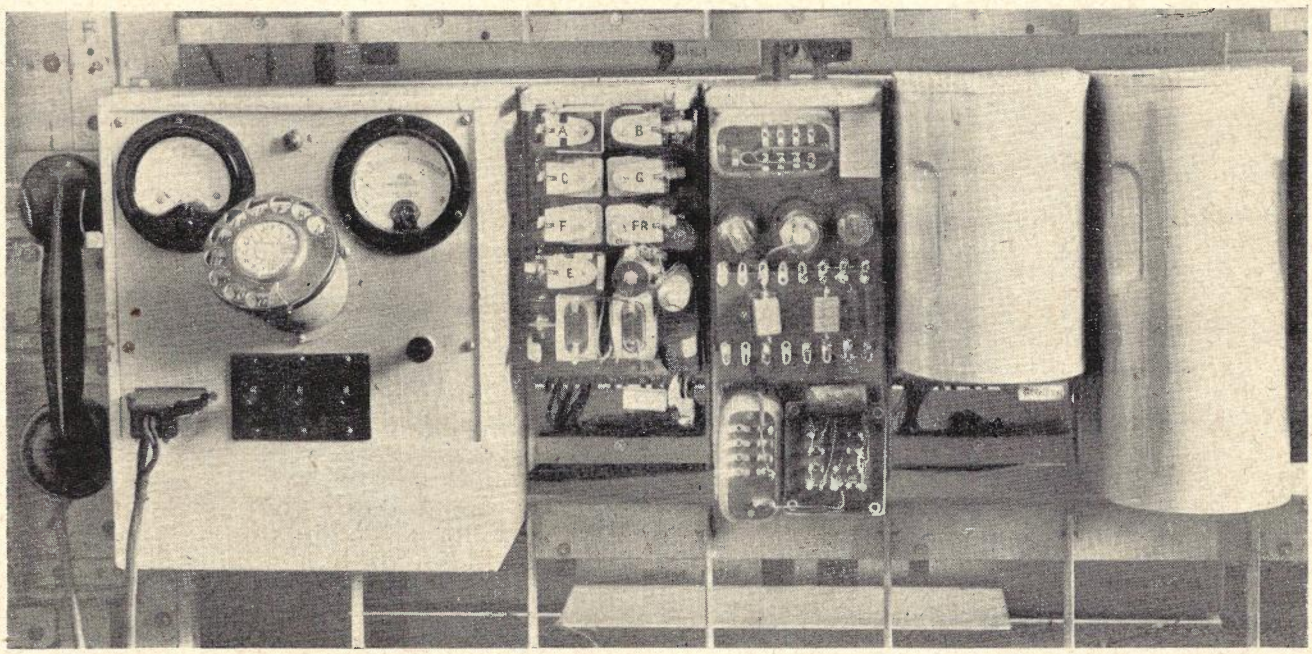

Fig. 8.—Equipment at Perth, showing test set, relay set and V.F. receiver.

17 c/s ringing to trunk line. Contact G2 connects 4 microfarad capacitor across G relay winding. During short (0.2 second) interruption in automatic ring, E relay releases, but G remains held by capacitor charging current. During long (2 second) interruptions G relay releases and capacitor discharges through 85 ohms resistor. The ring sent to trunk line thus consists of approximately 1 second bursts with 2 second interruptions. These are sufficient to overcome the lag in V.F. ringers while yet permitting seizing burst to be received.

Seizing burst arrives from country. Relays A and C operate as before. At end of burst B operates, final selector is looped at contact B3 and ringing tripped. Contact B5 opens G relay circuit. Reverse battery is fed from final selector and remainder of operation is as for incoming calls.

Country End: Ring arrives from Perth and operates indicator. Telephonist plugs up to answer; seizing burst is transmitted and lamp circuit operates as for outgoing calls. At end of burst circuit is ready for conversation.

On conclusion the plug is withdrawn and release burst transmitted as before.

Testing Equipment

To provide for routine testing and the location of faults, a test set is installed, adjacent to the equipment at the Perth end, and can be seen in Fig. 8 at the end of a row of relay sets and receivers. Comprehensive tests can be made on any V.F. dialling circuit without moving from the test set. The set includes a 2200 c/s oscillator, dial, speaking circuit, A.C. and D.C. meters and the means of connection, by dialling a number, to any desired circuit. By its use the maintenance staff can:—

(a) Listen or speak both ways on the trunk connection.

(b) Measure incoming V.F. level.

(c) Measure detector cathode current (the 20 ohms resistor in the cathode circuit functions as a meter shunt in this test).

(d) Introduce to the V.F. receiver seizing, dialling and releasing signals identical with those produced at the country end.

(e) Connect continuous 2200 c/s tone for making tests or adjustments on the V.F. receiver or impulsing relay.

(f) Beat the local oscillator signal against that received from the country technician for comparison of frequency, by either the aural or the visual beat method.

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MANUAL C.B. MULTIPLE EXCHANGES AND SLEEVE CONTROL TRUNK SWITCHBOARDS

J. S. Silvester, A.M.I.E. [Aust.] M.I.R.E. [Aust.] and J. L. Harwood, M.I.R.E. [Aust.]

PART 2—CIRCUIT ARRANGEMENTS AND OPERATING DETAILS

General

This article describes the circuits and operating methods associated with the standard C.B. multiple and sleeve control trunk switchboards. Reference should be made to Part 1, Telecommunication Journal of Australia, Vol. 8, No. 1, June, 1950, in which the physical design and construction of these switchboards is described.

Three types of operating positions are installed to meet the full range of operating requirements. These are as follows:—

(1) "A" positions, on which all unit fee traffic is handled, i.e., calls between local subscribers and between nearby manual or automatic exchanges and local subscribers.

(2) "Terminating trunk" positions, which are used to establish connections between the local subscribers (or subscribers connected to other exchanges, but within the unit fee network) and any trunk line connected to the switchboard.

(3) "Through trunk" positions, which are used to establish connections between any two trunk lines or between a trunk line and a rural automatic exchange or automatic exchange outside the unit fee area.

Both types of trunk positions are equipped with suitable operating aids for the efficient control of all connections, together with call timing facilities.

The provision of two types of trunk positions, which at first sight may seem to have certain operating limitations, was determined by engineering as well as traffic handling requirements as follows:—

(a) In large exchanges it is desirable to separate the "terminating" and "through" traffic to facilitate the different operating and recording procedures involved in the setting up, supervising and timing of calls.

(b) The need for 4-wire switching on "through" trunk calls necessitates the provision of spe-

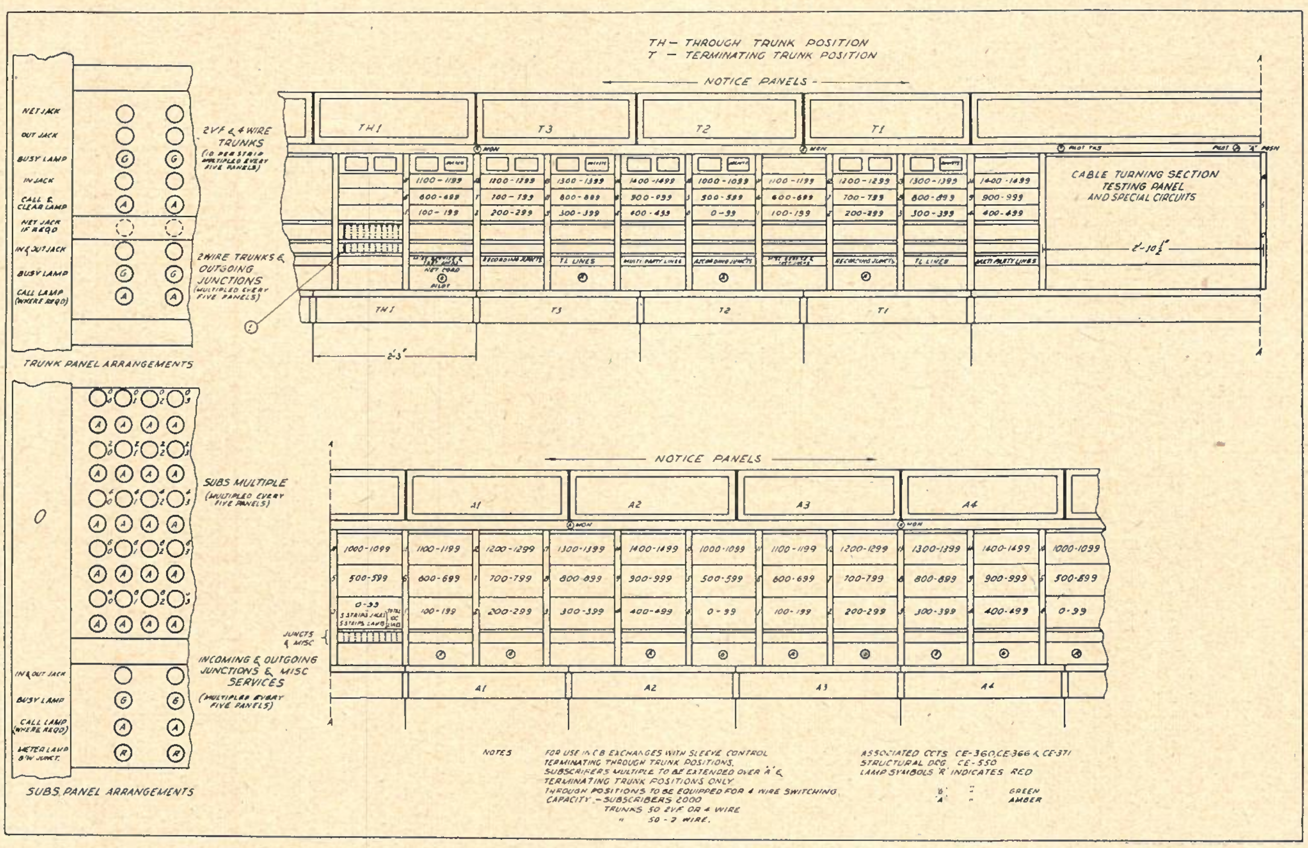


Fig. 1.—Face Layout of C.B. Multiple "A" and Trunk Positions.

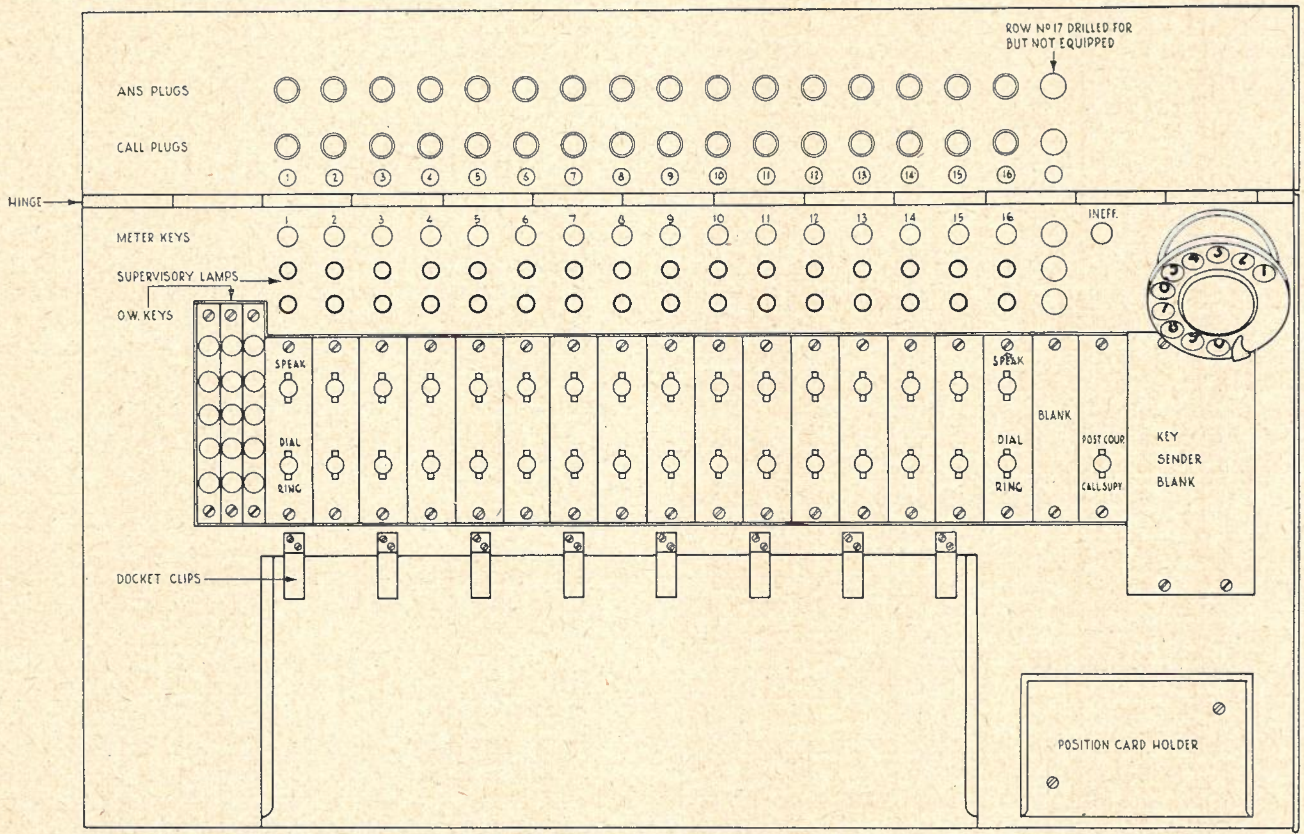


Fig. 2(a).—"A" Operating Position.

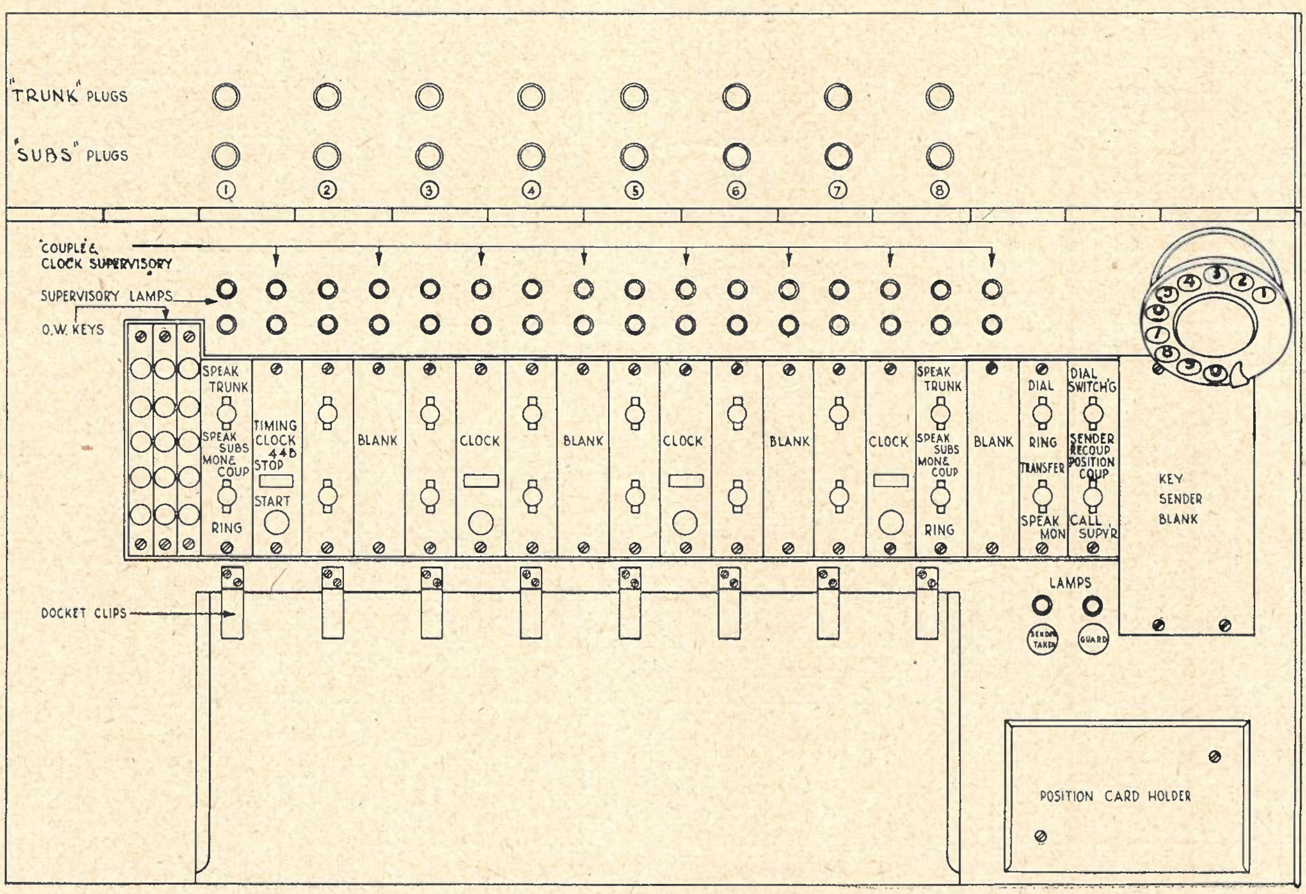


Fig. 2(b).—Terminating Trunk Position.

cial cord circuits (net cords) to satisfy transmission requirements. This also involves additional operating sequences which may be neglected if "through" calls are handled on terminating positions, particularly during busy periods.

(c) The different sleeve potential conditions on subscribers' and trunk circuits would require a complicated and elaborate cord circuit to meet all of the circuit conditions involved in a "terminating" and a "through" trunk call. In this regard it may seem an obvious solution to connect earth potentials instead of negative potential to the K relays of the subscribers' line circuits, but one of the initial design requirements for these exchanges was that the subscribers' line circuits should be convertible to, or work in with, automatic equipment.

The face layout of a typical C.B. multiple trunk exchange is illustrated in Fig. 1, and the layout of the three types of cord and keyshelves is illustrated in Figs. 2a, b and c. It will be seen that the system is highly flexible, and can be extended with comparative ease to the maximum capacity of the switchboard structure. It should be noted that both the local and trunk switchboard positions are of identical construction.

The table shown in Fig. 3 sets out the more important circuits and operating sequences involved in establishing connections between the various types of lines terminating on the switchboard. Some idea of the operating procedure may also be gained by an examination of the face panel and key-shelf layouts shown in Figs. 1 and 2. Each of the major circuits associated with the switchboard will now be described with reference to the appropriate operating procedures.

"A" POSITIONS

Subscribers' Line Circuit, Fig. 4 (CE.366, Sheet 4)

Rack Equipment: Subscribers' lines are connected to the L and K relay rack, which accommodates 500 circuits together with the necessary tags for terminating the I.D.F. and meter cables. The L and K relays are strip mounted 600 type for ultimate use with uniselectors on conversion to automatic working.

Switchboard Equipment: No local jacks are provided. The subscribers multiple, including the lamp jacks, is extended over all panels and one appearance only of the subscriber's number is equipped with a line lamp. This system dispenses with the usual double sided type of I.D.F., and simplifies and reduces cabling. A rack type I.D.F. is provided as a convenient terminating point for the different sized cables and as a connecting point for service observation equipment.

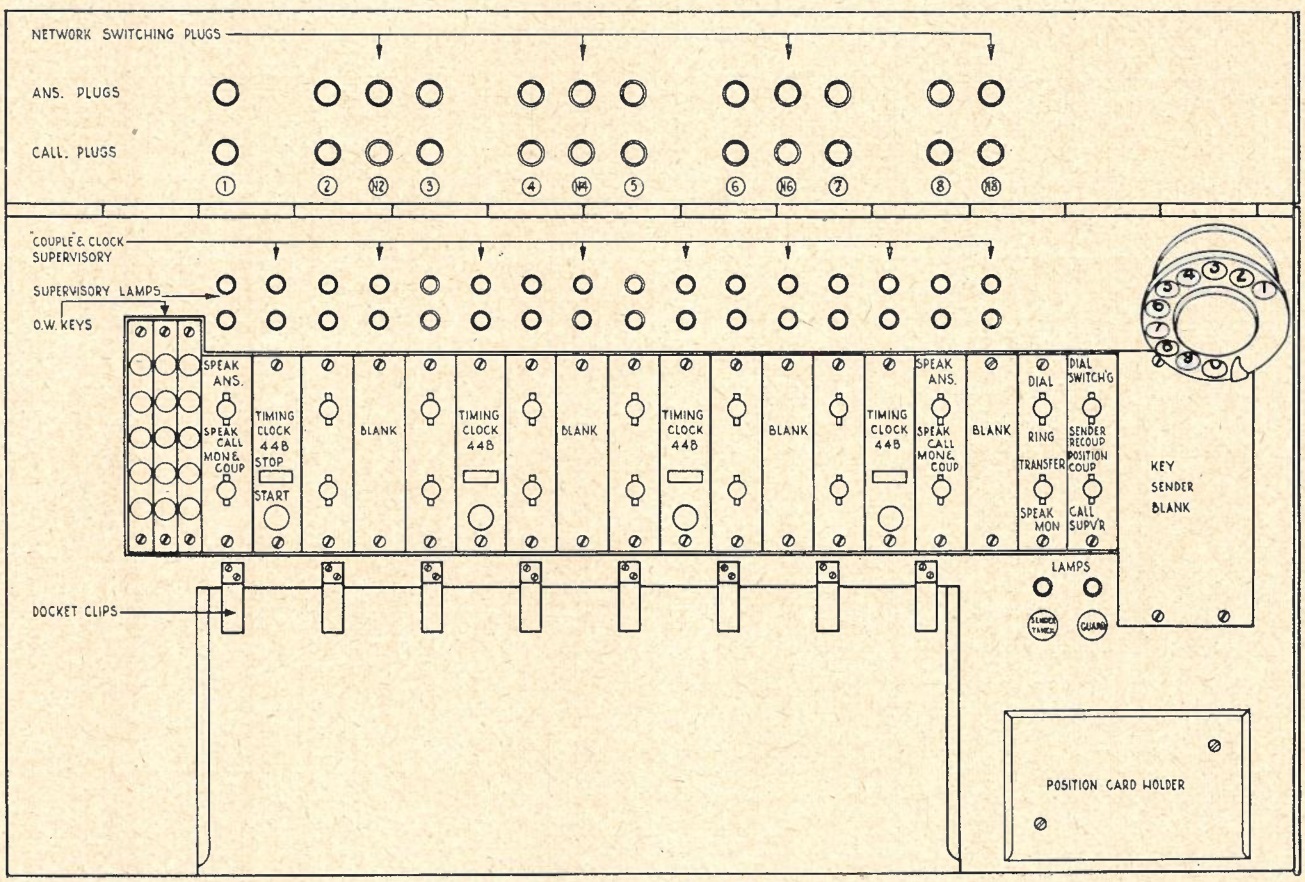


Fig. 2 (c).—Through Trunk Position.

Circuit Operation: The subscriber removes his receiver and loops the line to operate relay L, which lights the call lamp and operates the night alarm relay. The NA relay lights the NA pilot and closes an audible alarm circuit if the NA is switched on. In earlier installations 50V. D.C. was used to light the subscribers' line lamps, and a separate 1200 ohm resistor for each line lamp

	Circuit Sequence							C.E. Drawing		Figure Number (Note 2)
	From	To						Number	Sheet	
		Local Subscriber or Party Line	Automatic Exchange Junction	Generator Signalling Trunk 2-wire	Generator Signalling Trunk 4-wire	Automatic Exchange or R.A.X. Trunk	V.F Dialling Trunk			
1	2	3	4	5	6	7	8	9	10	11
A	Local Subscriber or Party Line (Note 1)	A, R,M	A, D, M,	A, RJ TG, R S, T	A, RJ TG, R S, T	A, RJ TG, D S, T	A, RJ TG, D S, T	366 366	4 5, 6, 11	4 7, 8, 9
B	Automatic Exchange Junction (Unit fee area)	A, R,M	—	A, RJ TG, R S, T	A, RJ TG, R S, T	A, RJ TG, D S, T	A, RJ TG, D S, T	366	9	10
C	Generator Signalling Trunk									
	(i) 2-wire	TG, R S, (T)	TG, D S, (T)	TG. TF TH, R S, (T)	TG, TF TH, R S, (T)	TG, TF TH, D S, (T)	TG, TF TH, D S, (T)	371	1	20
	(ii) 4-wire	TG, R S, (T)	TG, D S, (T)	TG, TF TH, R S, (T)	TG, TF TH, R S, N (T)	TG, TF TH, D S, (T)	TG, TF TH, D S, N (T)	371	2	21
D	Automatic Exchange or R.A.X. Trunk	TG, R S, T	TG, D S, T	TG, TF TH, R S, T	TG, TF TH, R S, T	TG. TF TH, D S, T	TG, TF TH, D S, T	371	3	22
E	V.F. Dialling Trunk	TG, R S, (T)	TG, D S, (T)	TG. TF TH, R S, (T)	TG, TF TH, R S, N (T)	TG. TF TH, D S, (T)	TG, TF TH, D S, N (T)	371	4	23

KEY TO SYMBOLS

Code	Circuit or Function	C.E. Drawing Number	C.E. Drawing Sheet	Figure Number (Note 2)
A	"A" Cord Circuit	366	1	5(a)
D	Dialling (or sending where applicable)	590	1	19
M	Metering	—	—	—
N	Net Cord Circuit	360	11	14
R	Ringing	—	—	—
RJ	Recording	366	3	6
S	Monitoring/Coupling	—	—	—
T	Timing	360	6	18
(T)	Timing (if required)	360	6	18
TG	Terminating Trunk Cord Circuit	360	2	11(a)
TH	Through Trunk Cord Circuit	360	1	12(a)
TF	Transfer of Incoming Trunk Call to Through Position	—	—	—

Notes 1. Calls from multi-party subscribers are recorded by the telephonist.

2. Numbers refer to figures in this article. Figures 21-23 inclusive will be included in another part of this article which will appear in a subsequent issue of the journal.

Fig. 3.—Circuits and operating sequences involved on various types of calls.

circuit was provided.

Isolating keys (associated with the NA pilot lamp) are provided in the NA circuits for locating permanent NA contacts or locating a calling subscriber if the line lamp is open circuit. The keys are duplicated on the relay racks, and the cable turning section of the switchboard. The K

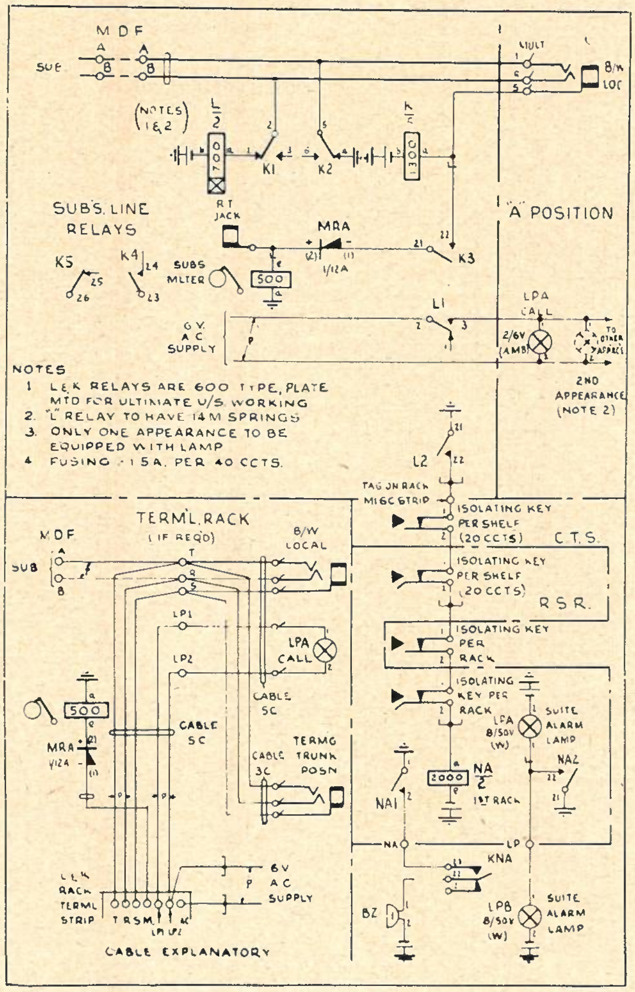


Fig. 4.—Subscriber Line Circuit.

relay operates when the plug is inserted in the jack and relay L is disconnected and releases slowly.

The operation of the cord circuit meter key at the end of the call will connect 50 V. positive battery to the sleeve of the answering cord and will operate the subscriber's meter in series with the 1/12A metal rectifier.

"A" Cord Circuit. Fig. 5(a) (CE.366, Sheet 1).

The cord circuit relay sets, on both "A" and trunk positions are mounted on shelves fitted in the rear of the switchboard. This arrangement, although perhaps undesirable from maintenance and power distribution aspects, in comparison with the relay sets mounted in the apparatus room, minimises cord circuit cabling and crosstalk.

Circuit Operation—Local Call: The telephonist answers the calling subscriber by inserting the answering plug. Relay K operates in the line circuit and disconnects relay L and earth from the line. Relay L releases, opening the calling lamp and NA circuit. Relay SA in the cord circuit operates and closes the circuit of the answering supervisory lamp. The earth, via SA relay, provides the engaged test potential on the sleeve for multiple appearances of the subscriber's line and also prevents access from the final selector (if provided) by earthing the P wire. Relay A operates to the subscriber's loop and extinguishes the answering supervisory lamp. The telephonist now operates the speak key, ascertains the number required and tests on the sleeve of the jack of the desired number with the tip of the calling plug. If disengaged, the calling plug is inserted and the ringing key operated. Ringing current is applied via relay AC in the position circuit (Fig. 5(b)) to the line over the tip conductor to ring return earth on the ring side. If continuity exists through the line circuit the ringing pilot glows. The call supervisory lamp glows until the called party answers. SC relay is operated via the sleeve of the called subscriber's line circuit K relay, and closes the call supervisory lamp circuit. Relay D operates when the called party answers and extinguishes the call supervisory lamp.

When both parties restore their receivers relays A and D release, and both supervisory lamps glow. The telephonist then presses the meter key to register a call on the calling subscriber's meter and takes down the connection. The meter pilot lamp glows if metering is effective. The position effective meter also operates from contacts of relay M.

On the first "A" position the answering cord battery feed relays are arranged to operate the night alarm at the conclusion of a call. On the first two cord circuits on position A1, however, the NA circuit is connected to the front contacts of the A relays, so that the answering cords of these circuits may be used to enable subscribers whose line circuits are out of order to call the exchange. Calls made in this way should be completed on another cord circuit.

"A" Position Circuit. Fig. 5(b) (CE. 366, Sheet 2)

The "A" position relay set is mounted at the rear of the appropriate switching position, and is adjacent to the cord circuits which it serves. The circuit operation is as follows:

Coupling: When the position coupling key KPC is operated relay C operates and transfers the tip, ring and engaged test leads of the telephonist's circuit to the next position.

Order Wire: When an order wire key is operated relay OW operates and disconnects the telephonist's circuit from the position and cord circuits.

Dialling (R.A.X. or main exchanges in unit fee areas): Provision is made to dial from the calling

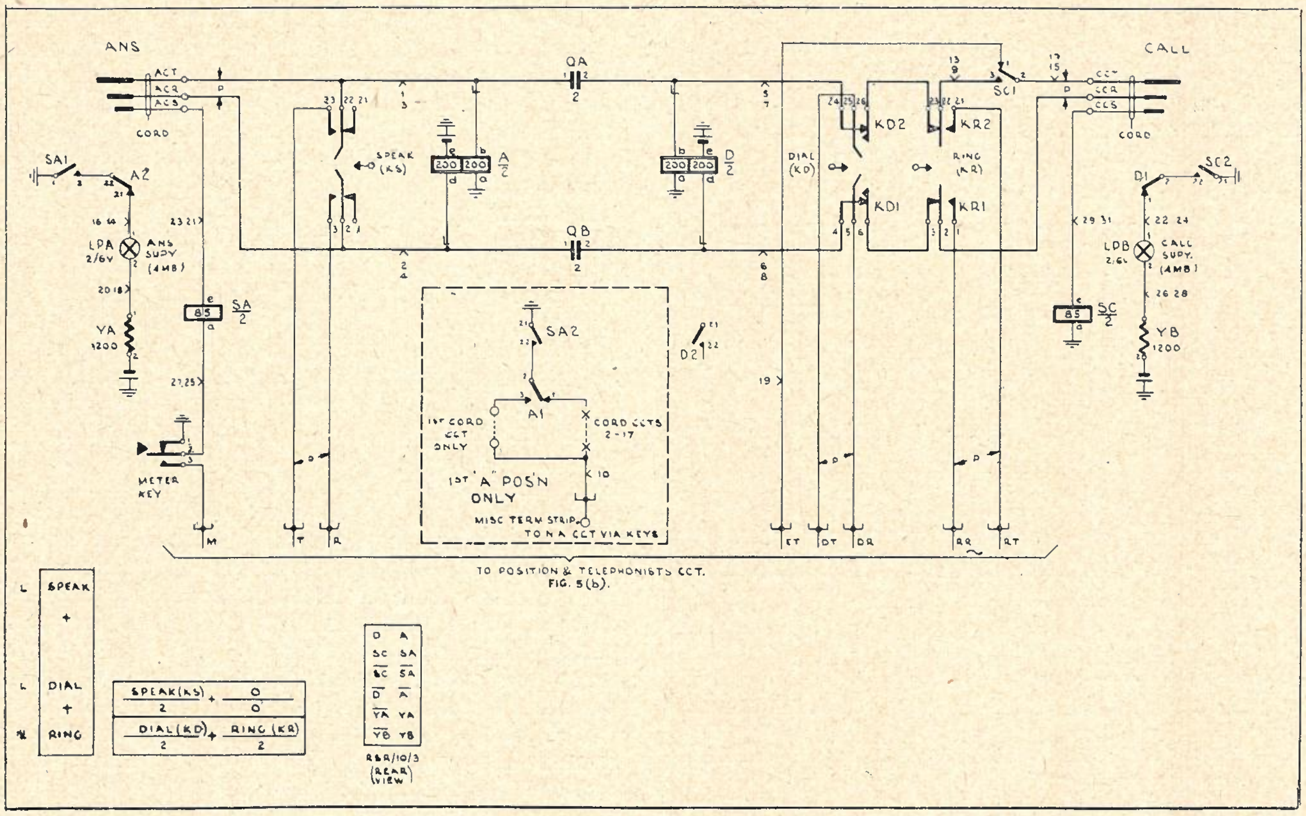


Fig. 5(a)—"A" Cord Circuit.

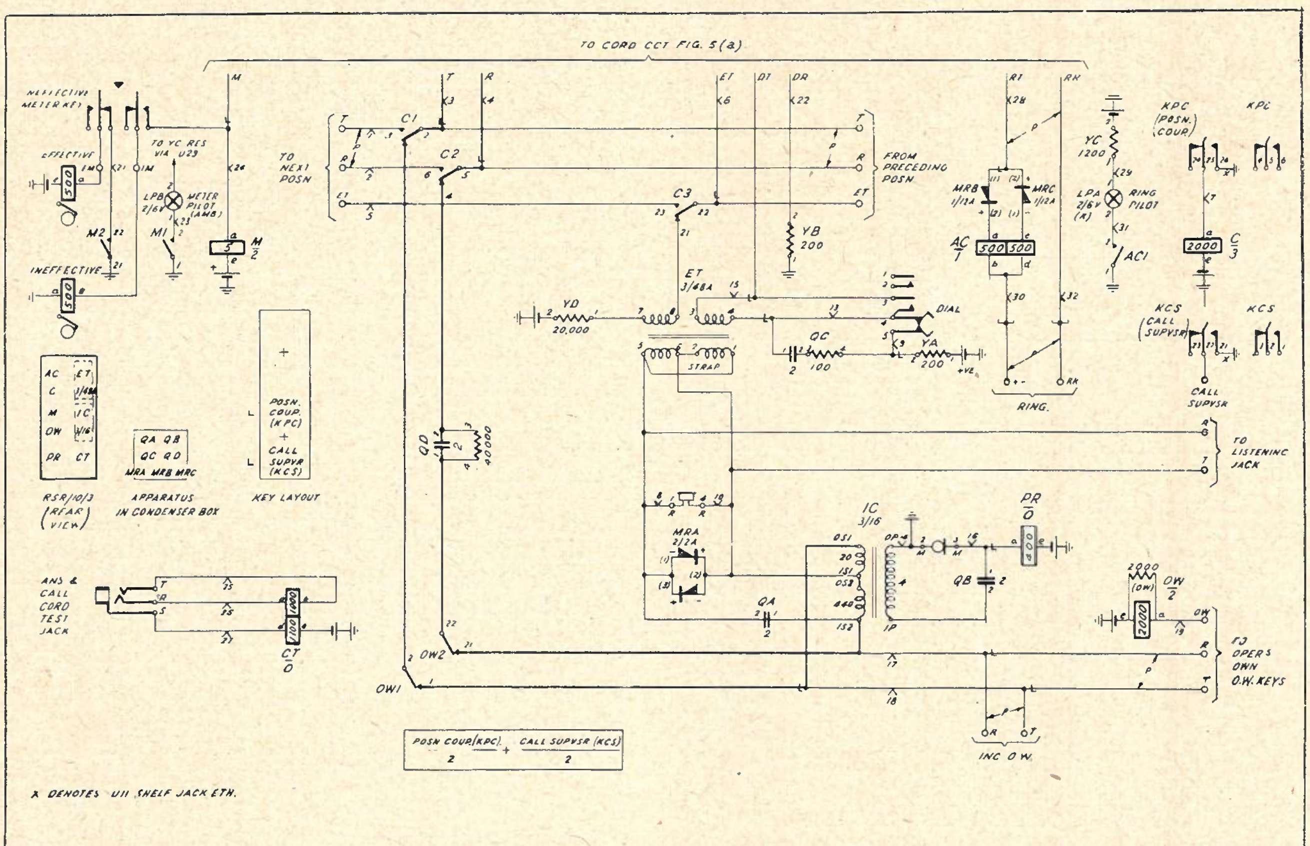


Fig. 5(b)—"A" Position Circuit.

cord via the dial key KD, with positive battery and earth instead of a loop. The shunt springs of the dial short circuit one coil of the transformer ET whilst impulsing. The progress of the call whilst dialling is supervised via this coil in the telephonist's circuit.

Metering: The meter pilot glows only if the subscriber's meter is in circuit when metering an effective call. Relay M in the position circuit should be adjusted to operate with 80 mAs., but not to operate with 70 mAs. The meter pilot also glows when an ineffective call is registered by means of the ineffective meter key. As metering is effected at the conclusion of the call, the momentary release of the K relay will not affect the conversation.

Telephonists' Circuit: The intensity of clicks in the telephonist's receiver when making engaged tests, or due to other extraneous disturbances, is reduced to a satisfactory level by the 2/2A metal rectifier across the receiver. The arrangement is such that the rectifier normally acts as a high resistance shunt, but when the PD across the receiver rises the rectifier permits the passage of current through its plates and by-passes the surge.

The possibility of direct current flowing through the receiver and breaking down the rectifiers has been guarded against by providing a 2 mF condenser in series with the receiver. Whilst reducing the loud clicks or speech to a tolerable level, the arrangement has little effect upon faint clicks or speech. The rectifier also reduces high levels of speech or noise from the telephonist's own transmitter.

To prevent demagnetisation of receivers, due to surges of current in a demagnetising direction (in the original telephonist's circuit surges of order of 250 mAs. were possible) the wiring to the instrument plug and jacks should be arranged to ensure that the receiver circuit is open when the transmitter circuit is intermittently disconnected during the insertion or removal of the instrument plug, or due to faulty instrument plugs or jacks. The design of the present standard concentric plug provides for this facility. The receiver circuit should be connected to terminals 1 and 4.

The 40,000 ohm "wetting" resistance across the condenser QD is to overcome fading troubles due to "dry" contacts.

It will be seen that no direct current flows through the primary winding of the induction coil. This arrangement eliminates the possibility of core saturation, and effects a small improvement in sending and receiving efficiency in addition to reducing the intensity of surges in the operator's receiver whenever the primary circuit is interrupted.

Cord Test: Each cord is inserted in turn in the cord test jack. When partially inserted the supervisory lamp should glow, and when fully inserted the lamp should extinguish. The cord is then shaken to test for frayed or broken conductors.

Miscellaneous: The metering and ringing is controlled by manually operated keys (in preference to automatic methods) to permit code ringing on party lines and supervision of reversal on junction circuits. Engaged testing on the subscribers' multiple may be carried out with all keys closed, as on the associated terminating trunk positions.

The change-over key in the metering circuit, in conjunction with the marginal operation of the M relay, is to ensure that the position meter and pilot lamp operate only if the subscriber's meter circuit is complete.

Recording Junction Circuit. Fig. 6 (CE.366, Sheet 3.)

These circuits are jack ended at both "A" positions and terminating trunk positions, and are used to connect calls originating on the "A" positions from subscribers requesting trunk line service, to the trunk positions. The relay sets are mounted on the relay set rack in the equipment room.

Circuit Operation: The "A" telephonist plugs into the recording junction with the calling cord, operating relay A over the sleeve connection. A4

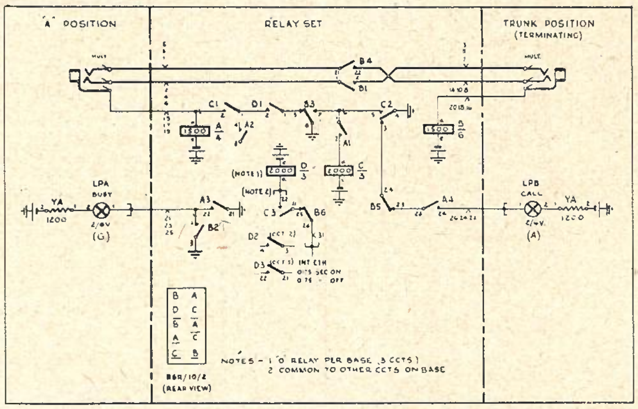


Fig. 6.—Recording Junction Circuit.

lights the calling lamps on the trunk positions. A3 lights the busy lamps on the "A" position multiple appearances. A1 and A2 prepare the circuit for the disconnect signal.

The trunk telephonist answers with the subscriber's cord (front), operating relay B over the sleeve circuit. B4 and B5 connect the tip and ring of the junction through. B1 operates relay C. B2 connects a multiple earth, to keep the busy lamps alight if the "A" position cord is removed before the trunk cord. B3 opens the call lamp. Relay C operates and locks to earth at C1. Relay D in the "A" cord circuit operates in series with relay A in the trunk cord circuit and opens the circuit of the call supervisory lamp on the "A" position.

The trunk telephonist then ascertains the calling subscriber's number and establishes connection directly by transferring the plug from the incoming recording junction jack to the calling party's multiple appearance. When the plug is removed from the recording junction jack, relay B releases. B4 and B5 open and release relay D in the "A" position cord circuit, causing the calling supervisory lamp to glow. B6 closes interrupted earth to the sleeve circuit of the "A" position cord, causing the supervisory lamp in the "A" cord circuit to flash intermittently by short circuiting relay SC. The busy lamps remain glowing until both ends of the circuit are free.

Party Line Circuits

Two Party Line Circuit: Fig. 7 (CE.366, Sheet 5)

Two subscribers' line circuits are used in the exchange jumpered together at the line side of the M.D.F. The jumpers are reversed to provide and LA1 provides an earth on the opposite leg, so that when the caller allows the call button to restore and remove the earth, the line is held by the telephone loop. LA2 lights the call lamp and also operates relay PNA for control of the night alarm circuit.

The telephonist plugs in and operates relay KA from earth on the sleeve of the answering cord. KA1 and KA5 disconnect the line relays LA and LB and earth from the line. KA3 prepares the meter circuit, KA2 earths the sleeves of the multiple appearances of the second party's line to provide the engaged test.

At the completion of the call the telephonist registers a call on the subscriber's meter by operating the meter key in the cord circuit before taking down the connection. Positive battery over the sleeve conductor via KB2, KA3 and MRA operates the meter of the calling party. Relay

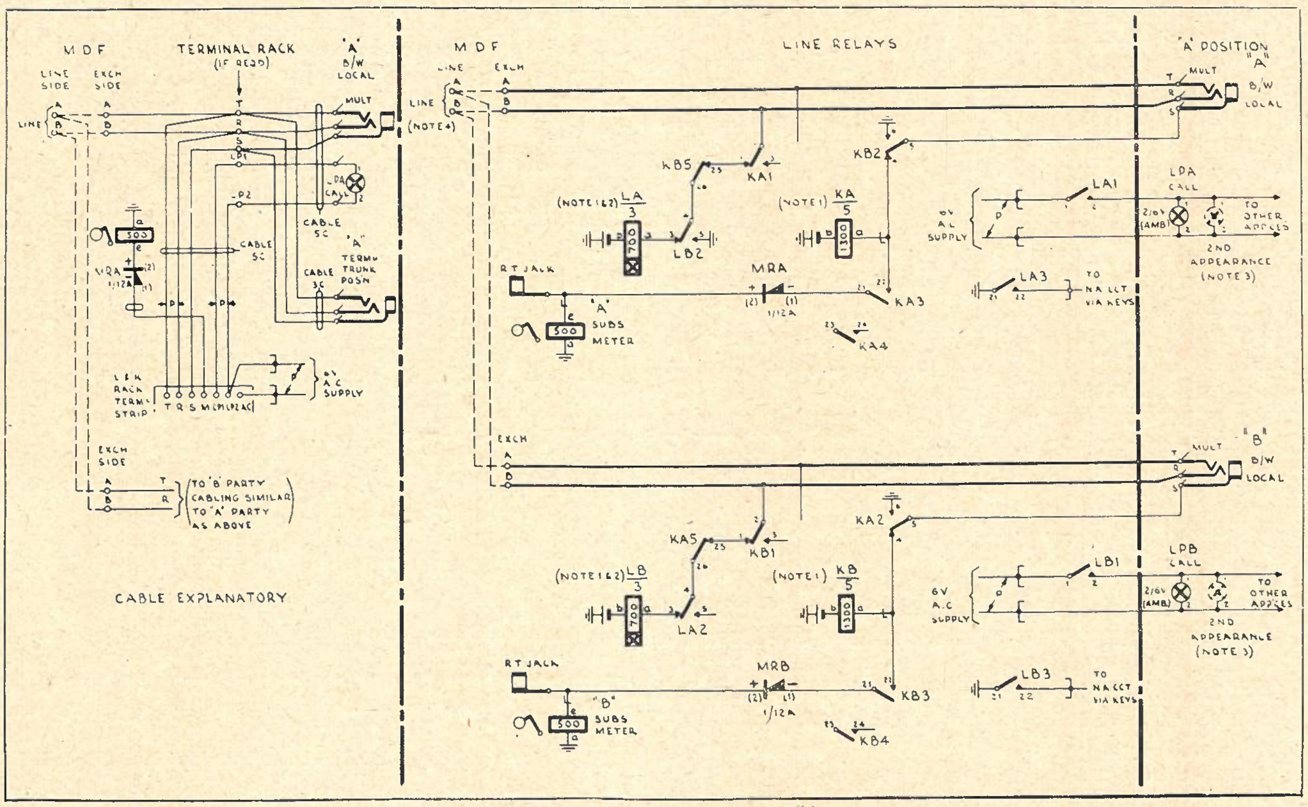


Fig. 7.—Two Party Line Circuit with C.B. Signalling.

1. L and K relays are 600 type plate mounted for ultimate uniselector working.
2. L relay to have 14 M springs.
3. Only one appearance to be equipped with lamp.
4. Subscriber's telephone in accordance with drawing CE.—44, but fitted with exchange call button and hand generator in lieu of dial.
5. Fusing—1-5 amps per 20 circuits.

for reversal of ringing when calling from the exchange; one party being called over the positive leg to earth via the bell, and the second party over the negative leg.

To originate a call a subscriber removes the handset and presses the call button, which earths one leg of the line (either positive or negative, according to the party calling) via the bell coils. If the "A" party is calling, relay LA operates M also operates in the position circuit to light the meter pilot and operate the position "effective" meter.

Calls between parties are completed without assistance from the telephonist. Each party is equipped with a local battery telephone with hand generator, the operation of which does not affect the "slow to operate" line relays in the exchange.

Multi-Party Line Circuit. Fig. 8 (CE.366, Sheet 6)

This circuit has been designed to operate with a slightly modified L and K relay set on a normal subscriber's exchange line circuit. The multiple jack is suitably marked to indicate a party line service. The parties are called by code ringing signals (metallic). Parties call each other by the same means. The exchange is called

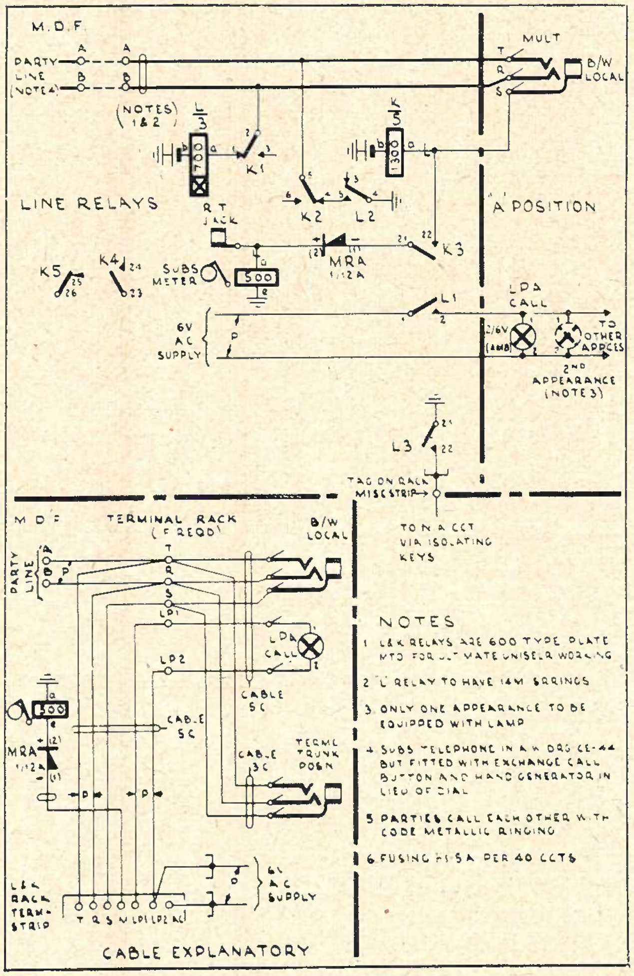


Fig. 8.—Multi-Party Line Circuit with C.B. Signalling.

by means of a press button at each telephone, which, when pressed, earths the negative line. The subscriber's meter in the exchange registers the total number of calls originating from all the parties. No means of automatically registering calls from each individual party is provided in the circuit, as these calls will be ticketed by the telephonist. The telephones are magneto type with local battery and generator, and as common battery signalling with the exchange is used, a condenser in the receiver circuit with a retard coil for holding is necessary in each telephone circuit.

To call the exchange the calling party removes the handset and momentarily presses the exchange call button, which earths the negative leg of the line, operating relay L in the exchange line circuit. L1 lights the call lamp and L2 provides an earth on the positive leg of the line to complete the loop via the telephone to hold relay L when the press button restores to normal. The telephonist answers the call by plugging in with the answering cord. Relay K operates from earth via the SA relay in the sleeve of the cord circuit, K1 and K2 disconnect the line relay and earth from the line. Relay L releases and opens the line lamp and NA circuits. The earth via the SA relay provides the engaged test potential for the multiple appearance of the party line.

To call a particular party the telephonist plugs in with the calling plug and sends code signals with the ringing key. When the called party answers, relay D operates in the cord circuit and extinguishes the supervisory lamp.

Multi-party Line Circuit; for Long Subscribers Lines. Fig. 9 (CE.366, Sheet 11) This circuit has been designed for operation on very long subscribers lines (exclusive or party lines). The equipment is interposed by means of jumpers between the magneto subscriber's line and the ordinary line circuit (Fig. 4) modified as shown in Fig 9. Subscribers connected to these circuits call the exchange with a continuous ringing signal for a period of not less than three seconds. Inter-party calls are made in the usual manner. The circuit may be used on generator signalling trunk lines as a temporary expedient. The circuit operation is described in the following.

Incoming Call: An incoming ringing signal intended to call the exchange will operate relay L, which will connect resistor YB (2000 ohms) to ground, thus depriving the normally operated relay LA of its holding current. Condenser QD which is charged to approximately 40 volts while the circuit is idle, will now discharge in series with relay LA, which will release in approximately 3 seconds. When LA releases it maintains the direct ground on YB, irrespective of the condition of relay L. Relay LA will also operate the subscriber's line relay (Fig. 4), which will give the usual lamp and night alarm signals to the operator. Ringing signals which conclude in less than 3 seconds, will permit condenser QD to recharge and will restore the holding circuit of LA in series with YB. The circuit is thus insensitive to code ringing signals between parties on the same line.

When the operator answers, relay K (Fig. 4) will complete a circuit for relay S. This relay operates and will,

(a) transfer the short circuit on YB to contact unit K2 in the subscriber's line circuit;

(b) remove the electrolytic condenser QD from LA relay in order to enable this relay to respond to the short clearing signal from the subscriber;

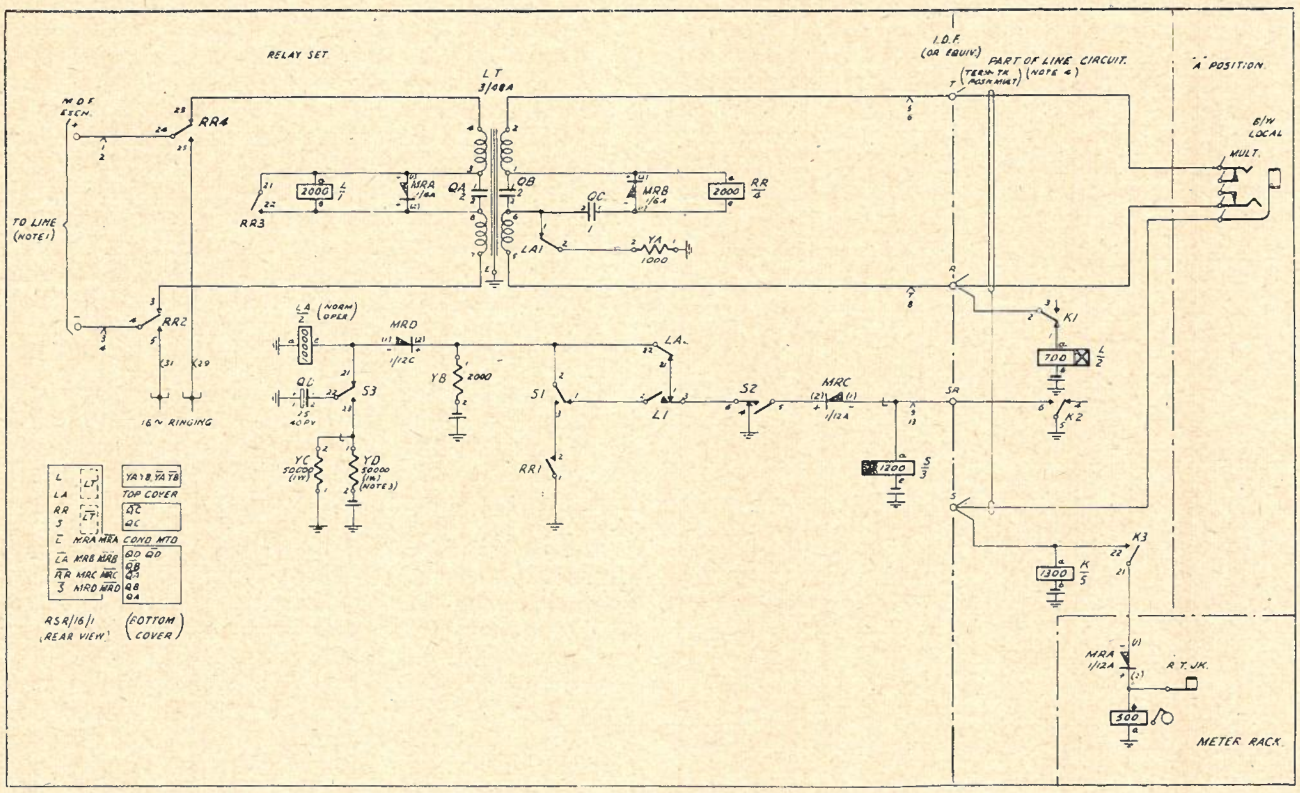


Fig. 9.—Multi-party Line Circuit for Long Subscribers Lines.

1. Subscriber's telephone to be magneto (M.T. or M.W.).
2. Only one appearance to be equipped with lamp.
3. Resistances YC and YD to be radio type (1 W.) suspended in wiring.
4. Remainder of subscribers line circuit similar to Fig. 4.

(c) charge condenser QD to approximately 25 volts, via resistors YC and YD during the progress of the call.

Relay LA remains un-operated during the conversation and, thereby, maintains a holding circuit for the battery feed relay in the cord circuit via resistor YA. This extinguishes the supervisory lamp while the conversation is in progress.

At the conclusion of the call the subscriber rings off and relay L operates. The earth is now removed from YB during the incoming ring, thus permitting LA to re-operate and re-light the cord circuit supervisory lamp by the releasing of the battery feed relay operated via YA, and disconnect the short circuiting earth from YB so that it (LA) remains operated. When the telephonist withdraws the plug from the jack relay K releases, followed by the slow release of S. Relay LA remains operated until the next call is made.

Outgoing Call: The telephonist inserts the calling plug into the subscriber's jack and relays K and S operate. Relay S will,

(a) prepare the short circuit path, via S and RR, which is provided for the resetting of LA in the non-operated condition when the telephonist rings or recalls the subscriber;

(b) transfer the short circuiting earth to K contacts in the line circuit (no function at this stage);

(c) remove the condenser QD from LA relay to enable this relay to respond to the clearing signal at the conclusion of the call.

The cord circuit supervisory lamp remains alight as no circuit is provided for the battery feed relay to operate via YA.

When the operator rings the required subscriber's code, relay RR will repeat the ringing signal direct to line and will short circuit relay L to prevent its premature operation. Relay LA will be short circuited via S and RR contacts and will release quickly thus extinguishing the cord circuit supervisory lamp at the conclusion of the ringing signal. Relay LA remains short circuited by its own contacts LA2 for the duration of the call.

When the subscriber rings off (or recalls), relay L will operate and remove the short circuit from relay LA, which now re-operates. The cord circuit supervisory lamp glows due to the disconnection of the battery feed relay by LA contacts. Should the operator re-ring the subscriber at this stage relay LA will be released by the short circuit via S and RR contacts.

When the operator withdraws the plug from the jack the K relay in the line circuit, followed by relay S, will release, leaving LA operated. In the case where the cord circuit is disconnected while LA relay is unoperated (i.e., subscriber failing to ring off or an abandoned outgoing call), the delay in the release of relay S will permit relay LA to re-operate before the short circuit can be applied via S relay contacts.

Miscellaneous: The following are also relevant to the operation of the circuit:

(a) Condenser QD may be disconnected if this circuit is required for exclusive services.

(b) Rectifier MRC is provided to prevent chattering of relay S during the release of the circuit.

(c) Resistors YC and YD provide a charge of 25 volts on condenser QD to prevent the possibility of relay LA being released when relay S restores to normal.

(d) Rectifier MRD is specified as 1/12C as its "reverse" resistance is in parallel with LA during the slow release of this relay.

Both-way Junction to Automatic Exchange in Unit Fee Area. Fig. 10 (CE.366, Sheet 9).

This circuit is designed to operate in conjunction with "A" and terminating trunk positions. The battery reversal on calls from automatic to manual for supervision and metering is controlled by the telephonist on the incoming position. The telephonist connects the subscribers and after the called party answers, operates the meter key to effect the reversal of battery to the automatic exchange.

Incoming Call: When the junction is seized at the automatic exchange relays L and LA operate. LA lights the call lamps on the "A" positions, lights the busy lamps on both "A" and terminating trunk positions, short circuits relay AA and closes the NA circuit.

When the telephonist answers relay S operates, removes ring tone from the line and opens the call lamp circuit. Relay A operates in series with the A relay in the cord circuit and extinguishes the supervisory lamp. Relay S completes the circuit of the meter lamp which glows. The telephonist completes the connection and when the called subscriber answers, presses the meter key in the cord circuit to extinguish the meter lamp. Relay M operates, and locks to earth at LA contacts, and opens the meter lamp circuit. Relay M also reverses battery to the line for supervision and metering at the automatic exchange.

When the automatic subscriber clears, relay L releases, followed by relay LA. LA removes the shunt from relay AA increasing the resistance in series with relay A in the cord circuit. Relay A in the cord circuit releases and lights the supervisory lamp. Relay SA keeps the busy lamps glowing until the plug is removed from the jack.

Outward Call (From either an "A" position or a terminating trunk position): The telephonist plugs in and relay S operates from earth on the sleeve of the cord. Relay S operates relay SA, and SA contacts disconnect relay L from the line, connect the line through and prepare the circuit for looping the switch at the automatic exchange.

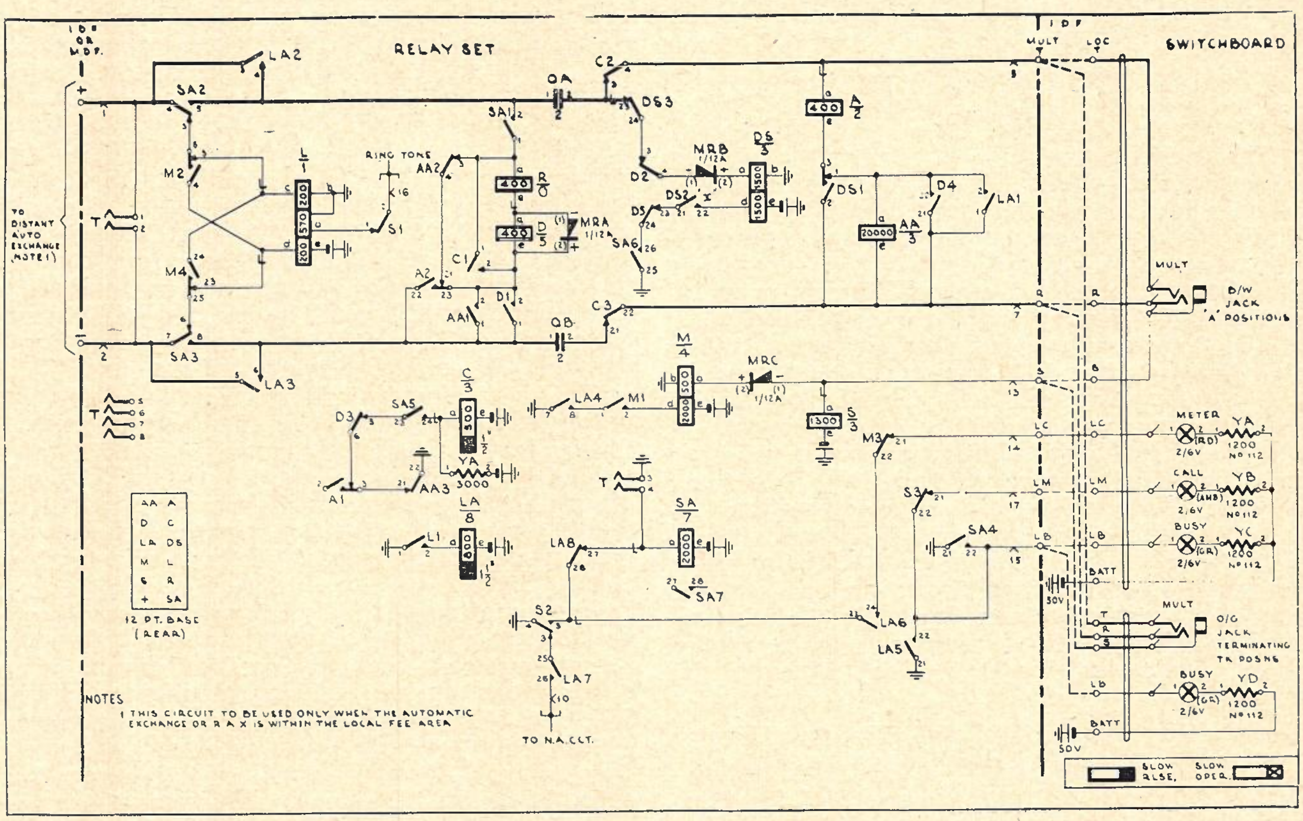


Fig. 10.—Both-way Junction to Automatic Exchange.

SA contacts also light the busy lamps on both the "A" and the terminating trunk positions. Relay AA operates in series with the A relay in the terminating trunk cord circuit or the D relay in the "A" cord circuit. The battery feed relay concerned does not operate and the supervisory lamp glows. Relay AA closes the loop across the line via relays R and D. Relay D is shunted by rectifier MRA and does not operate at this stage.

The telephonist now operates the dial key and connects positive battery from the position circuit to the tip side of the line to operate relay DS, which locks to earth at D contacts and removes its operating winding from the line. Relay DS disconnects relay AA from across the connection and connects relay A. Relay A operates and replaces AA contacts holding the loop across the outgoing line.

The telephonist's dial impulses relay A, which repeats the impulses to line at A2 contacts. Relay C operates and remains held, shunting both R and D whilst impulsing is taking place. Relay DS remains held until the called party answers. When the called party answers relay D operates and releases relay DS. DS reconnects AA shunted by D1 across the loop and causes the cord circuit supervisory lamp to be extinguished.

When the called party at the automatic exchange clears the reversal of battery on the line releases relay D, which removes the shunt from across AA, causing the supervisory relay in the cord circuit to release and light the supervisory lamp. SA contacts keep the busy lamps glowing until the plug is removed from the jack.

TRUNK POSITIONS

General

These circuits have been designed to operate in conjunction with the C.B. multiple switchboard circuits described in the foregoing. Two types of trunk line operating positions, namely, "terminating" and "through," are provided as previously explained. The subscribers' multiple is extended over the terminating trunk positions only.

The first terminating trunk position circuit is modified (see Fig. 13), to permit one "through" cord circuit relay set to be jacked in to enable this position to handle a small amount of "through" traffic in addition to the usual "terminating" traffic during slack periods. This saves staffing a "through" position unnecessarily.

The position coupling should be arranged so that as each coupling key is operated the position concerned is coupled to the previous position, i.e., coupling is extended towards the first trunk position. A through trunk position may be coupled to a terminating trunk position, but not vice versa.

Terminating Trunk Cord and Position Circuits. Figs. 11(a) and 11(b) (CE.360, Sheets 2 and 4).

The following features are provided by these circuits:—

(a) Facility to divide the cord circuit to enable the telephonist to speak on either side to the exclusion of the other (the cord circuit is divided if either "speak answer" or "speak call" key is operated).

(b) Cord circuit speaking keys arranged to prevent the operation of two keys on the same position being effective.

(c) Coupling key in each cord circuit to connect cord circuit through when required. Visual indication for de-coupled cord circuit.

(d) Engaged test in both trunk and subscribers' cords.

(e) High impedance monitoring circuit. Can be used to supervise whilst using a speak key to dial or ring on another circuit.

(f) Position ringing key for trunk cords and cord circuit ringing keys for subscribers' cords.

(g) Common dialling key for dialling on either cord.

(h) Transfer key, for transferring an incoming trunk call to a through position.

(j) Key sending on each cord if key senders provided.

(k) Position coupling to an adjacent position.

(l) Listening in tapping circuit.

(m) Order wire circuits.

Circuit Operation: The operation of either "speak trunk" or "speak sub." key will operate relay CK and divide the cord circuit.

The key KST (speak trunk) operates relay SKA, and the key KSS (speak sub.) operates relay SKC. Either of these relays will operate relay CK, which locks via its own contacts to earth at the Monitor/Coupling key KMC. Relay CK divides the cord circuit and terminates the trunk line with 600 ohms, and lights the couple lamp to indicate to the telephonist that the cord circuit is still divided if the speak key is restored to normal. The telephonist can connect the circuit through by momentarily operating the couple key KMC. The operation of KMC releases relay CK, which connects the cord circuit through and opens the couple lamp circuit.

The tip conductors of the subscriber cords are connected normally to the engaged test transformer in the telephonist position circuit.

The operation of the "speak trunk" key will divert the tip, ring, and sleeve circuits of the trunk cord to the position circuit for engaged test, speaking, dialling, ringing or transferring, etc.

The operation of the "speak sub." key will connect the telephonist's circuit in parallel with the subscriber cord, the battery feed circuit being disconnected during dialling or ringing. Relay SKA (or SKC) operates in series with a common 400 ohm resistor in the position circuit, and short circuits its 1,500 ohm winding and lowers the potential on the SK common, thus preventing the operation of a second SKA (or SKC) relay. Relay SKA also switches the supervisory lamp from the trunk cord sleeve circuit to the contacts of FA relay in the position circuit.

Dialling normally takes place on trunk cord circuits, but if it is necessary to dial on a subscriber cord (call to auto exchange within the unit fee area), the operation of SKC in the cord circuit causes DS in the position circuit to be energised, and the dialling circuit conditions are rearranged. Relay DC will operate during dialling (or sending) and the subscriber cord battery feed relay will be disconnected.

Should the telephonist restore the speak key before dialling or sending is completed, the operated SKA (or SKC) relay will remain locked up via the DB common and prevent mutilation of the call. This facility enables an operator to monitor another call while waiting for sending on the first call to be completed.

When a call between a VF trunk line and a subscriber within the local fee area is made, switchhook supervision to the distant trunk operator is provided by the subscriber cord battery feed relay A applying 1000 ohm negative battery to the ring side of the trunk line circuit via the cord circuit retard B. The A relay also disconnects a 600 ohm termination across the trunk line when the subscriber removes the receiver.

The time check circuit operation will be described under the appropriate heading.

Relay SC is provided with an auxiliary relay SCA to ensure that it (SC) will operate on a small current when the terminating trunk operator overplugs a subscriber's line when taking over a call for trunk connection. In this case the SC relay in the trunk cord circuit is in parallel with an "A" cord circuit sleeve relay.

When the trunk line is coupled to the position circuit, via relay SKA, supervisory signals are relayed to the cord circuit supervisory lamp by the operation of FA. Relay TA connects the tip conductor through to the telephonist's circuit. Relay TA should not release if another telephonist plugs into the same trunk line circuit with the speak key unoperated.

The dialling circuit is brought into use by the telephonist operating the position dial key (KD) in conjunction with a cord circuit speak key. If senders are not provided the dial switching key (KDS) is also operated (if not strapped out) and the telephonist proceeds to dial. Relays DA and DB will be operated by KD and will place retard R across the TA and RA commons in place of the telephonist's circuit, which is coupled for supervisory purposes, by two 2mF condensers QC and QD, to the dialling circuit. Positive battery is connected to the centre tap of the line, and the dial control relay in the trunk line circuit operates and extends the dialling loop to the trunk line in case of a trunk to an automatic exchange, or to

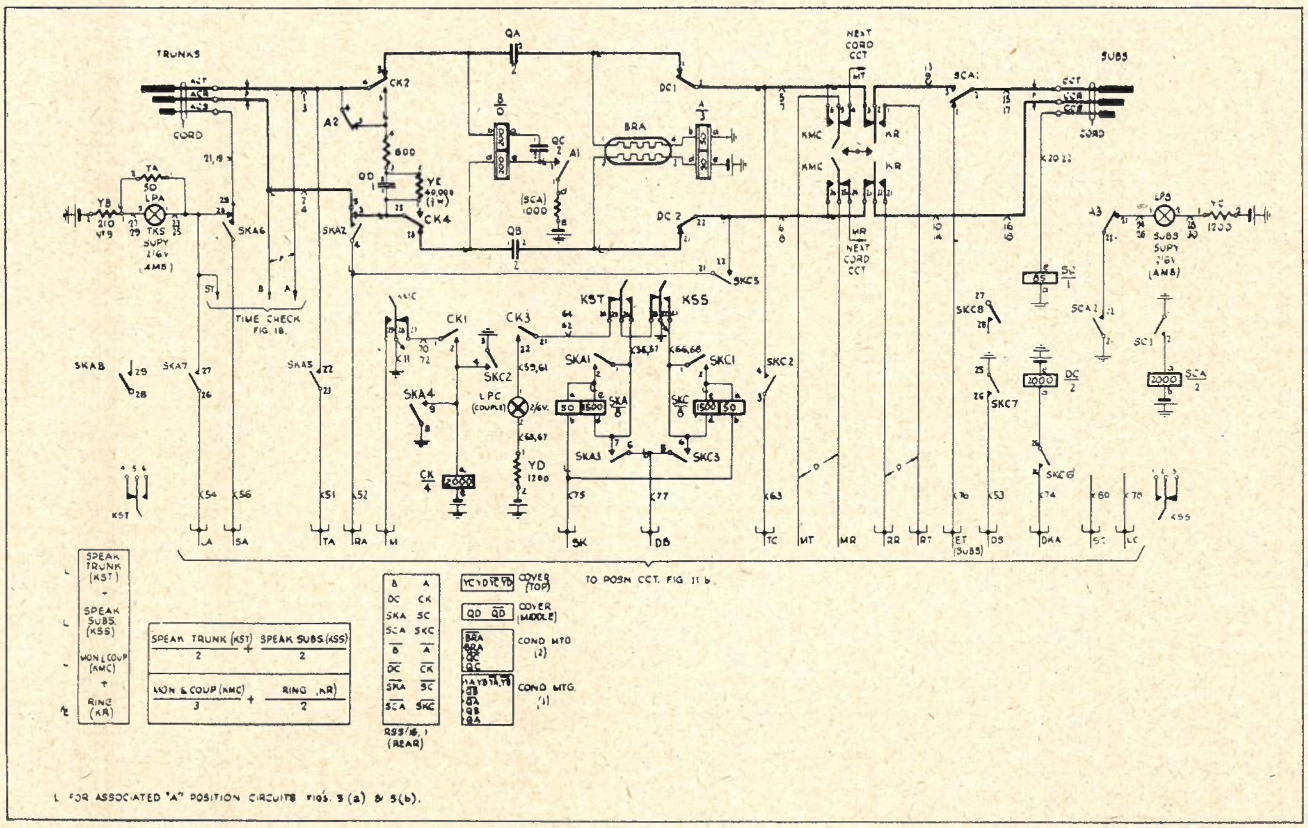


Fig. 11 (a).—Terminating Trunk Cord Circuit.

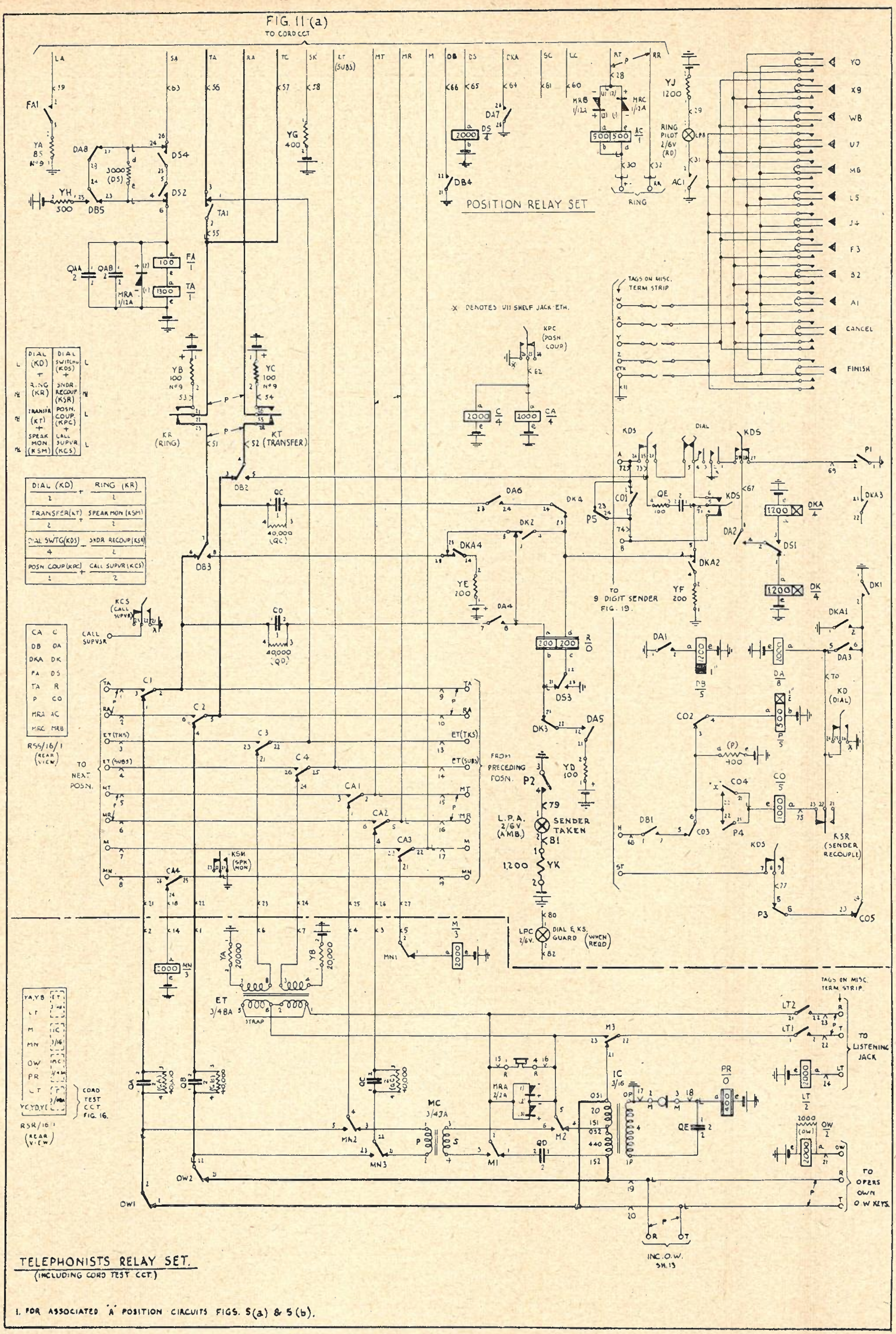


Fig. 11 (b)—Terminating Trunk Position Circuit.

the impulsing relay AA in case of a 2VF trunk line circuit. In addition, a high resistance (3000 ohms) is inserted in the sleeve circuit. When the dial moves off normal, relay DK is operated and removes the +ve battery and disconnects retard R from the dialling circuit. The telephonist's circuit is also disconnected during dialling, but is reconnected during the interdigital pauses to enable supervisory tones to be heard.

At the conclusion of the last impulse train KD is restored and relays DK, DA and DB release if the dial has returned to normal. During the release period of DB, a boosting current is applied via YJ (500 ohms) to the sleeve of the trunk line circuit, and the impulsing circuit therein is reset to normal. The release lag of DB should be at least 100 m.s. to provide an adequate time for the trunk line dial reset relay to operate and restore the holding circuit before disconnection of the dialling loop in the position circuit.

If keysending is employed the operation of the dial key KD will earth the start lead to the senders, and will operate DA and DB as above. Positive battery is connected to R/O, but when the keysender finds the position circuit, relay P will operate and will operate DK in series with the "sender taken" lamp, which glows. P and DK relays are slow to operate to permit the positive pulse to operate the dialling control relay in the trunk line circuit. Relay P will unmask the sender impulsing circuit and the operator proceeds to write up the number. The "finish" key is operated and sending commences. At the conclusion of sending relay CO operates and P releases, followed by DK, DA and DB.

If sending is required on the subscriber cord, relay SKC will operate DS, which rearranges the impulsing circuit for battery dialling. The dial control relay in the auto junction circuit is operated by a positive battery pulse fed on the tip conductor, while earth via the dial contacts if fed on the ring conductor. Relay DKA operates in lieu of DK, but performs similar functions.

Should the telephonist make an error in the setting up of a number on the keysender, the operation of the "cancel" key will disconnect the sender immediately. Relay CO will operate and release P and DK (or DKA). To prepare the dialling circuit again the telephonist must momentarily operate the "sender recouple" key (KSR) which releases CO and allows another sender to be coupled to the position circuit.

The telephonist's circuit is similar to that on the "A" positions, but provides a high impedance monitoring circuit and uses a separate relay LT for the listening taps to the observation panel. Two types of "engaged" test circuit conditions are catered for by two separate windings on the ET transformer. The remarks relating to the transmitter and receiver circuits on the "A" positions, also apply to both types of trunk operating positions.

To overcome the possibility of telephonists receiving slight electrical shocks when withdrawing

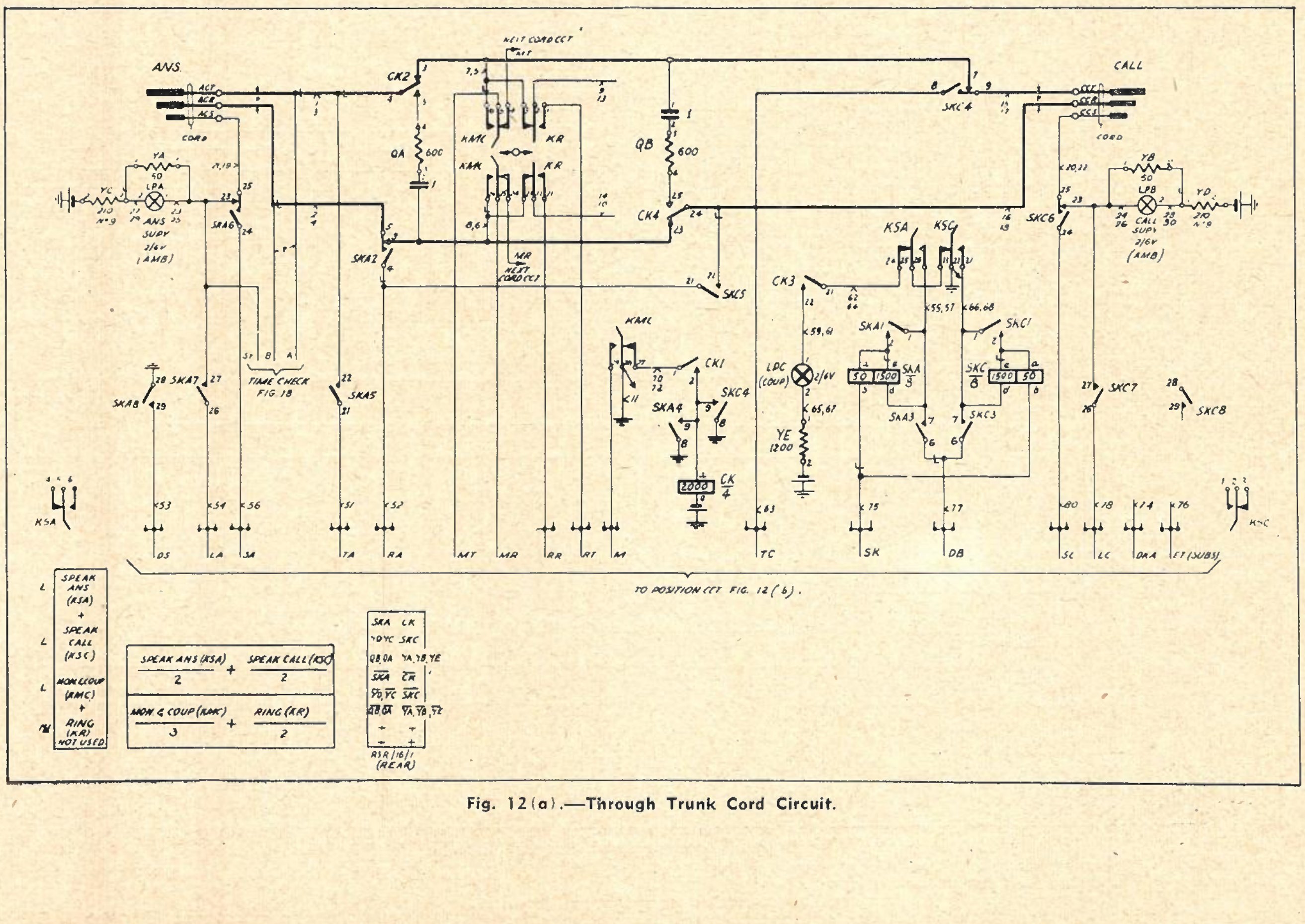


Fig. 12 (a).—Through Trunk Cord Circuit.

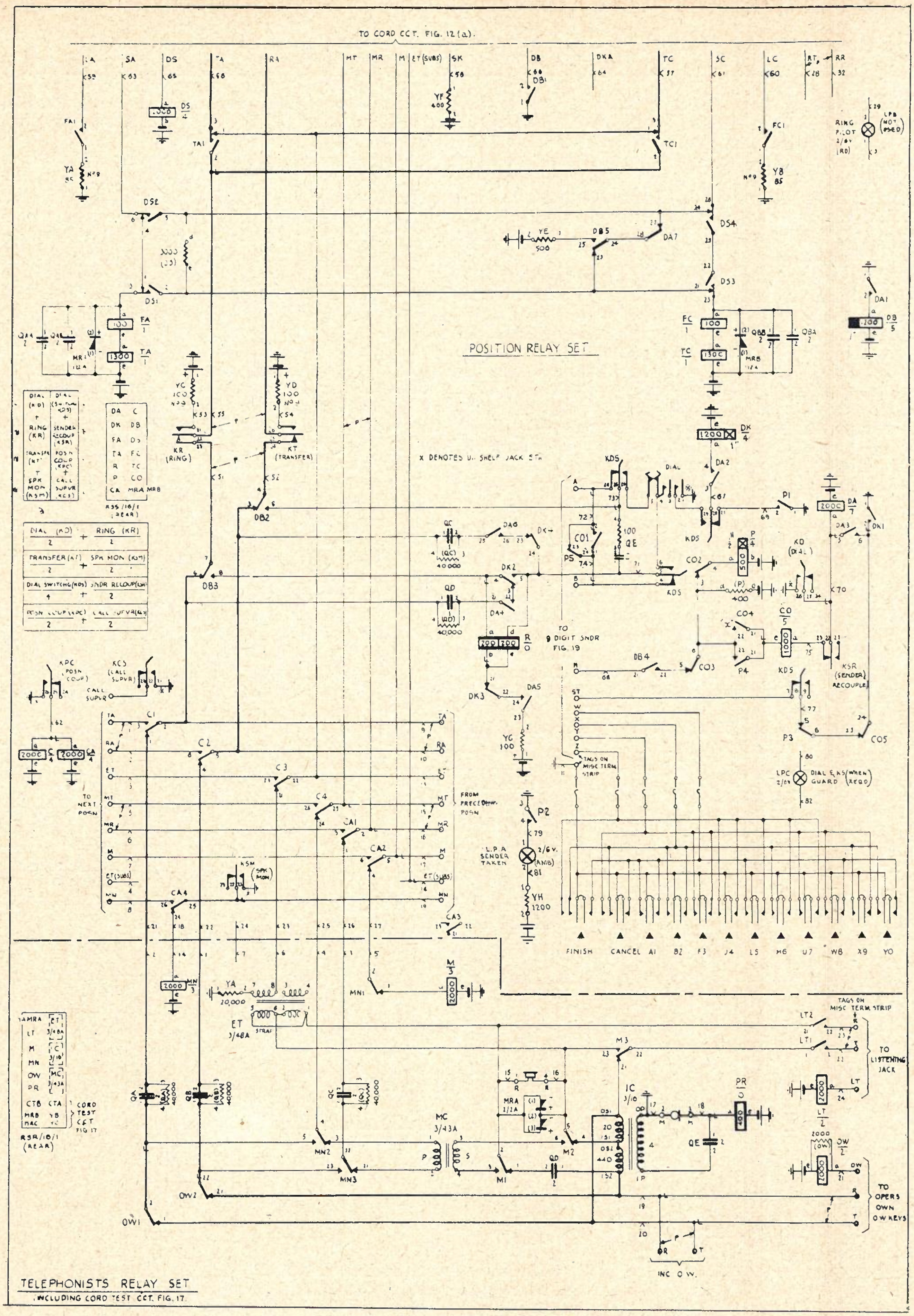
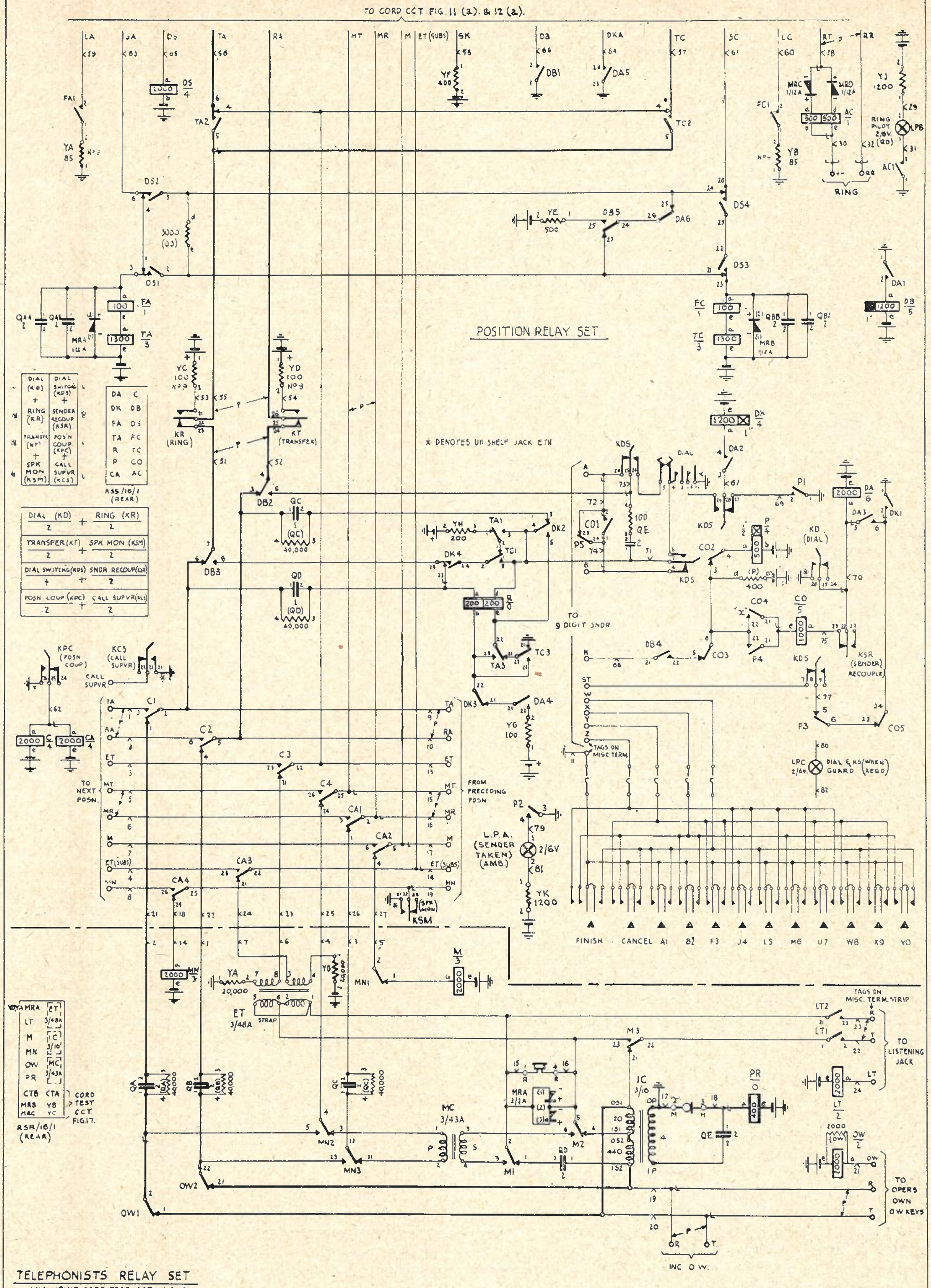


Fig. 12(b).—Through Trunk Position Circuit.

1. For associated "A" position circuits see Figs. 5(a) and 5(b).
2. Circuit Lab. Report No. 90 refers.
3. Coupling to be to Terminating Trunk position from this position.
4. Position wired for conversion to terminating position, for conversion substitute relay sets in accordance with Fig. 11(b).



1 FOR ASSOCIATED "A" POSITION CIRCUITS SEE DRG. CE-366

2 COUPLING TO BE ARRANGED FROM TERMINATING TRUNK POSITIONS TOWARDS THIS POSITION (TK. 1).

Fig. 13.—Composite Terminating and Through Trunk Position.

trunk plugs while the speak trunk key KST is operated, condensers QAA, QAB and rectifier MRA have been provided to suppress the surge from relays TA and FA.

Through Trunk Cord and Position Circuits

Figs. 12(a) and 12(b) (CE.360, Sheets 1 and 3)

The facilities provided by this type of cord and position circuit are similar to those provided on the terminating trunk positions, with the following exceptions:—

(a) The cords are designated "answer" and "call" in lieu of "trunk" and "subs."
(b) The transfer key in the position circuit has no function.
(c) The cord circuit ringing keys have no function.
(d) The tip, ring and sleeve conductors of either answering or calling cords may be extended into the position circuit by the operation of the appropriate speak key.

Circuit Operation: These circuits operate in a similar manner to the terminating cord and position circuits. However, the following differences should be noted:—

(a) The cord circuit provides a clear speech pair, free of any transmission bridge, between two trunk line circuits for pad control purposes in addition to minimising the switching losses.
(b) Both sides of the cord circuit are terminated with a compromise network of 600 ohms, while the circuit is divided.
(c) The dialling (or sending) circuit arrangements are identical for either cord.
(d) No "subscribers" engaged test is required.
(e) Relays TC and FC perform identical functions on the calling side to TA and FA on the answering side.

Composite Trunk Position

Fig. 13 (CE.360, Sheet 14)

Where dialling from terminating trunk positions to automatic exchanges or R.A.X. networks is required, a special composite trunk position circuit is installed on the first terminating trunk position, to enable both through and terminating cords to be used on this position. If no local fee dialling is required, the standard through position circuit may be used, with the addition of a ringing pilot relay and the subscriber's engaged test circuit wiring via the spare contact unit of CA (See Fig. 12(b)). The first terminating trunk position circuit will be wired in accordance with Fig. 13, which provides all of the facilities incorporated on both terminating and through trunk position circuits. The cord test circuit will be in accordance with Fig. 17, to enable the through cords to be tested. The terminating cords may be tested on the adjacent position.

Relays TA and TC are used to effect discrimination between a junction and a trunk line when dialling is required.

Net Cord Circuit

Fig. 14 (CE.360, Sheet 11)

Four net cord circuits are provided on each through trunk position for use on connections between 4-wire trunk line circuits, namely, carrier channels or trunk lines fitted with terminal VF amplifiers.

Four-wire switching and attenuation pad control is performed in accordance with Fig. 15 (CE. 459) and is carried out automatically when the net cord is inserted.

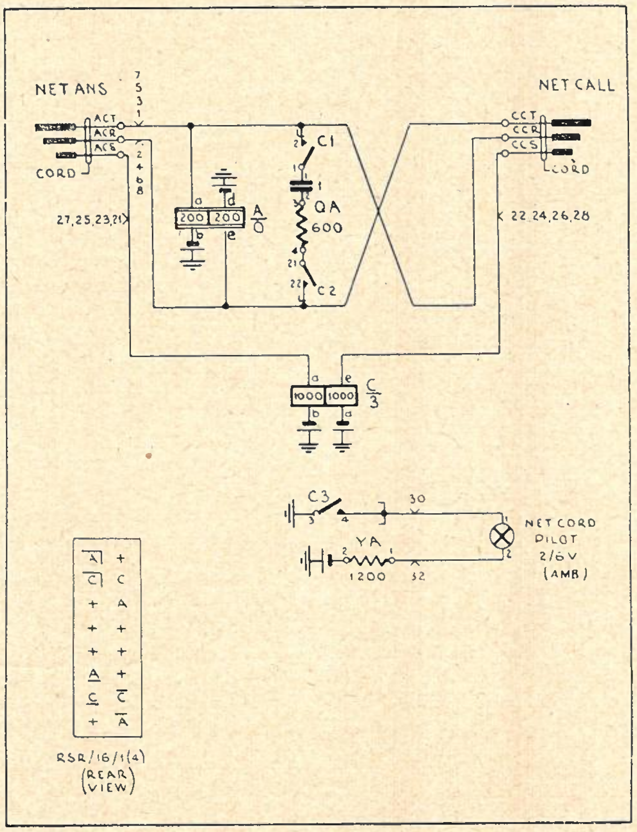


Fig. 14.—Net Cord Circuit.

Circuit Operation: Relay C operates when the net answering cord is inserted in the trunk line net jack, and lights the common net cord pilot lamp. The trunk line net circuit is terminated with 600 ohms until the connection is fully established. When the cord circuit is coupled the net call cord is inserted in the appropriate trunk line net jack and relay C is forced to release. The two trunk line net circuits are now connected together and reversed, the termination is removed and the so-called "tail chasing" 4-wire connection now exists.

The retard A feeds negative battery to the trunk line circuits for the operation of the pad control relays under certain conditions. The connection reverts to 2-wire transmission should the operator re-enter by the operation of a speak key. The speech path remains divided only while the telephonist has the key operated. At the conclusion of the call the telephonist takes down the net cords, together with the through cords. If only one net plug is removed the net cord pilot lamp will glow.

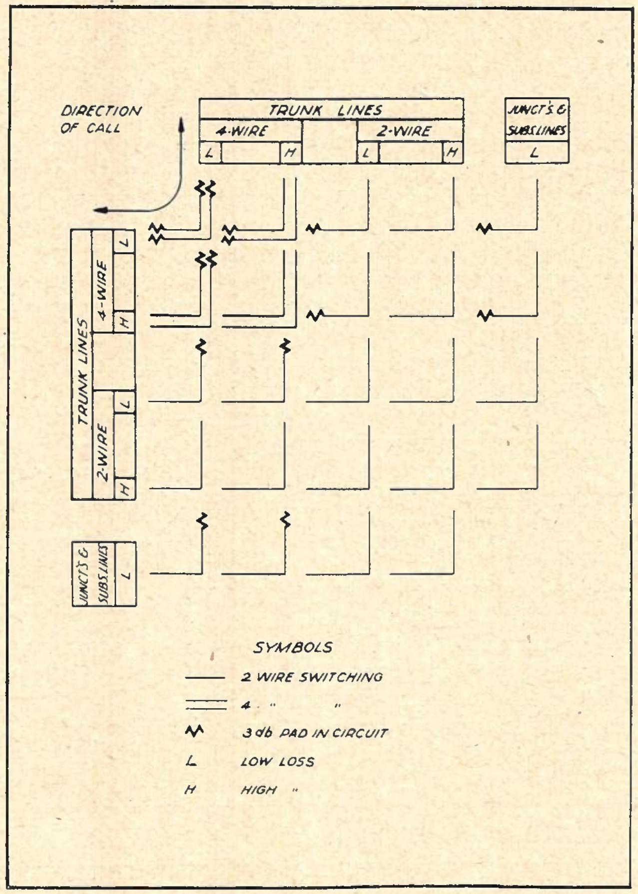


Fig. 15.—Attenuation and Pad Control Arrangements.

Cord Test Circuit—Terminating Positions Fig. 16 (CE.360, Sheet 8)

Circuit Operation: The trunk plug is inserted into jack "A", and the trunk supervisory lamp in the cord circuit glows. The subscriber plug is then inserted into jack "B," and when partially inserted the subscriber supervisory lamp should glow, but both lamps will be dimmed when the plug is fully inserted, by the removal of the short circuit across the 5,000 ohms (YE) by the operation of relay CT. CT operates from battery via 1000 ohms and retard B (in the cord circuit) over the R conductor of the cord when the battery feed relay A is looped by the windings of transformer T.

The position ringing key is now operated with the speak trunk key (KST) thrown, and battery over the tip side of the cord will operate CT in

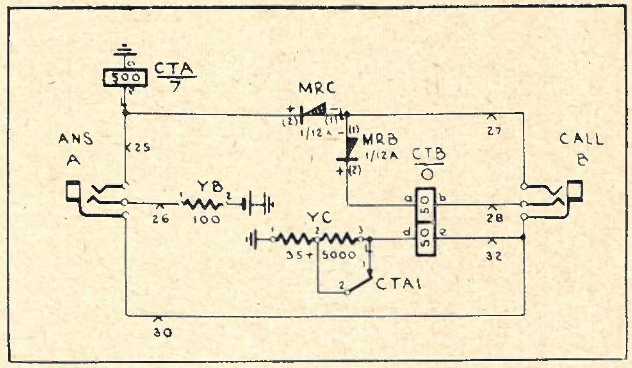


Fig. 16.—Cord Test Circuit—Through Trunk Position.

the cord test circuit and cause the trunk supervisory lamp to be dimmed whilst the key is operated.

Both cords are then shaken with the monitoring key operated to test for breaking conductors.

Faults are indicated as shown in Table 1.

Cord Test Circuit—Through Positions Fig. 17 (CE.360, Sheet 7.)

Circuit Operation: The answering plug is inserted into jack "A" completing a circuit for the supervisory lamp via the sleeve of the jack. The answering supervisory lamp glows. The calling plug is now inserted into jack "B." When the plug is partially inserted the calling supervisory lamp circuit is completed to earth via YC connected to the sleeves of jacks "A" and "B." When the plug is fully inserted both lamps are dimmed owing to the operation of relay CT via the T and

Fault	Supervisory Lamp
Sleeve open circuit trunk cord	Does not glow when plug is inserted.
Sleeve open circuit subs. cord	Does not glow when plug is partially inserted.
Tip open circuit trunk cord	Remains glowing when ringing test is applied
Tip open circuit subs. cord	Glows when subs. cord plugged up.
Ring open circuit trunk cord	Remains glowing when both plugs are up.
Ring open circuit subs. cord	Glows when subs. cord plugged up.
Tip and ring in contact trunk cord	Remains glowing when both plugs are up.
Tip and sleeve in contact trunk cord	Glows faintly when both plugs are up.
Tip and ring in contact subs. cord	Does not glow when subs. plug partially inserted.

Table 1.

R conductors of both cords. CT removes the short circuit from YC (5,000 ohms) increasing the resistance of both sleeve circuits.

The answering speak key KSA is thrown, opening relay CT, and both lamps glow owing to the shunting of YC (5,000 ohms). The ringing key is then operated with the speak key thrown, applying battery over the tip side of the cord circuit to operate relay CT. CT operates and removes the short circuit from YC (5,000 ohms) and both lamps are dimmed. This test is repeated with the speak call key KSC. Cords are then shaken with monitoring key KMC operated to test for conductors breaking.

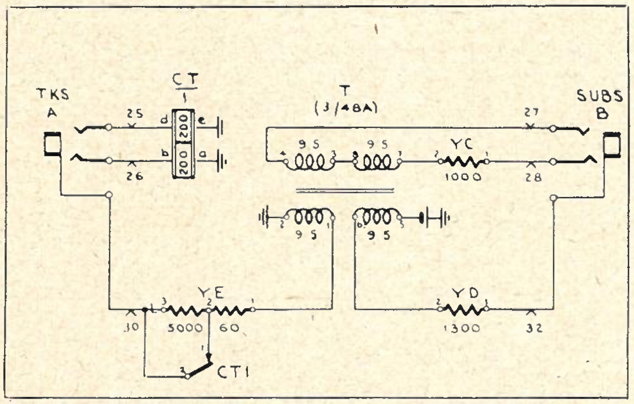


Fig. 17.—Cord Test Circuit—Terminating Trunk Position.

Faults are indicated as shown in Table 2.

This sequence of events is continued until one minute has elapsed and then the minute cam takes one step, and steps every subsequent minute. After two minutes and forty-eight seconds have elapsed cam springs 5 and 6 and 25, 26 and 27 are made, thus completing a circuit for PP and also the time check lamp. Relay PP is operated via PS, which is operated by battery from the tone and time pulse circuit. On the operation of PP the "pip-pip" tone is connected to the line to indicate to the subscriber that three minutes have expired. The same sequence of events continues if the subscriber does not hang up, and the tone is also put on the line at the 6 and 9 minute intervals. The time check lamp glows for 12 seconds and at the end of the first two 3-minute periods. After the 9th minute, relay SP is operated, and locks via its "x" contacts. SP will start the flicker circuit, which causes the time check lamp to flash, and will open the circuit of relay SY. SP also breaks its original operating circuit. The telephonist, on observing the lamp flashing, knows that the subscribers have conversed for 9 minutes, and after challenging the call, will reset the clock.

Release: When the telephonist observes that the conversation is finished, she restores the start key KST, which opens the start circuit to the tone and time pulse circuit. KST also opens the circuit of DM, removes earth from the circuit of the time check lamp and relay SP. The circuit of SY is also opened thus releasing all the apparatus.

Faults	Supervisory Lamp
Tip disconnected	Does not glow in ringing test.
Ring disconnected	Glows with both cords plugged up.
Sleeve disconnected	Does not glow when plug is partially inserted.
Tip and ring contact	Does not glow when plug is fully inserted (use speak key to divide cord circuit).
Tip and sleeve contact	Glows faintly with both plugs up (use speak key to check).
Ring and sleeve contact	Glows faintly with answer plug up.
Tip and ring reversed	Glows with both plugs up.
Tip and sleeve reversed	Does not glow when plug is partially inserted.

Table 2.

Time Check Circuit
Fig. 18 (CE.360, Sheet 6).

Circuit Operation: At the commencement of the conversation the start key KST is operated to start the tone and pulse circuits and prepare the circuits of DM, and relays SP and SY. After 6 seconds duration TP operates, and does so every 6 seconds. With each impulse of TP, relay SY also impulses, the circuit being from earth at TP1, routine test jack, SP4, start key KST, relay SY to battery in cord circuit via supervisory lamp. SY causes the 1/10 minute cam of DM to take one step.

In order to check the operation of these circuits the "routine test key" is operated and earth is applied to the flicker start lead and routine test lamp. Flicker earth is applied to relay FL, which will impulse. With the start key KST thrown, the conditions are the same as already described, and if a plug is inserted in the routine test jack impulses will be transmitted to SY via contacts of FL. In this manner the operations already described are carried out, except that the speed of impulsing is increased from 10 impulses per minute to 150 impulses per minute (flicker earth).

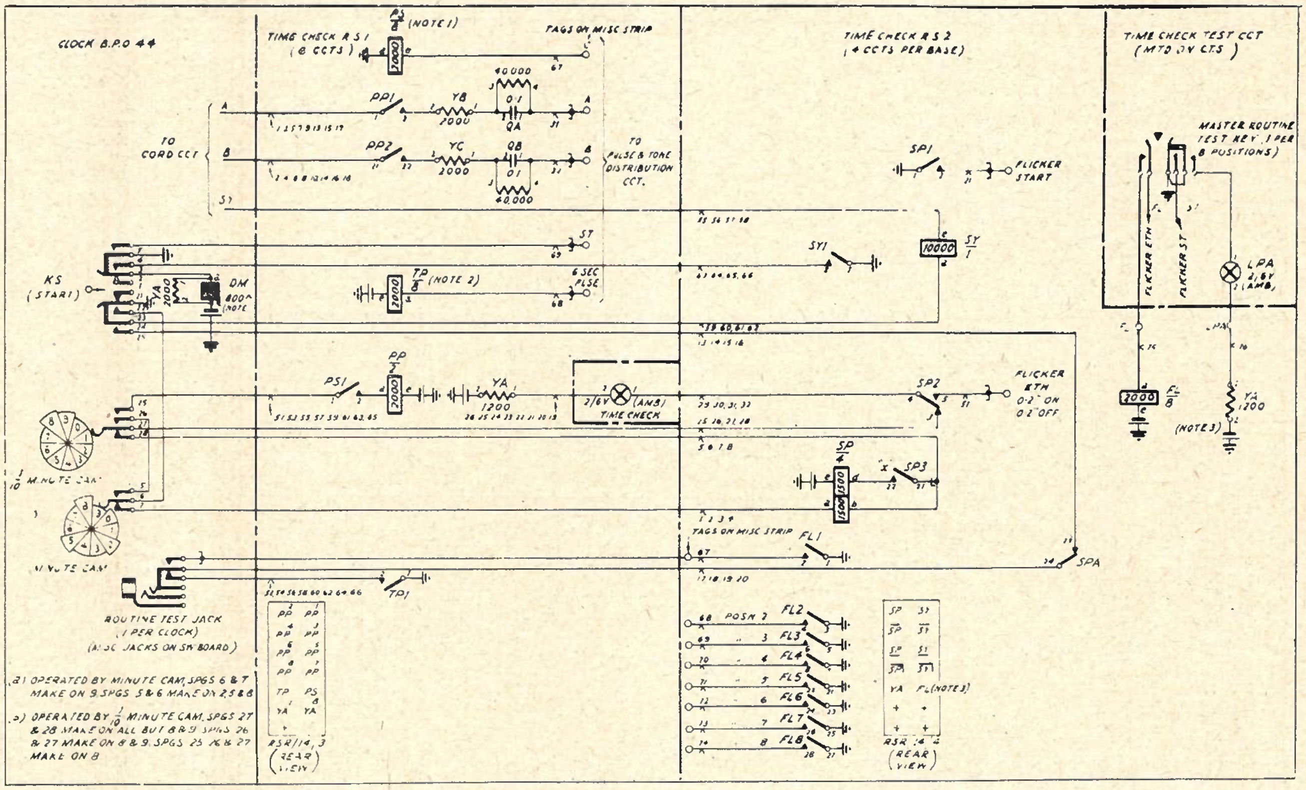


Fig. 18.—Time Check Circuit.

1. PS relay serves 8 clocks. Contacts 3-4, 5-6, 7-8, 21-22, 23-24, 25-26, 27-28 wired similar to 1-2.
2. TP relay serves 8 clocks. Contacts 3-4, 5-6, 7-8, 21-22, 23-24, 25-26, 27-28 wired similar to 1-2.
3. FL relay and YA resistance serve 8 positions and are only fitted on RS2 when specified.
4. Clock drive magnets pulsed from RS2. Also earth for clock keys wired from RS2.
5. Change-over on RT jack must break before making.

When the test has been carried out the start clock key KST is restored, thus releasing the circuit as previously described. By withdrawing the plug from the test jack the impulses to the time check circuit are disconnected and on restoration of the routine test key the circuit for FL is broken, the flicker start lead disconnected and the lamp extinguished.

Sender Circuit

Fig. 19 (CE.590, Sheet 1)

General: The position equipment consists of a strip of 12 keys designated A1, B2, F3, J4, L5, M6, U7, W8, X9, Y0, "Finish" and "Cancel," together with a "sender taken" supervisory lamp which indicates to the telephonist the engagement of a sender. The circuit arrangement is such that the sender impulsing loop merely replaces the dial, and the telephonist must not manipulate other position keys until the sender has disengaged itself. During impulsing a continuous lamp signal is given to the telephonist for supervisory purposes.

The relay sets are mounted on the relay set rack, each sender consisting of two relay sets. A condenser bank is associated with each sender and is used for the storing of digits written up by the telephonist.

Relay Functions:

Relay Set No. 1

B	Connecting and holding.
CN, CNA, CNB	Cancel.
DL	Delayed automatic start.
PA, PB	Impulse generation.
PC	Pulsing-out control.
PF	Sending finished.
SA, SB, SC	Start sending.
ST	Start finder.
SQ	Sequence control.
T	Drive stop and hold.
W, X, Y, Z	Digit code set-up.

Relay Set No. 2.

AS, BS, CS, DS, ES, FS, GS, HS, JS	Sequence relay group.
CA, CB, CC, CD, CE	Counting.
IP	Interdigital pause.
RW, RX, RY, RZ	Reading.
SP	Stop pulsing.

Circuit Operation: The functions of the sender can be divided into the following: (a) seizing, (b) storing, (c) sending start, (d) sending, (e) sending finished, (f) clear down.

The operation of the cancel key at any stage after (a) will release the sender immediately and

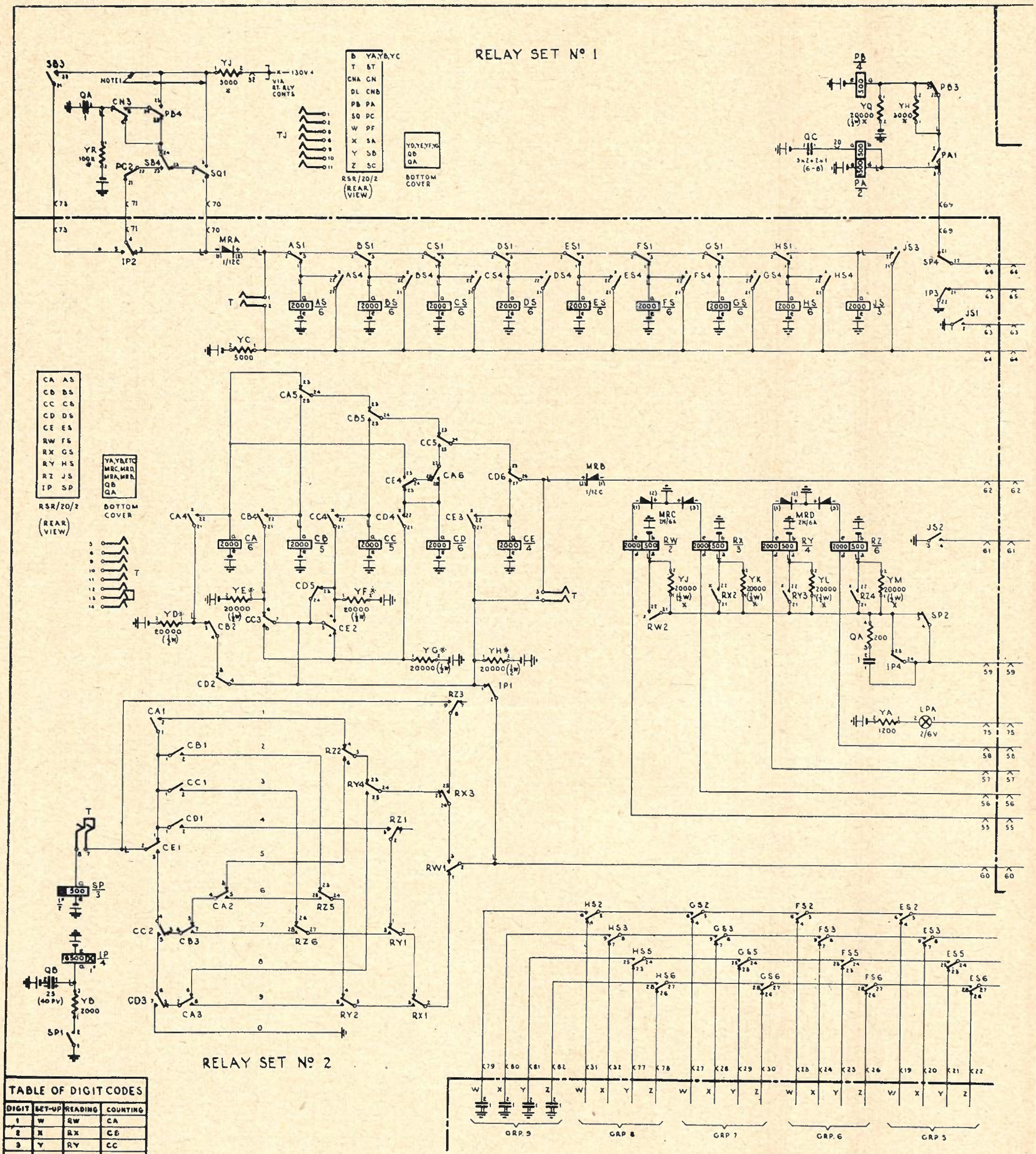


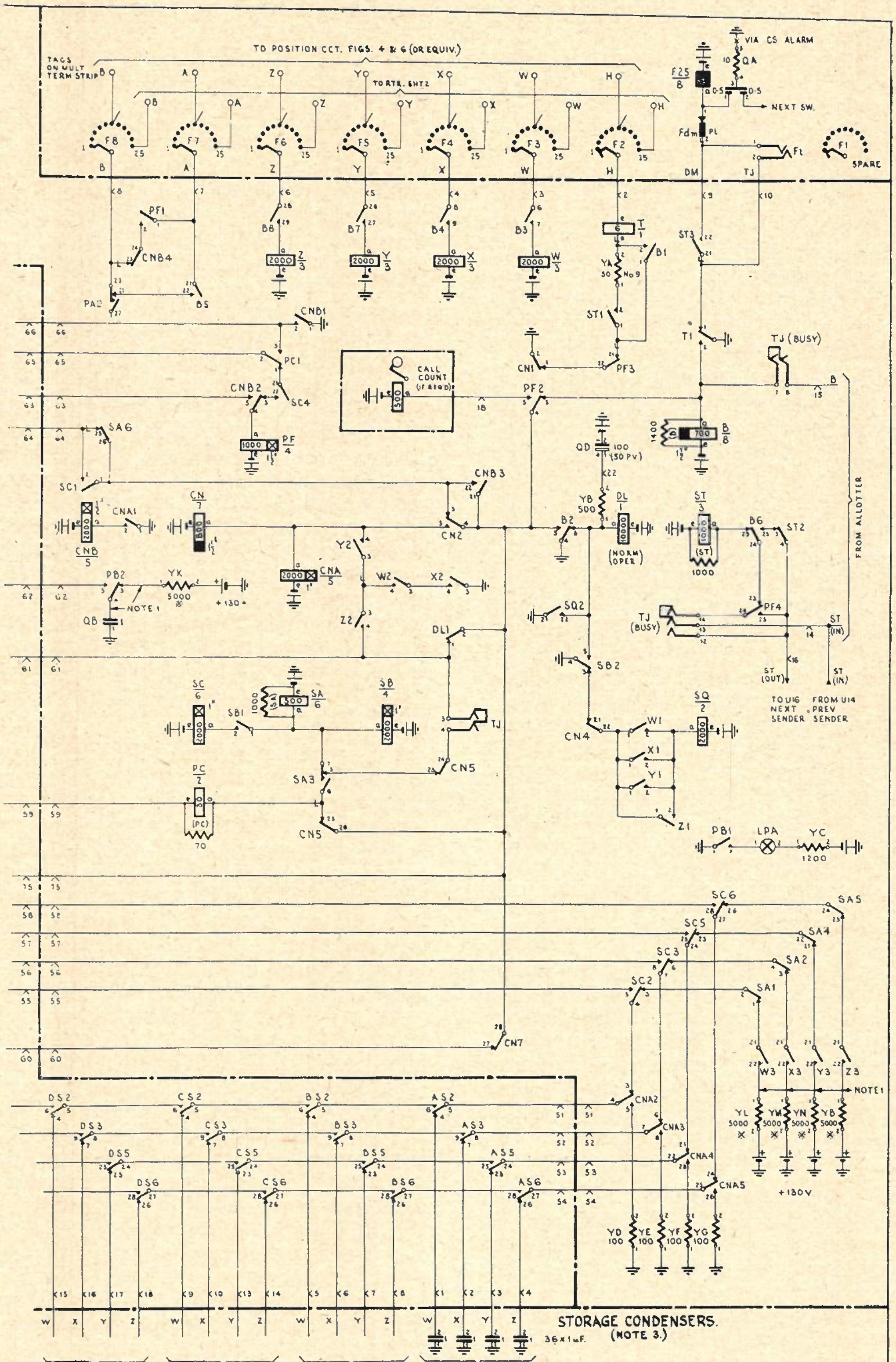
TABLE OF DIGIT CODES

DIGIT	SET-UP	READING	COUNTING
1	W	RW	CA
2	X	RX	CB
3	Y	RY	CC
4	Z	RZ	CD
5	WZ	RW, RZ	CE
6	XZ	RX, RZ	CE, CA
7	YZ	RY, RZ	CE, CB
8	WY	RW, RY	CE, CC
9	XY	RX, RY	CE, CC, CA
0	WX	RW, RX	CE, CC, CD
FINISH	WXZ		
CANCEL	WXY		

NOTES

1. WIRES CARRING +130V POTENTIAL TO BE COVERED WITH RED SPAGHETTI.
2. RESISTORS MARKED THUS * MAY BE RADIO TYPE, SUSPENDED IN WIRING OR MTD. ON CARD.
3. ALL STORAGE CONDENSERS (1μF) MUST WITHSTAND 500 V. DC. TEST AND MINIMUM I.R. TO BE 100 MΩ WITH WIRING AND SHELF TAG INCLUDED.
4. U14 AND U16 TO MAKE CONTACT WHEN RELAY SET IS REMOVED

Fig. 19.—Sender Circuit.



restore the relay sets to normal in approximately two seconds. The sender is available for use after this time from any operating position.

Seizing: With the cord circuit speak key operated, the telephonist operates the position circuit dial key. The common start lead is earthed and marking battery is applied to the H lead to the finder multiple. The allotter assigns a free sender and extends the starting earth thereto. Relay ST operates and the uniselector commences to search for the marked position circuit. Relay T operates when the circuit is found, and disconnects the finder driving circuit and operates relay B, which locks and couples the sender to the position. Relay T now holds direct to the H lead, and the negative potential on the H multiple is reduced to approximately 1 volt, thus ensuring that no other finder can cut in on the position circuit. The start lead will be disconnected in the position circuit and the allotter will step on to the next free sender.

In cases where the allotter circuit is not used or is faulty, the allotter change-over key will be operated and the start lead extended direct to the first sender of the group. If this sender is busy, the start lead is extended to the second sender and so on.

Storing: The telephonist now proceeds to write up the required number and, in so doing, operates the digit set up relays W, X, Y and Z in the various combinations necessary. As the digit set up relays operate, the condenser banks are charged in succession up to the maximum of 9 digits. Relay SQ operates when any of the digit set up relays operate and charges condenser QA (1mF) with 130 volts positive, and on its release sends this charge into the sequence relay group. Each sequence relay thus operates when the successive digit keys are released and prepares a fresh set of condensers to receive the next digit. When the number is set up the telephonist operates the "finish" key and relays W, X and Z operate, and, in addition to registering on a condenser group, will complete a circuit for the start relay group (SA, SB and SC).

Sender Start: If the telephonist writes up 9 digits, sending will commence automatically on the release of the last digit key. If the telephonist writes up any less than 9 digits, and neglects to operate the "finish" key, sending will not take place until a period of approximately 10 seconds has elapsed, when relay DL will release and operate the start relay group. This prevents a telephonist from holding a disengaged sender.

Sending: Relay SA operates and disconnects the 130 volts from the W, X, Y and Z leads over which the condenser banks are charged. Relay SA will also break the holding circuit of the sequence relays which release immediately while relay SC (slow to operate) restores the holding circuit for their subsequent operation. Relay SC will switch the first group of condensers into the marking or reading relay group, while SB prepares the operating circuit of the sequence relays via contacts of IP. The reading relays corresponding to the condensers which have been charged in the first group now operate and hold to a common earth via relay PC. Each reading relay has a 20,000 ohm leak resistance to provide a light preliminary flux to assist its operation on the condenser discharge. Relay PC now starts relay PA and PB impulsing at 10 impulses per second. PA sends impulses to the telephonist's position circuit via A and B leads, while PB operates the counting relays.

At the beginning of the first impulse QB, charged to 130 volts, discharges into relay CA via contacts of CD, CC, CB and CA. CA locks itself by means of its "x" contacts to the common earth. At the end of the first impulse relay PB releases and recharges condenser QB, and at the beginning of the second impulse this charge is switched into relay CB. CB locks via its "x" contacts to the common earth, and releases CA, and, at the same time, prepares the circuit for CC. Relays CC, CD and CE operate in succession in a similar manner to CA and CB. CE, in addition to releasing CD, locks itself for the remainder of the impulse train. The sixth impulse is now directed back to relay CA, the seventh to CB, and the eighth to CC, which now remains locked. The ninth impulse now operates relay CA via contacts of CD and CC, and the tenth impulse will operate relay CD which releases CA. The counting relay combinations, therefore, are (1) CA, (2) CB, (3) CC, (4) CD, (5) CE, (6) CE + CA, (7) CE + CB, (8) CE + CC, (9) CE + CC + CA, (10) CE + CC + CD.

The reading relays will have marked one of ten leads from the counting relay contact tree, and as counting takes place each lead is tested in succession, until the marked lead corresponding to the digit stored is found. The circuit for relay SP is now complete, and SP breaks the circuit of PA and PB, and prevents any further impulsing. IP, operated by SP, releases the reading relays, releases relay PC and the counting relays and measures off the interdigital pause. Relay IP also causes condenser QA to be charged to 130 volts and SP, whose circuit is opened by the release of the reading and counting contact trees, is released, followed by IP. The first sequence relay now operates and locks to the common earth. A fresh set of condensers is switched to the reading relay group and the digit combination corresponding to the charged condensers is set up. The reading relay contact tree is again established and relay PC, operated in series with the holding lead from the reading relays, starts the impulsing circuit which in turn operates the counting relays in succession until the marked lead is found, whereupon SP and IP again operate. Thus each impulse train is counted and stopped when the required number of impulses have been sent and each digit is written off by the successive operation of the sequence relays.

If 9 digits had been stored the operation of the last sequence relay could not switch a fresh condenser bank into the reading relays, and hence no operation of relay PC would occur.

Relay PF now finds a circuit and operates slowly. In cases where less than 9 digits have been recorded, the last bank would be charged with the finish code (W, X and Z) and thus the reading relays RW, RX and RZ and relay PC would operate and prepare the impulsing circuit. However, the reading relay contact tree prepares a direct circuit to the SP relay which operates before any impulses can be sent to line. The reading relays are released via IP contacts and if switched to the next condenser group do not operate, as no charge is present.

Clear Down: Relay PF now has time to operate and releases relay B and removes the earth from the hold lead into the position circuit. The CO relay in the position circuit now operates. Relay B in releasing, restores the sender circuit to normal by releasing the start sending relays SA, SB and SC, and the sequence relays AS to JS. The circuit of PF is broken when SC restores. PF is thus the last relay to release and will restore the start and busy leads of the sender to normal.

Cancel Set-up: The operator is able to cancel the set-up of a number at any stage after the sender has become engaged. By depressing the "cancel" key, relays W, X and Y are operated and a circuit is provided for the cancel relay group CN, CNA and CNB, which lock up. CN will release any sequence relays which have operated, unlock the start sending relays (if operated), and will release any reading and counting relays which have operated. Relay CNB, slow to operate, will replace the hold lead to the sequence relays and will apply an earth to the impulsing relays PA and PB. The hold lead to the position circuit is broken by relay CN and the telephonist is free to engage another sender immediately by the operation of the "sender recouple" key.

Relays PA and PB will now operate the sequence relays in rapid succession (10 per second) and each condenser group will be discharged via contacts of CNA to 100 ohm earth in succession. When the last sequence relay JS operates, a circuit is completed for PF, which now operates and restores the entire sender circuit to normal.

Part 3 of this series of articles describing the Trunk Line Circuits, will appear in a later issue of the Journal.

LONG-DISTANCE PROGRAMME TRANSMISSION — PART I

J. G. Bartlett

Introduction

At the present time broadcasting in Australia is catered for by 49 National stations (1), including nine short-wave stations, and 102 Commercial stations, which are linked regularly in various combinations to form the many Commonwealth-wide networks for the relaying of programmes. To meet the needs of the broadcasting companies for relay facilities, an extensive network of programme channels has been provided throughout the country by the Department. The transmission requirements of these programme circuits, together with details of the equipment used in their provision, are described in this article.

Trunk circuits in Australia are provided mainly by means of open wire copper pairs, with or without superimposed carrier systems, although an ever-increasing amount of trunk traffic is being carried on underground cables, most of which are designed for carrier operation.

It is possible to classify programme transmission equipment into the two broad categories of carrier frequency and audio frequency. Programme equipment of both types has been developed for use on cable and open wire construction, although generally, audio frequency transmission is employed on open wire lines while carrier methods are used on cable circuits.

Audio frequency programme channels are sometimes provided over cables where a voice frequency local trunk cable has been laid in conjunction with the long-distance carrier cable, while it is likely in the future that audio frequency operation of programme circuits over some types of carrier cables will be employed by transmitting the programme over phantoms. This method has already been employed in Great Britain and on the Continent with satisfactory results.

TRANSMISSION REQUIREMENTS OF PROGRAMME CIRCUITS

A programme circuit may be considered to provide a high quality service when the programme material is transmitted with little loss of realism. The principal factors affecting the quality of transmission are the:—

(a) frequency range,
(b) non-linear distortion,
(c) delay (or phase) distortion,
(d) volume (or dynamic) range,
(e) noise level,
(f) attenuation distortion.

The effect of the factors mentioned on transmission performance will now be considered and in doing so, it is important that the characteristics of the human ear and of the programme material be taken into account.

Frequency Range: It has been shown (2) that the average normal human ear can detect sounds which fall within the boundaries of the curve shown in Fig. 1, while listening tests (3, 4) have proved that frequency bands equal to those shown in Fig. 2 are necessary for the realistic transmission of speech and music. It will be seen that the ear is sensitive to sounds which range from about 20 to 20,000 c/s, although this varies with age and with the individual. However, it is apparent from an examination of Fig. 2 that high

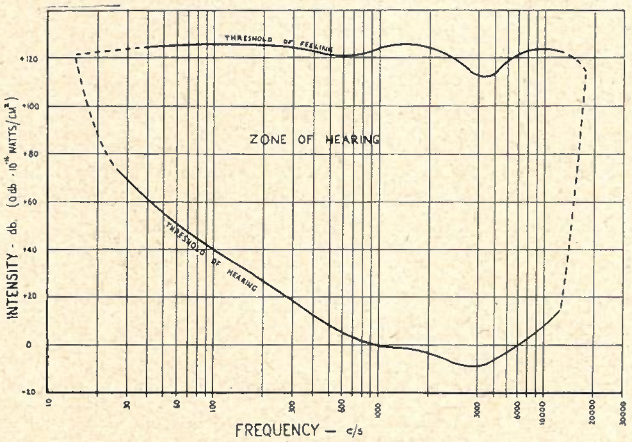


Fig. 1.—Limits of Audibility.

class programme material, such as orchestral works, can be transmitted effectively over a channel which extends from 40 to 15,000 c/s.

A programme circuit which could transmit frequencies from 40 to 15,000 c/s would, therefore, be practically ideal in this respect. Such a circuit would not, however, prove economical for general use and it is therefore necessary to restrict the bandwidth of normal programme channels. As a compromise in bandwidth between technically desirable and economically attainable circuits is necessary, it is of interest to consider the effects of a limited bandwidth on programme transmission. Tests conducted overseas (5) have indicated that the upper frequency limit for music transmission has to be reduced from 15 kc/s to 8 kc/s before the difference can be detected by 90 per cent. of discriminating listeners, and that a change from 8 kc/s to 5 kc/s is needed to obtain a similar noticeable difference. With speech transmission, similar changes are even less likely to be detected.

Since a programme circuit capable of transmitting frequencies up to 8 kc/s will provide reasonably faithful transmission of speech and music, it is unlikely that equipment capable of transmitting higher frequencies than this will be provided in this country for many years. Furthermore, unless frequency modulation is established on a commercial basis, it is unlikely that there will be any demand from broadcasting organisations for wider bandwidth channels, as the congestion which exists in the broadcast band at the moment does not allow of the transmission of frequencies much higher than this from radio stations.

Although many new programme circuits will have a bandwidth of 8 kc/s there are still large numbers of existing channels which have a bandwidth of only 5 kc/s, and even though it is realised that such a bandwidth is far from desirable,

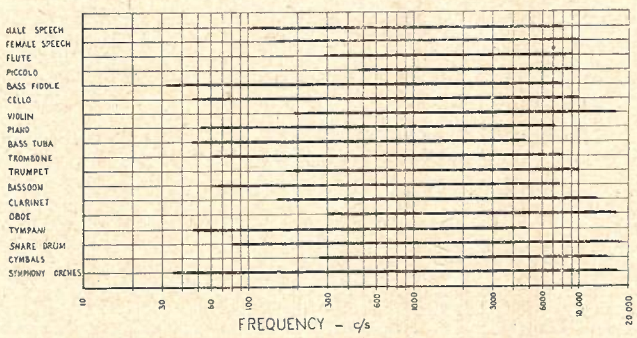


Fig. 2.—Required Frequency Range for Speech and Music.

for music transmission at any rate, economic considerations will necessitate the retention of these circuits for some time in many parts of the Commonwealth.

Non-Linear Distortion (6): The presence of non-linear distortion in a programme circuit causes two effects:—

(a) Harmonics of the various frequencies present in the transmission are produced.

(b) Intermodulation occurs between the different frequencies being transmitted, thus producing new frequencies, which are not necessarily harmonically related to the original frequencies.

Of these two effects the latter is the more serious as the tones resulting from inter-modulation sound unpleasant to the ear.

As harmonics of a fundamental frequency are produced by all musical instruments, the production of further harmonics in the transmission equipment results only in a change of character of the original sound. Such a change would not be noticed by most listeners unless the non-linear distortion present on a circuit was abnormally high, and in any case, with such an amount of non-linear distortion, intermodulation products would prove intolerable. The amount of non-linear distortion which can be tolerated varies with the transmitted bandwidth, the tolerable distortion decreasing with an increase in bandwidth. It is also apparent that non-linear distortion becomes more objectionable when higher-order harmonics are produced, as these result in the production of a greater proportion of inharmonic intermodulation tones.

Measurements of non-linear distortion are generally made using a sinusoidal source of sound, and subjective tests using such a sound have indicated that non-linear distortion products should be of the order of 40 db below the level of the fundamental if the circuit is to provide reasonable transmission. The figure of 40 db applies to circuits having a bandwidth of 8 kc/s. If the bandwidth of the circuit is reduced a greater amount of non-linear distortion may be tolerated.

Delay Distortion: The velocity of propagation of an electromagnetic wave through most trunk circuits and equipment varies with frequency. Consequently, during the transmission of programme material some frequencies will be delayed more than others, and this delay, if long enough, will be noticeable in the reproduced sound. This deterioration in quality caused by the differing transmission times of various frequencies is known as delay distortion. Generally the transmission time over a circuit is greater at the upper and lower limits of the transmission band than it is at the mid-band frequencies.

Delay distortion becomes noticeable if the delay at 100 c/s is more than 20 milliseconds greater than that at 1 kc/s and if the transmission time at 10 kc/s (or at the highest frequency transmitted over the circuit) is more than 8 milliseconds greater than that at 1 kc/s. Delay distortion in programme equipment can generally be controlled during manufacture by careful attention to the design of filters, amplifiers and other circuit elements. In cases where it is impossible to reduce the delay distortion of circuits and equipment to reasonable values in the design stage it can be reduced in service by the insertion of delay equalisers at appropriate points in the circuits. A particular instance where this has been done is in the A1 carrier programme terminal which is described later.

Volume Range and Noise: As the volume range of a circuit is determined largely by the circuit noise it is advantageous to consider these two factors together. The volume range of a circuit is the difference in level between the loudest and softest signals which can be transmitted effectively. The maximum signal level which can be transmitted is limited by the power handling capacities of amplifiers in the circuit and by crosstalk considerations, while the lower signal limit is determined by the circuit noise level.

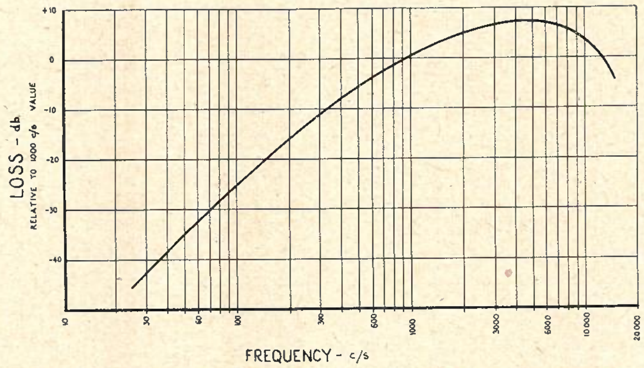


Fig. 3.—C.C.I.F. Programme Weighting Network Characteristics.

The main source of noise on a programme channel is the transmission medium and the energy present in this noise is usually distributed evenly throughout the frequency spectrum. It is apparent then that the noise level will be greater on wide band circuits than it will on circuits having a restricted band-width. However, as the ear is more sensitive at frequencies of the order of 2000 to 4000 c/s than it is at high frequencies a greater amount of noise can be tolerated at high frequencies.

To allow for the non-linear sensitivity of the ear with respect to frequency, it is necessary when measuring the noise level on a circuit to include in the measuring instrument a weighting network, which is a network having approximately the same insertion loss versus frequency characteristic as does the human ear. The characteristics of the C.C.I. programme weighting network are given in Fig. 3. The weighted value of noise so measured is an indication of the amount of noise perceived by the listener. The weighted noise level on long programme circuits varies from about 45 to 65 db below one milliwatt.

Reference to Fig. 1 will show that the ear can detect sounds which differ in intensity by about 100db, but, however, the range of sound from a symphony orchestra is about 70 db, while the range of sound intensities from most other programme material is much less than this. For example, the dynamic range of speech is only about 15db.

The dynamic range of most programme circuits is of the order of 40 to 50 db, the values for the volume range for a physical circuit being arrived at in the following manner. Firstly, the circuit noise level, weighted, is assumed to be in the range of —50 to —60 dbm. Secondly, a signal to noise ratio of 10 db under the worst conditions (that is, for low signal levels) is considered necessary so that the lowest level to which a signal should fall should be —40 to —50 v.u. (7, 8). Lastly, a margin of 10 db must be allowed between the maximum programme volume and the maximum power which can be transmitted over the line, such a margin being necessary to prevent the overloading of amplifiers by occasional peaks of programme material which exceed the average peak voltage, and to allow for the ageing of valves. This and crosstalk considerations limit the maximum programme volume to +8 v.u., so that the volume range in this case would be 48 to 58 db.

It is apparent from the previous statements that it is necessary at times to compress programme material having a volume range of 70 db to a range of 40 db. This is generally done in the originating studios by boosting the level of quieter passages and cutting back the level of loud passages. Obviously, this is undesirable as the delicate shades of tone in say, a symphony performance, are lost. A more satisfactory method, and one which is likely to be used to a large extent in the future, is the installation of compandors, which are described later, on all major programme circuits. In the meantime, although it is impossible to achieve a satisfactory volume range for certain musical programmes on existing circuits, this is not very serious, as some compression of the programme is necessary in any case to obtain a satisfactory signal to noise value in most radio transmissions.

A further point to be considered is the signal to noise ratio at different frequencies. It is clear from Fig. 4 that the energy from programme

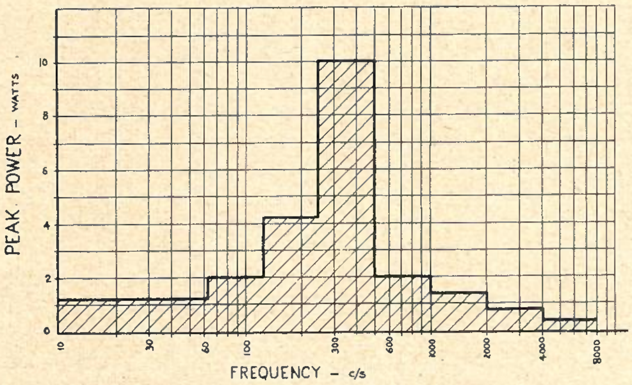


Fig. 4.—Orchestra Peak Power Distribution.

material is concentrated at frequencies from about 100 to 1000 c/s. This means that the signal to noise ratio will be worse at higher frequencies, and unless the higher frequencies are to be masked by the noise it is necessary to reduce the volume range of programme channels. Equipment which allows the higher frequencies to be transmitted at a higher level, and which restores the original perspective at the receiving end, has been developed to overcome this problem and is described later.

Attenuation Distortion: When the complex character of sound waves is considered, it is obvious that if the gain of a programme circuit varies with frequency, the character of the programme material will be altered during transmission. Most programme circuits exhibit this nonlinearity, which is known as attenuation distortion, to a greater or lesser degree. It is the aim in practice to limit the gain variations from linearity to within one db of the mean. It is generally possible to design equipment in which the attenuation distortion is negligible. However, the line itself introduces a considerable amount of attenuation distortion, which is reduced to suitable limits during installation by the provision of suitable equalisers at the receiving terminals and at intermediate stations.

Summary: To provide reasonably satisfactory performance a programme circuit should have the following characteristics. It should be capable of transmitting frequencies ranging from 40 to 8000 c/s, the response being linear to within plus or minus one db over this range. The delay at 100 c/s should be no more than 20 milliseconds longer than that at 1000 c/s, while that at 8000 c/s should not exceed that at 1000 c/s by more than 8 milliseconds. The weighted noise level should be at least 60db below one milliwatt, which means that the volume range will be at least 58 db. The total level of harmonics at 1000 c/s should be at least 40 db below the fundamental.

While, singly, many programme circuits will meet the requirements given above, it is often necessary to connect circuits in tandem, and under such conditions the performance of the over-all channels is degraded. Thus, there is a limit to the number of circuits which may be connected in tandem, the actual number of circuits which may be linked together being dependent on the performance of the individual links and on the performance standard which can be tolerated. The tolerable standard of performance will be determined by the class of programme material which is to be transmitted, musical programmes such as symphony performances requiring programme channels of the highest standard.

CARRIER EQUIPMENT FOR PROGRAMME TRANSMISSION

Various types of equipment used for programme carrier transmission will now be described. Most of this equipment is currently in use in Australia, although a few types of equipment, not in use in this country, but which show the trends of overseas development, are described also.

Carrier programme equipment may be classified into three broad categories. These are:—

(a) equipment used in conjunction with broadband carrier systems,

(b) equipment which can be used independently of other carrier systems, and

(c) split-band equipment.

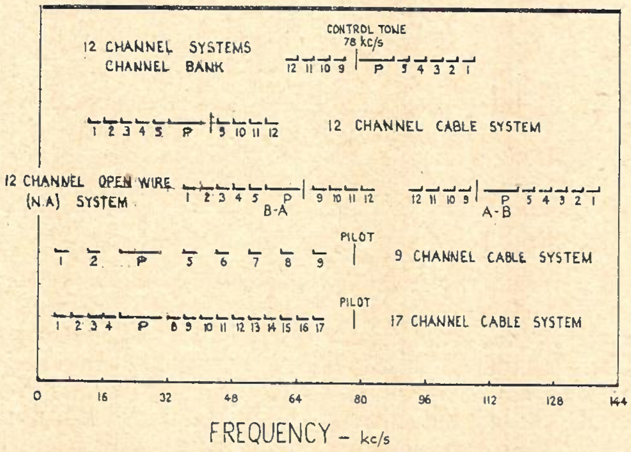


Fig. 5.—Frequency Allocation of Broad Band Carrier Systems.

There is a place for all three types in the programme transmission network of Australia, although the equipment coming within category (a) has by far the largest field of application. As a large and ever-increasing proportion of trunk telephone channels in Australia is provided by means of broad-band carrier systems, it is logical that equipment should be developed to provide for the transmission of programme material over these systems.

Broad-band systems operating in this country are of two types:—

(1) Those which incorporate an initial stage of modulation in the range 60-108 kc/s, and

(2) those in which modulation is carried out directly at the line frequencies.

The former group includes twelve channel open wire (15, 16) and cable systems (17, 18), while the nine and seventeen channel cable systems (19) fall in the latter group. Co-axial systems, which, although not used here at present, are certain to have a wide application in the future, are included in the first group. Fig. 5 shows the essential frequencies used in broad-band systems. The position of carrier programme circuits in the frequency spectrum is shown also in this figure.

Programme Equipment Associated with 12-Channel Systems.

General: Programme equipment for use with 12-channel carrier systems has been developed by the Western Electric Co. in America (20), and by Standard Telephones and Cables Pty. Ltd., in this country. As the principles of operation of both types are substantially the same, only one, that manufactured by Western Electric, will be described. This equipment, which is known as the A1 carrier programme terminal, was designed originally for use with cable carrier systems, but it can be used with type J open wire systems, although this results in slightly inferior performance. A photograph of two terminals is shown in Fig. 6.

Operation: The A1 programme terminal provides a reversible single side-band programme circuit which replaces channels 6, 7 and 8 on a J or K system. Fig. 7 shows a block diagram, for one direction of transmission, of a programme circuit provided over a K system, and the general principles of operation are clear from an examination of this figure.

The programme material at audio frequencies extending from 35 to 8000 c/s is modulated with an 88 kc/s carrier, and the lower sideband is selected by the band pass filter for transmission over the K system. Together with a 78 kc/s tone which controls the reversing of the programme circuit, the programme sideband is fed through a hybrid into the group modulator of the associated carrier system, where it is translated to the line transmission frequencies which, on a K system, extend from 32 to 40 kc/s. Channels 6, 7 and 8 of the K system are disabled by cutting off their carrier supply when the programme circuit is in use.

The same operation in reverse takes place at the receiving terminal, the programme sideband being selected by the band pass filter and demodulated to audio frequencies.

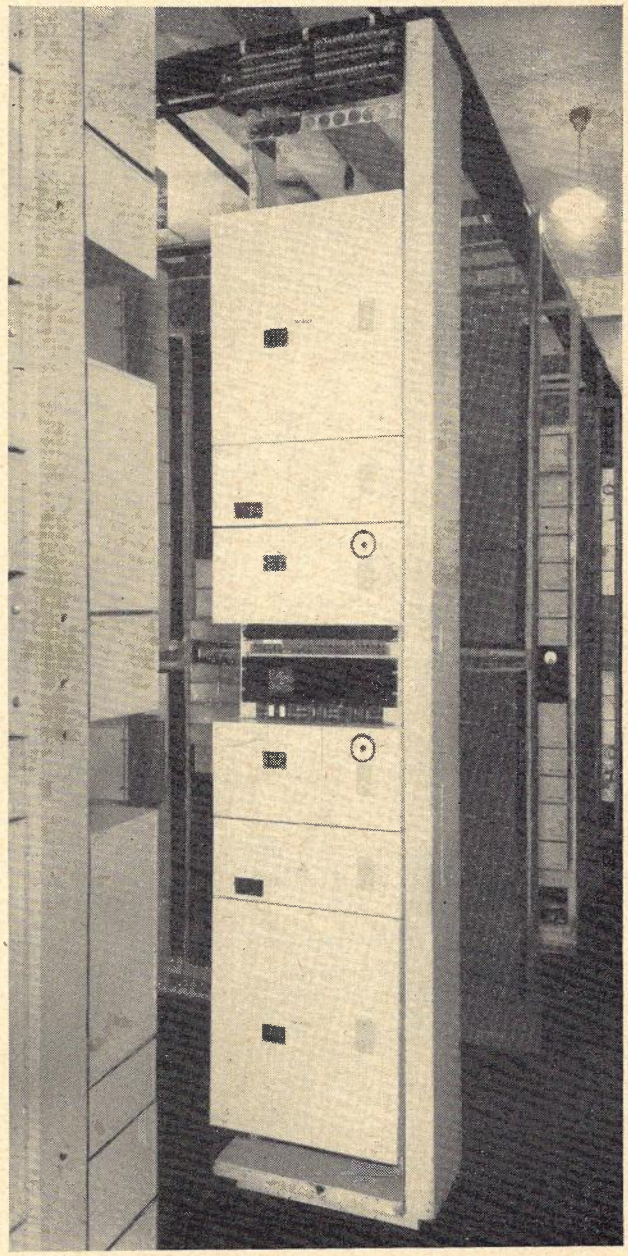


Fig. 6.—Rack mounting two Western Electric A1 Carrier Programme Terminals.

Equipment Features: The equipment used in an A1 terminal, with the exception of the predistorter and restorer, is used for both directions of transmission, re-arrangement of the equipment for sending or receiving being performed by relays operated by the 78 kc/s control signal,

Common Equipment: The main items of common equipment are the modem, band-pass filter and delay equalisers. The modem is of the copper oxide varistor type arranged in a double bridge configuration. To ensure that a high degree of balance is obtained in the bridge, each arm of the bridge comprises 16 separate varistors arranged in series and shunt. This results in lower values (of the order of 12 db) of carrier leak and non-linear distortion than are obtained with normal modulators and demodulators.

The band pass filter has the insertion loss-frequency characteristic shown in Fig. 8, and as the frequencies in the wanted and unwanted sidebands differ by only 70 c/s, the problem of designing a filter which would pass one and effectively suppress the other were, naturally, considerable. The problem was overcome in this instance by using a filter (21) employing crystal elements, which, although having satisfactory attenuation-frequency characteristics, introduced an excessive amount of delay distortion into the circuit

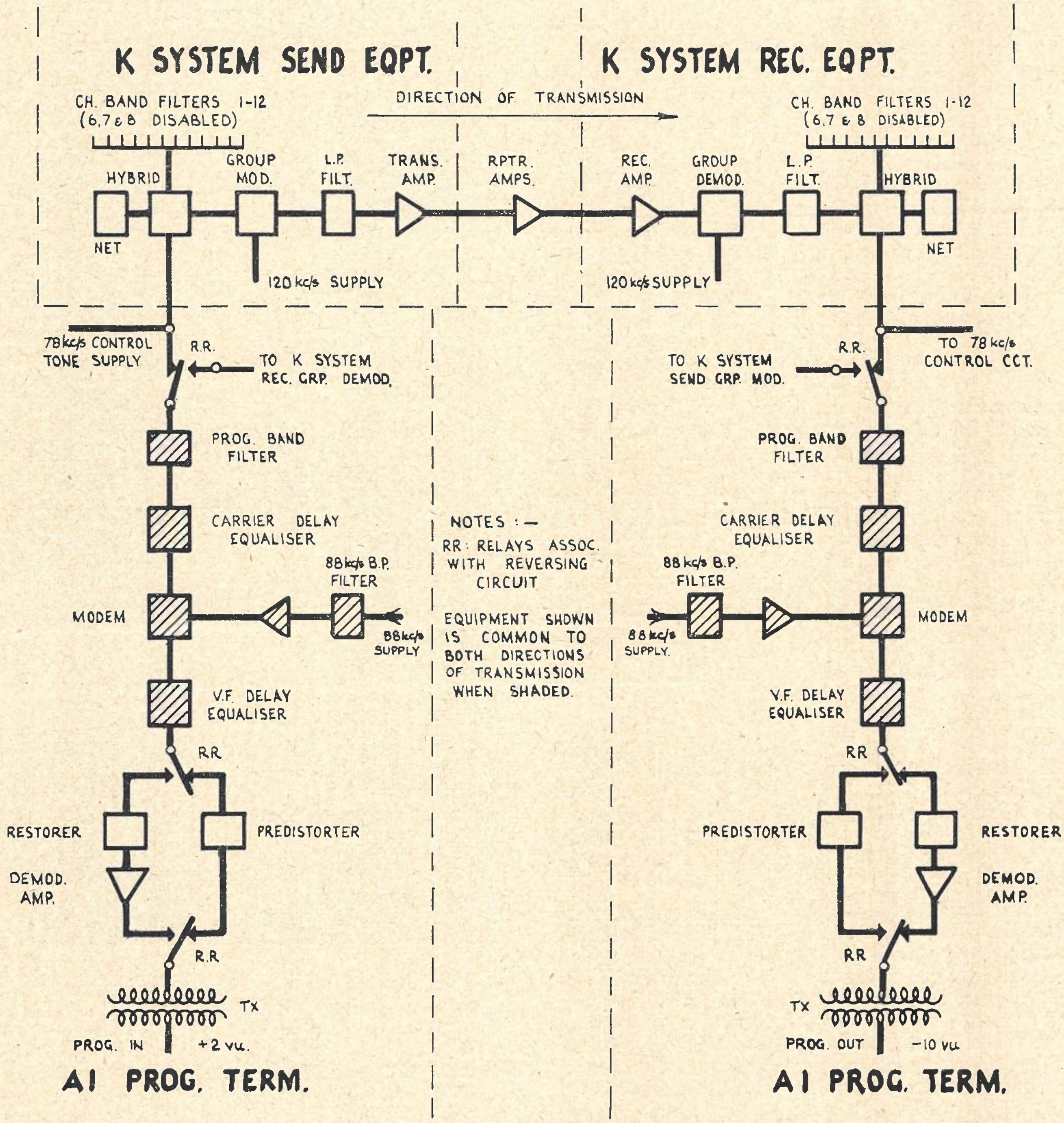


Fig. 7.—A.1. W.E. Programme Terminal Block Diagram.

when more than two links were operated in tandem.

By using two delay equalisers (22), one operating at audio frequencies and the other working in the carrier range, it has been possible to reduce the delay distortion to satisfactory limits for at least ten links in tandem. The audio frequency delay attenuator which comprises 31

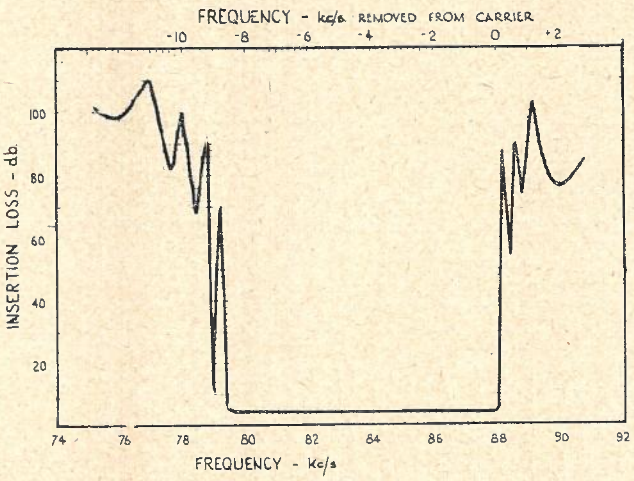


Fig. 8.—A.1. Programme Terminal Band Pass Filter Characteristics.

sections, functions as an attenuation equaliser in addition to correcting most of the delay distortion. As the delay distortion is very great at the lower audio frequencies it would need an excessive number of sections in the equaliser to reduce the delay at these frequencies to satisfactory limits. For this reason a second delay equaliser, made of crystal elements and working at carrier frequencies, has been provided. This equaliser, although of relatively simple design, provides the necessary correction of the remaining delay distortion. The delay over two terminals, before and after equalisation, is shown in Fig. 9.

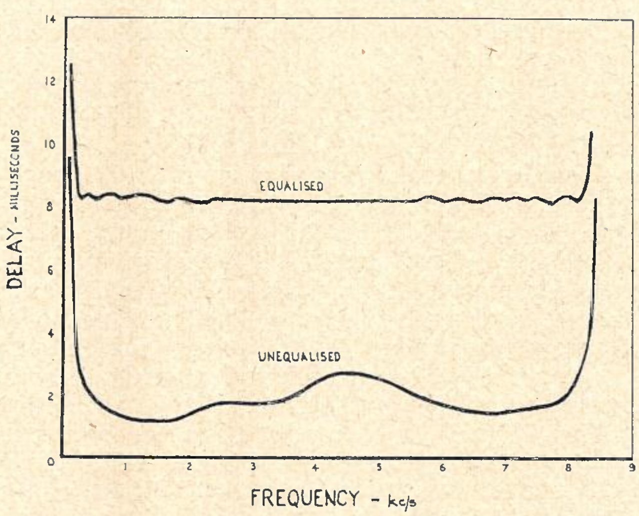


Fig. 9.—A.1. Programme Terminal Delay Characteristics for Two Terminals.

Pre-distorter and restorer: It was mentioned earlier, that while the energy from noise is distributed uniformly throughout the frequency spectrum, the power contained in speech and music is present mainly at frequencies of the order of 100 to 1000 c/s. This means that the signal to noise ratio is poorer at high and low frequencies than it is at mid-band frequencies.

The pre-distorter and restorer have been included in the A1 programme terminal to increase the signal to noise ratio at the higher frequencies. This is done by inserting a network, which is known as a pre-distorter, and which has a greater insertion loss at lower frequencies than it has at higher frequencies, in the send terminal. As a result the higher frequencies are transmitted to line at a level higher than they would be normally. At the receiving terminal a restorer, which has characteristics inverse to those of the pre-distorter, restores the levels of the various fre-

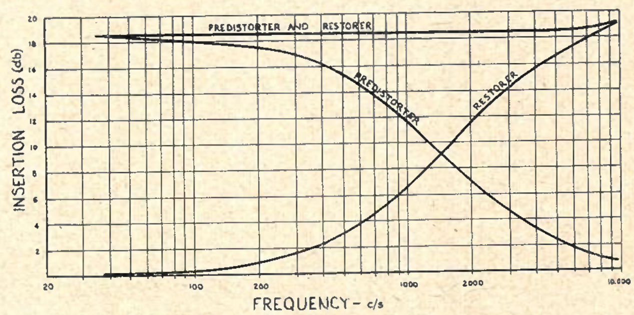


Fig. 10.—Restorer and Predistorter Characteristics.

quencies to their original relationship. These operations are illustrated by the characteristics shown in Fig. 10, while Fig. 11 shows typical circuits of both networks.

Demodulator amplifier: The demodulator amplifier is a two-stage negative feedback type of conventional design. It has a gain of 38 db and is capable of delivering an output power of plus 18 dbm, the response being substantially flat be-

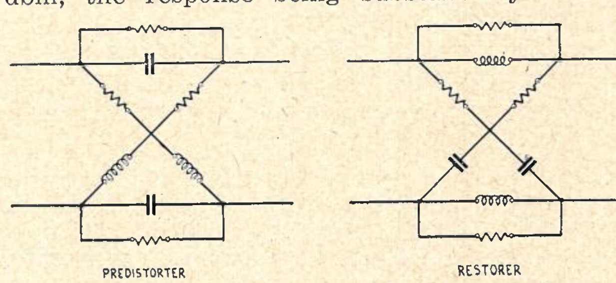


Fig. 11.—Predistorter and Restorer Schematic.

tween 35 and 15,000 c/s. A gain control variable over a range of 12 db is included in the amplifier.

Carrier Supply: The 88 kc/s carrier supply is obtained from the normal carrier distribution system of the associated J or K system.

Control Equipment: The control equipment, a simplified circuit of which is shown in Fig. 12, enables the programme terminal to be remotely and automatically reversed. The main functions of the control equipment are to:—

(a) Reverse the connections to the common equipment in the terminal.

(b) Connect either the restorer or pre-distorter, (depending upon whether the terminal is receiving or sending) into the circuit.

the 78 kc/s crystal in the feedback path of the amplifier in the control unit, thus causing it to oscillate at the resonant frequency of the crystal. A volume limiter is connected across the output of this amplifier so that a constant level 78 kc/s signal is transmitted to line with the programme material. Lastly, relay C disconnects the rectifier circuit and relay A from the control circuit.

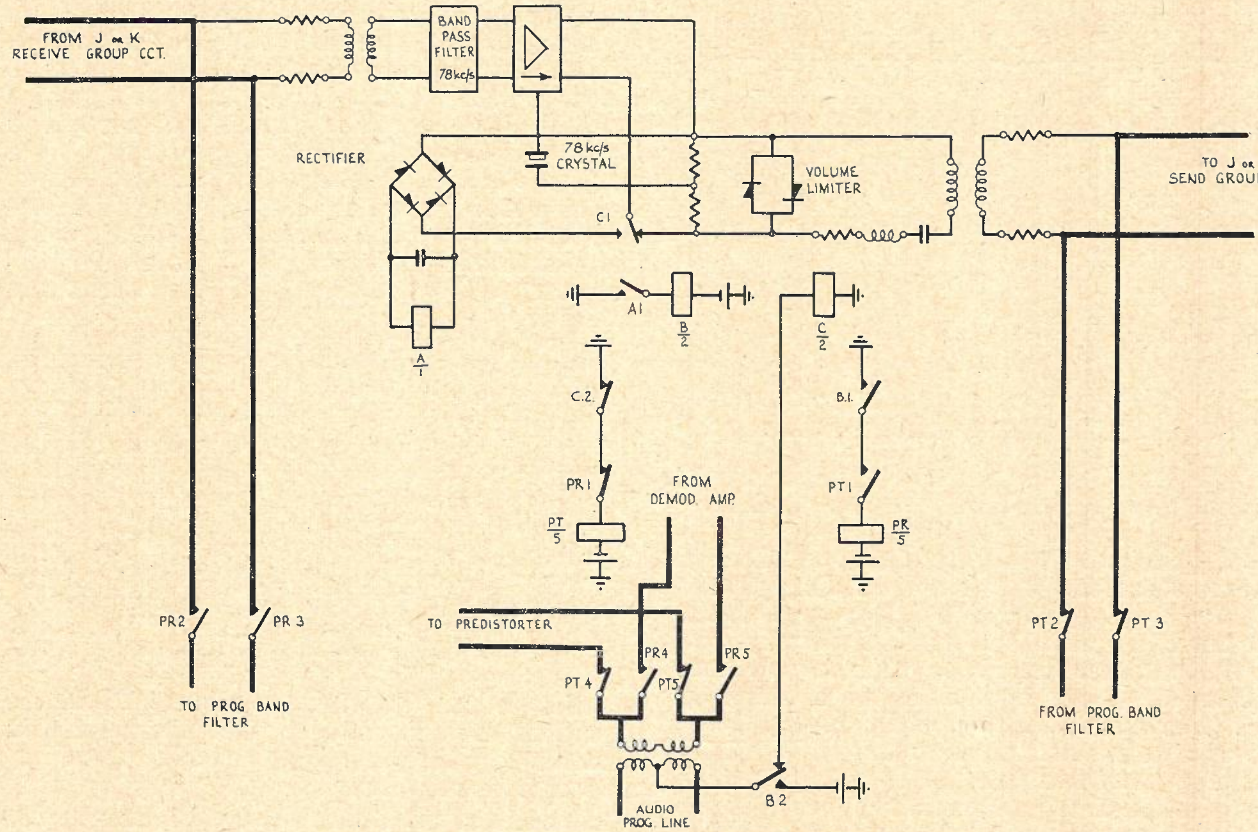


Fig. 12.—W.E. A.1. Programme Terminal Control Equipment Schematic.

(c) Connect the band pass filter to either the send or receive group equipment of the associated carrier system.

(d) Guard against false operation caused by momentary line interruptions.

(e) Change the control equipment itself, from a sending to a receiving unit.

The manner in which these functions are performed will now be described. Consider first the control unit functioning in the transmitting direction. Battery fed over a cailho of the physical programme link operates relay C, which performs three functions. Firstly, it completes a circuit for relay PT, which operates and performs the necessary functions to arrange the equipment in the programme terminal in the sending direction, to connect the incoming programme to the predistorter, to connect the output of the programme terminal to the K system send group equipment and to guard against any operation of the receive direction relay PR. Secondly, relay C connects

The programme terminal is then completely arranged as a transmitting unit. It will remain in the sending condition until such time as battery is removed from the cailho and relays C and PT release. At that stage the terminal is ready to receive a control signal from the distant terminal and function as a receiving unit.

Considering now the receiving terminal. It will be seen that the input of the control unit is permanently wired across the receive group equipment of the K system. When the 78 kc/s control signal is received, it is selected by the 78 kc/s narrow band pass filter, amplified and rectified, thus operating relay A, the volume limiter and associated filter being removed from the circuit by relay C, which is normal. Relay C has also removed the 78 kc/s crystal from the amplifier circuit. Relay A operates relay B, which feeds battery over the cailho to reverse any switching equipment connected across the physical programme line. In addition, relay B operates relay

PR, which arranges the programme terminal in the receiving condition and in addition prevents PT from operating.

It will be seen that relays PT and PR can never be operated at the same time. In addition, when no control tone or D.C. control voltage is present, both relays PR and PT are released. These features guard against accidental reversal caused by an interruption of the control signal.

Performance: The following details, which were obtained on a reversible system operating over a type J open wire system, between Sydney and Seymour, connected to a type K cable system between Seymour and Melbourne, give some indication of the performance of these programme systems. Many of the figures obtained would be bettered on many other open-wire routes, and certainly on all carrier cables as six J systems were operating on this route when the tests were conducted.

The harmonic distortion in both directions was slightly less than 1 per cent. with a test signal sent at the normal programme level. The weighted value of noise was of the order of —60 dbm. Crosstalk from the programme system into telephone channels on the same system and on other systems on the same route was negligible. It was found, however, that there was appreciable crosstalk from telephone channels into the programme systems, the principal source being from 2 VF signalling tones used on the telephone channels. This can be overcome by using compandor equipment at the terminals. The frequency response was substantially flat from 35 to 8000 c/s.

Duplex operation: Although, in some instances, the reversing facilities offered by the system just described are of considerable benefit, in general it is preferable to work this equipment on a duplex basis, that is, two unidirectional channels, one in each direction, thus gaining full benefit from the four wire path of the bearer system. This becomes apparent when one realises that one direction of the four wire path of the K system must always be idle when a reversible system is used. By duplicating the common equipment in each programme terminal, and dispensing with the control equipment a programme circuit can be provided in both directions of transmission simultaneously, thus giving an additional programme channel at a negligible extra cost.

The arrangement of the programme terminal when providing duplex facilities is shown in Fig. 13. The equipment used in this arrangement is identical with that used in the reversible programme terminal, except that no control equipment is provided, and, in addition, all of the common equipment has been duplicated. As the use of duplex equipment is restricted to permanent programme channels, there is no need to equip channels 6, 7 and 8 in the associated J or K system.

The operation of the equipment is basically the same as that of the reversible equipment, and Fig. 13 is self-explanatory. The performance of the system on a duplex basis is identical with that of the reversible system.

15 kc/s Programme System: Programme carrier equipment similar to that just described, but capable of transmitting frequencies up to 15 kc/s,

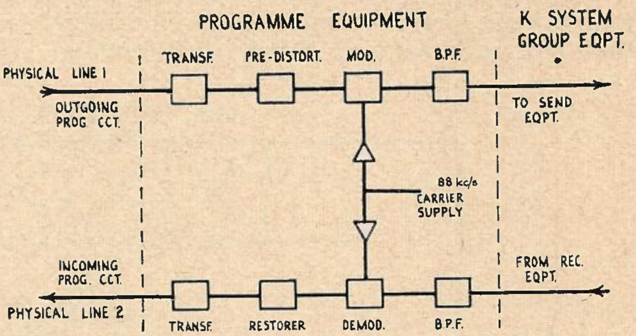


Fig. 13.—W.E. A.1. Programme Unidirectional Equipment.

has also been developed. This equipment (23) displaces six telephone channels when used over a K, J, or coaxial system, the programme carrier frequency being 88 kc/s and the lower side-band is transmitted as is the case with the 8 kc/s equipment.

The only major difference in the two systems is that no band pass filter is used in this equipment, instead, the upper side-band is suppressed by special phase shift networks associated with the modulator. This method of side-band suppression is necessary because of the difficulties associated with the construction of a 15 kc/s band pass filter capable of working in the 60-108 kc/s range of the K system channel bank.

The circuit arrangement of the phase shift networks and modulators is shown in Fig. 14. It will be seen from this that the audio input is fed to two separate modulators through separate phase shift networks. The phase shift in the circuit to modulator A is 90° plus θ, and to modulator B is θ. Hence the audio inputs to modulators A and B differ in phase by 90°. However, the input levels to the modulators are identical, this being adjusted by the attenuator in the circuit to modulator A. In addition, a 90° phase shift network is provided in the carrier supply circuit to modulator A, so that the phase of the carrier inputs to the modulators also differs by 90°, although the level to each is the same.

By virtue of the various phase shifts involved, the phase of the side-bands at the combined output of the modulators is such that one will be eliminated. In this particular case the upper side-band is suppressed. By reversing the audio input connections to one modulator the lower side-band would be suppressed. A similar operation takes place at the receiving terminal, the lower side-band being translated to audio frequencies. The operation of this equipment is similar in all other respects to the 8 kc/s system described previously, and illustrated in Figs. 7 and 13.

Because the 15 kc/s programme equipment displaces a large number of telephone channels, it is naturally expensive to provide and operate. It is therefore unlikely that it will be introduced into this country for many years, unless there is a large public demand for high quality reproduction. At the present time there is no indication that any such demand will be forthcoming. If frequency modulation broadcasting services are introduced on a commercial basis the demand may be stimulated, but is seems unlikely, in the near future at any rate, that frequency modulation will be introduced on a scale large enough to influence present trends.

The S12B Programme System.

The S12B programme system (24) has been developed by Communication Engineering Pty. Ltd. for use in conjunction with their nine and seventeen channel carrier telephone systems. Like the 8 kc/s programme carrier described previously, three channels of the associated carrier telephone system are displaced by this programme system. However, no reversing facilities are provided, although, of course, duplex operation is possible by providing the necessary transmitting and receiving equipment at each terminal.

Operation: The mode of operation of the system may be followed by referring to Fig. 15. At the transmitting terminal the programme material is fed first through a 10 kc/s low pass filter to eliminate all higher frequency currents, which, in general, are mainly produced by noise. It is then modulated by a 21 kc/s carrier, after which the upper side-band is selected by the programme band pass filter for transmission over the 17 channel system to line. The programme sideband is transmitted to line at frequencies extending from 21 to 31 kc/s, that is, in place of telephone channels 5, 6 and 7. The unwanted side-band is not completely suppressed at this stage, frequencies adjacent to the carrier frequency being transmitted at a reduced level. Complete suppression is obtained in the receiving terminal.

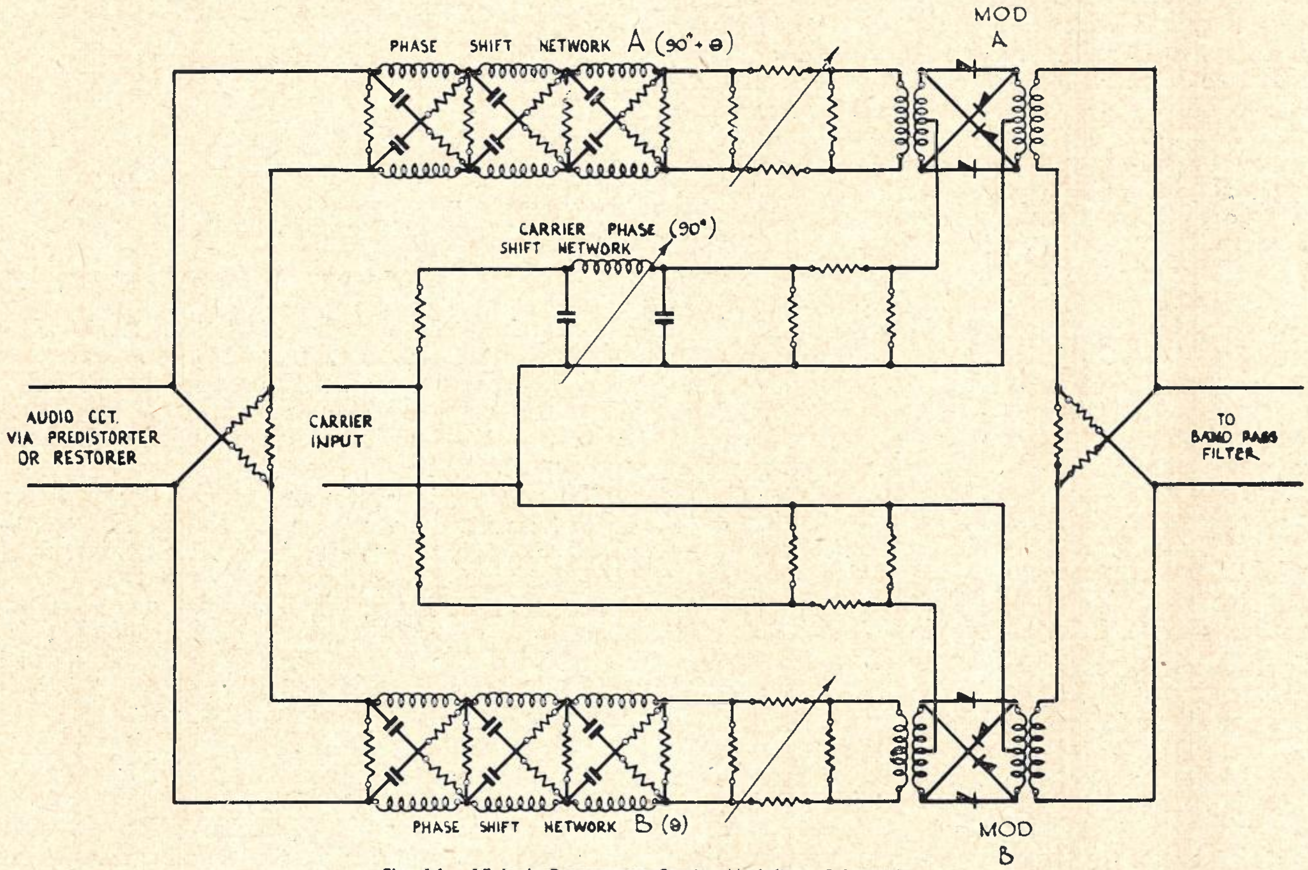


Fig. 14.—15 kc/s Programme Carrier Modulator Schematic.

At the receiving terminal the programme sideband frequencies are selected by the programme band pass filter and then modulated with a 20 kc/s carrier, after which the lower sideband, which now extends from 1 to 11 kc/s, is selected by a band pass filter. It is in this filter that complete suppression of the original unwanted sideband is achieved. The purpose of the frequency translation to the 1 to 11 kc/s range is that this enables a sharp cut off filter to be constructed to obtain the required sideband suppression. This would be extremely difficult with a filter extend-

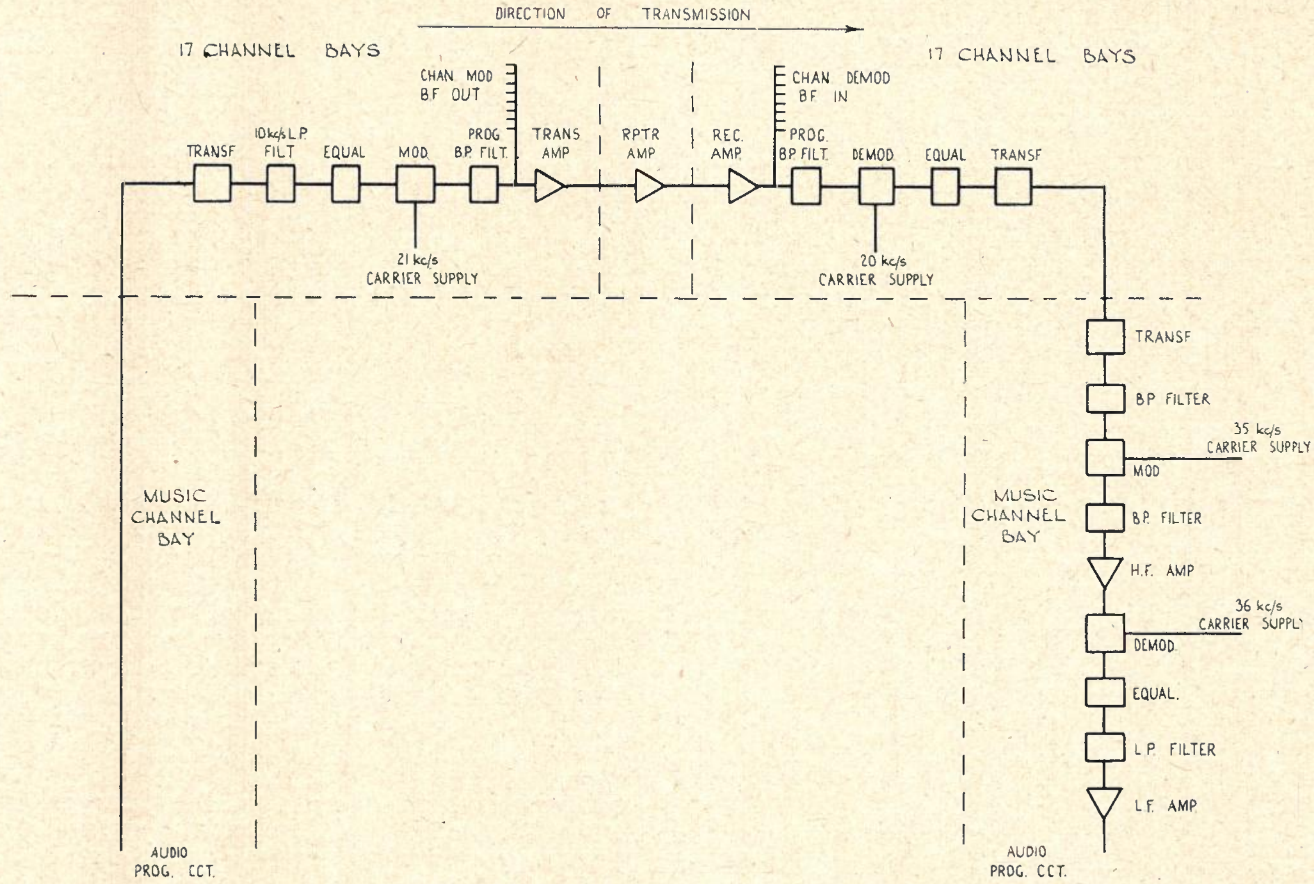


Fig. 15.—C.E.P. S.12.B Programme Carrier Block Schematic.

ing from 35 c/s to 10 kc/s. To translate the 1 to 11 kc/s sideband to audio frequencies two further stages of modulation are employed. This is done so that spurious products of modulation fall outside the programme band. In the first stage of modulation a 35 kc/s carrier is used, and the upper sideband extending from 36 to 46 kc/s is selected, amplified and then fed to the second modulator, which has a 36 kc/s carrier supply. The lower sideband, which is now at the original audio frequencies, is then selected, amplified and wired to the audio programme link.

Mounting: The equipment is mounted on standard 10 ft. 6 in. racks. Reference to Fig. 15 shows that portion of the equipment is mounted on the 17 channel system bay in place of the equipment for the three telephone channels which are displaced by the programme system. The remainder of the equipment, apart from that for the carrier supply, is mounted on a separate rack; three send and receive terminals being mounted on one rack. A carrier supply bay which supplies carrier for up to 20 systems is also provided.

Equalisers: Constant resistance type equalisers are provided at various points throughout the circuit (see Fig. 15) to correct for losses introduced by the filters.

Carrier Supply: The various carrier frequencies are derived from the master 4 kc/s oscillator associated with the 17 channel system. This master oscillator, which uses coils and condensers in the tuned circuit, is mounted in a controlled temperature oven for better stability. The master oscillators at opposite terminals are synchronised by means of a 76 kc/s tone transmitted over the cable pair. A simplified circuit of the carrier generating equipment is shown in Fig. 16. An auxiliary carrier supply circuit is provided, although it is not shown in this figure.

The normal 17 channel carrier frequencies, which are harmonics of 4 kc/s, are obtained by placing narrow band pass filters tuned to the required frequency across the output of a multivibrator driven by the master oscillator. These are then amplified and wired to the various systems. In the programme system two frequencies, 21 and 35 kc/s, which are not multiples of 4 kc/s are used. These are derived by modulating 28 kc/s with 7 kc/s, which produces as sidebands the required frequencies. It will be seen that the 7 kc/s oscillator is synchronised by the 28 kc/s supply, which is in turn controlled by the master oscillator, thus ensuring stability of all carrier frequencies.

Performance: The performance of this system is comparable with the A1 programme terminal;

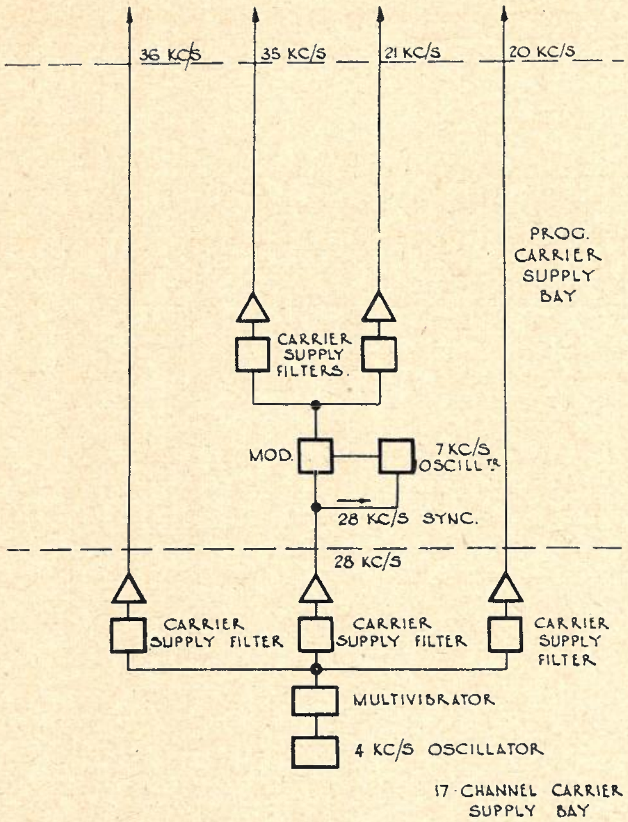


Fig. 16.—S.12 B Programme Carrier Supply.

crosstalk and noise on the system when operated on properly balanced cables is better than 60 db below one milliwatt. The harmonic distortion is of the order of 0.5%. The insertion loss-frequency characteristics for a typical system are shown in Fig. 17, and the delay distortion is shown in Fig. 18.

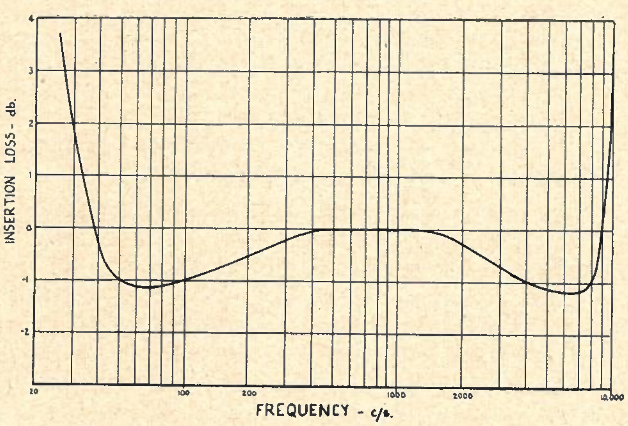


Fig. 17.—Insertion Loss/Frequency Two Terminals.

Programme Carrier Systems for Open-Wire Lines

General: Programme carrier systems which operate independently of other carrier systems on open wire lines have been in use in this country for many years. However, as there are serious difficulties, because of crosstalk, in operating the present type of system on J routes, its use is not

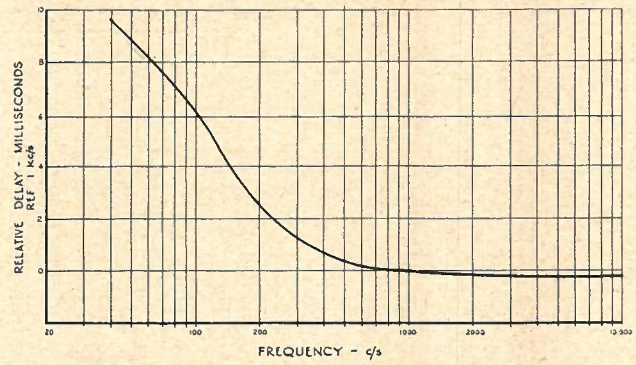


Fig. 18.—Delay Distortion Characteristics.

being extended. A new type of system which avoids crosstalk problems has been developed recently.

34 to 42.5 kc/s Systems (25): These systems provide a channel of 7.5 kc/s bandwidth and operate in the range 34 to 42.5 kc/s. The operation will be explained by reference to Fig. 18, which is a block diagram of a typical system. Additional line filters having a cut-off frequency of 32 kc/s, are required for these systems, and their location is also shown in Fig. 19.

At the transmit terminal, the audio programme frequencies are fed through a 7.5 kc/s low-pass filter into the modulator, which has a 42.5 kc/s carrier supply, and the lower sideband is selected by the filters shown. A band-pass filter arrangement has been achieved by using a L.P. and H.P. filter in tandem, while a sharp cut-off adjacent to the carrier frequency has been obtained by using a crystal filter which is actually a two-stage amplifier with a quartz crystal as a coupling device. The side-band is then amplified and fed to line together with a 34 kc/s control tone which automatically synchronises the modulator and demodulator oscillators. The operation at the receiving terminal is exactly opposite to that at the send terminal.

Synchronising is achieved by making the demodulator oscillator frequency dependent on the control tone received from the transmit terminal. The control tone is in turn controlled in frequency by the modulator oscillator. This has been done by making the pilot and demodulator oscillators unstable, and having a nominal pilot oscillation frequency which is related by a simple ratio (in this case 4:5) to the modulator oscillator. In practice this method of synchronising has proved to be a source of trouble, as momentary line interruptions often cause the system to lose synchronism for periods far in excess of the actual interruption time. To overcome this drawback consideration has been given to providing crystal controlled oscillators, which require no synchronising because of their inherent stability. It is likely that all systems of this type remaining in service will be modified in this way.

It was mentioned earlier that the use of these systems is not being extended because of crosstalk difficulties on J routes. This is apparent when it is realised that in the A-B direction (that is with identical frequencies on the programme carrier and the J system being transmitted in opposite directions) level differences in excess of 50 db may exist adjacent to repeater stations. Even when transmitting in the B-A direction level differences greater than 20 db may exist unless programme repeaters are provided at the same spacing as J repeaters. Consequently, the few systems of this type still in use are located on non J routes, and it is expected that, with the rapidly expanding use of J systems, this equipment will be non-existent within 10 years.

6-30 kc/s Systems: Two new types of programme carrier systems have been developed recently to meet special requirements on open wire routes, and to avoid the crosstalk problems of the 34-42.5 kc/s system. Their chief application is for cases where programme channels having a bandwidth in excess of 5 kc/s are required, or alternatively, where it is not possible to obtain a 5 kc/s physical channel on the route, due to the intermediate office facilities required. The crosstalk problem is avoided by locating the programme channels in the same position in the frequency spectrum as those of a three channel carrier system, namely, 6-16 kc/s in the A-B direction and 17-30 kc/s in the B-A direction. One system of this type provides a unidirectional channel of 10 kc/s bandwidth in each direction of transmission, and a second type of system, several of which have been ordered by the Department, provides two 6 kc/s channels and one speech channel. Minor advantages of open wire carrier programme channels over physical channels are that power hum is generally less, and automatic gain regulating equipment can be provided with the carrier equipment, making the channel loss independent of line attenuation changes.

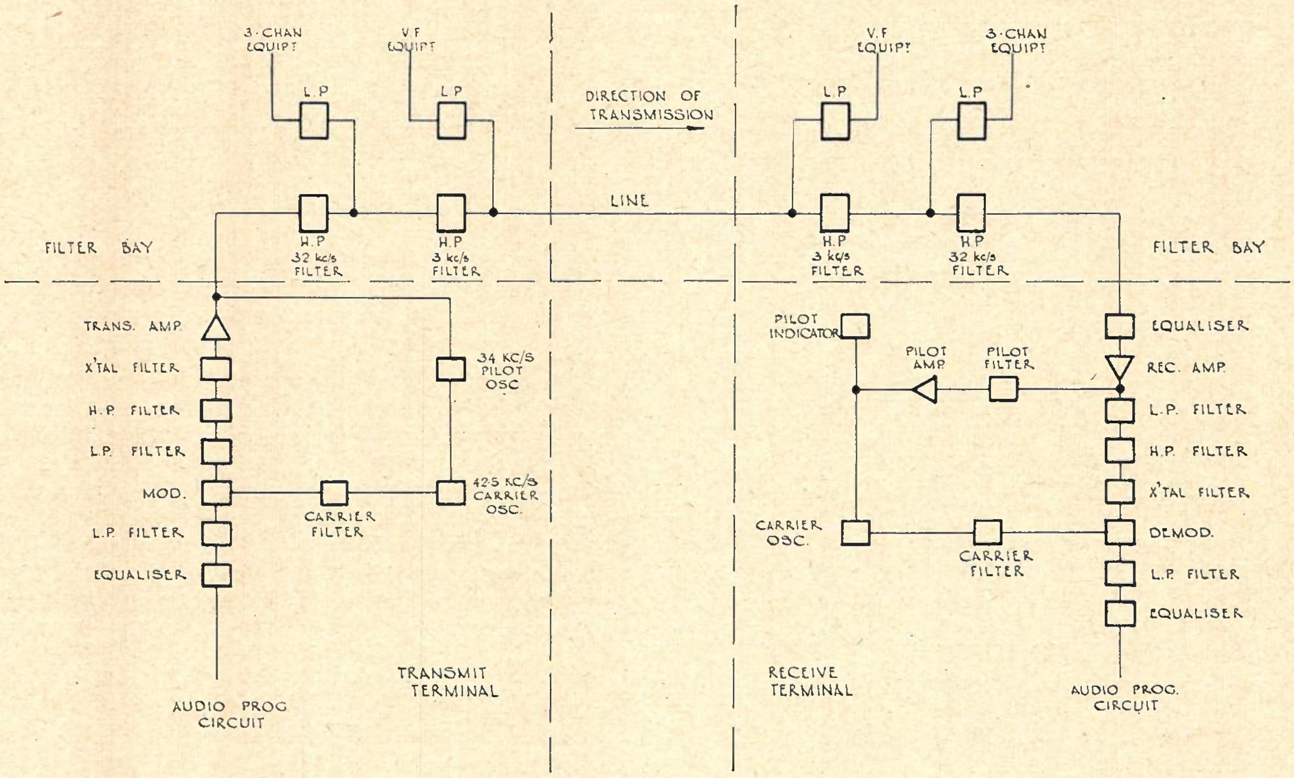


Fig. 19.—Programme Carrier for Open-wire Lines.

Split Band Equipment: Split band equipment provides a means of obtaining a programme channel by using two or more telephone channels, which may be either carrier or physical circuits. The equipment to be described provides a programme channel having a bandwidth of 50-4000 c/s from two telephone channels which have a bandwidth of not less than 300-2500 c/s.

To obtain a programme channel by this means the incoming programme material is separated into three bands by filters. These bands extend from 50 to 300 c/s, 300-2500 c/s and 2500-4000 c/s respectively. The second band (300-2500 c/s) is fed directly over one telephone channel, while the other two bands are modulated and are together fed over the second telephone channel. Fig. 20, which shows the filter characteristics of the receive terminal, illustrates the method of splitting.

The operation of the send terminal may be followed from the block schematic in Fig. 21. The incoming programme material is fed to three filters via a hybrid coil, and is split into the three bands already mentioned, any frequencies out-

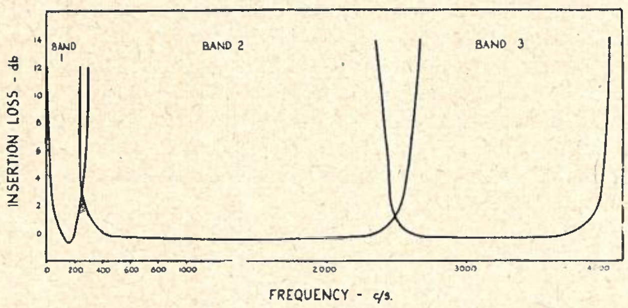


Fig. 20.—Split-band Receive Equipment Characteristics.

side of the range 50-4000 c/s being rejected. Band 2 (300-2500 c/s) is fed through a pad directly into telephone channel B. If channel B is a physical circuit an amplifier is used in place of the pad so that a suitable sending level is

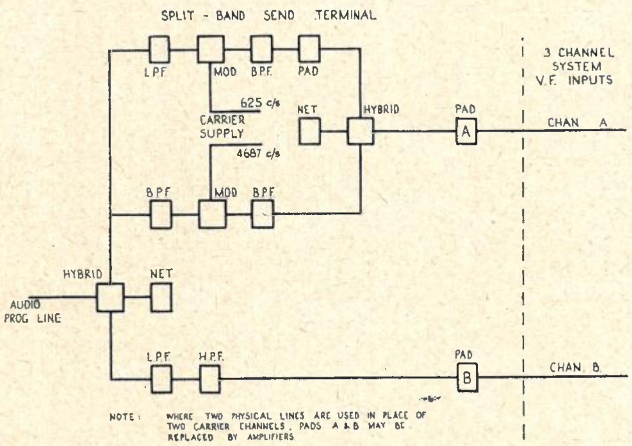


Fig. 21.—Split-band Send Terminal.

obtained. Band 1 (50-300 c/s) is modulated with a 625 c/s carrier and the lower side-band, which extends from 325 to 575 c/s, is combined with the lower side-band (687-2187 c/s) resulting from the modulation of band 3 (2500-4000 c/s) with a 4687 c/s supply and fed through a pad to telephone channel A.

At the receive terminal, a block schematic of which is shown in Fig. 22, band 2, which has been transmitted over telephone channel B, is selected and fed via a pad to the audio programme line. Bands 1 and 3 are selected and separately demodulated to the original audio frequencies, which are combined and associated with band 2 to complete the overall circuit.

Performance: The frequency response of the system is graphed in Fig. 23, and it will be seen that the response is by no means flat over the range 50-4000 c/s, most of the deviation being produced by the filters. Delay distortion on the system is appreciable, most of it occurring on band 1 and it is of the order of 20 milliseconds compared to bands 2 and 3. This delay is caused by the large number of filter sections used to derive this band. The delay distortion is also par-

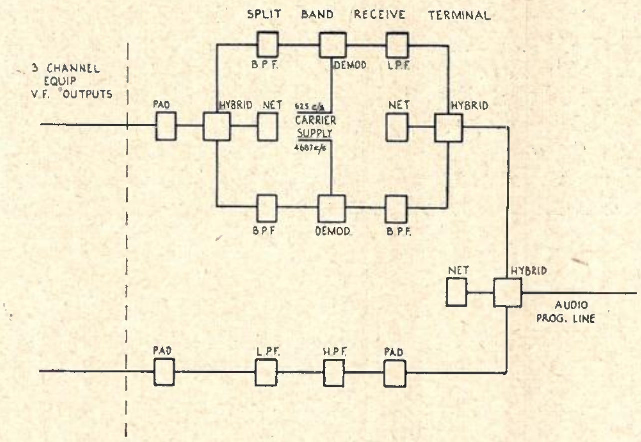


Fig. 22.—Split-band Receive Terminal.

ticularly serious at the crossover frequencies of the various filters. The harmonic content of a signal at normal transmission level is of the order of 40 db below the fundamental frequency.

Application: The main application of split band systems is in providing emergency programme circuits between centres which are not connected by a regular programme circuit nor by a telephone circuit suitable for programme transmission. A typical example of its use would be between two centres linked by a three channel carrier system operated over a bearer which is used as a multi-office trunk. However, as the performance is poor, the use of the system is very

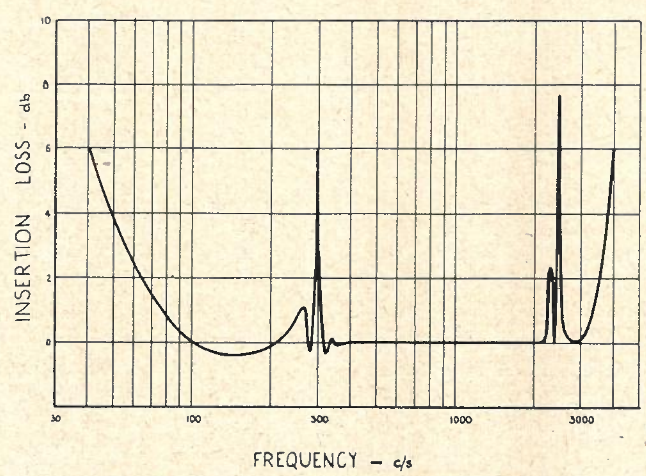


Fig. 23.—Split-band Equipment Overall Response.

limited, and it is unlikely to be used except in cases where the only alternative for programme transmission is the use of a normal telephone channel.

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(To be continued.)

ANSWERS TO EXAMINATION PAPERS

The following answers generally give more detail than would be expected in the time available under examination conditions. The additional information should be helpful to students.

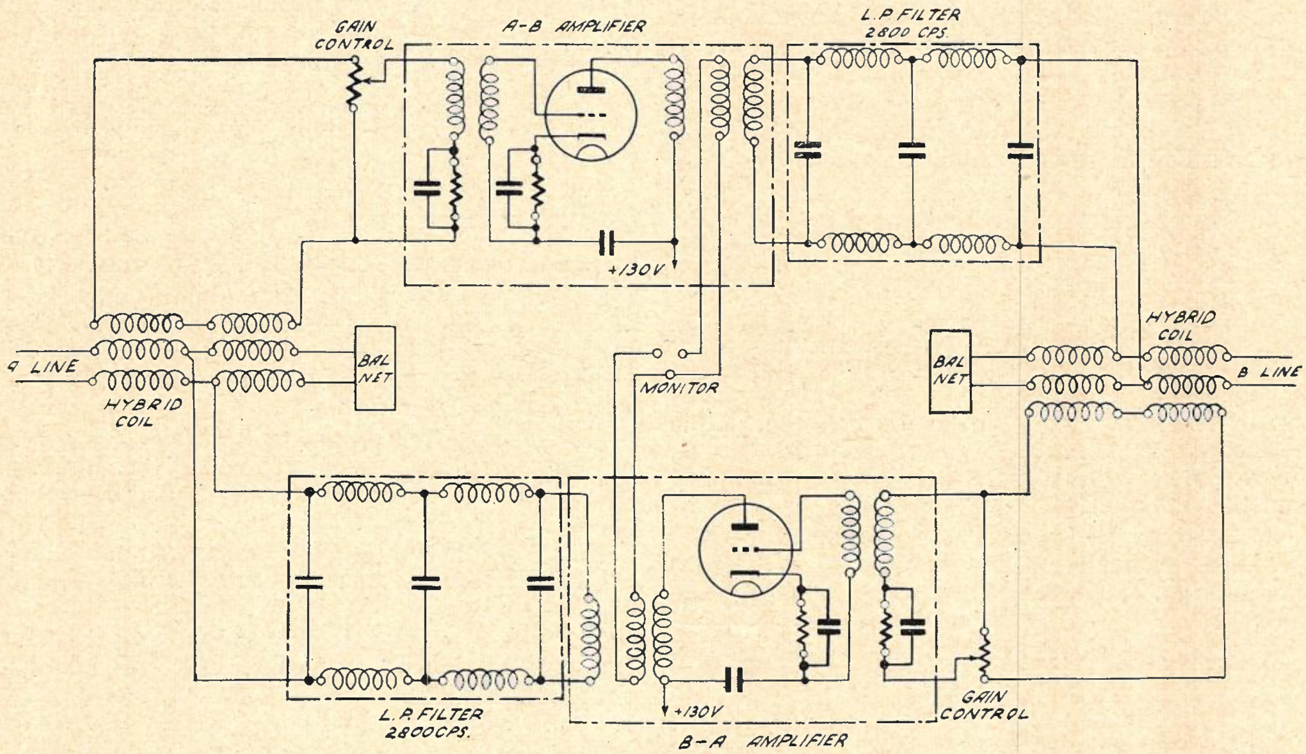
EXAMINATION No. 2824—SENIOR TECHNICIAN, TELEPHONY (II) SECTION 1

E. J. ANGEL

Q.1—Draw a schematic circuit of a two-wire voice frequency repeater and explain briefly the functions of each item of equipment used in the circuit.

Amplifier.—A single stage amplifier of 26 db gain provided in each direction of transmission to compensate for the line losses. The amplifier has an equaliser which attenuates frequencies below 200 c/s.

Low Pass Filter.—This limits the frequencies transmitted in the amplifier path to those below 2.8 kc/s and makes it unnecessary for the balance network to match the line beyond this frequency. This simplifies the net-



Q.1, Fig. 1.

A.—Fig. 1 represents a typical schematic circuit of a two-wire voice frequency repeater.

Functions of Components.

Hybrid Coil.—A differential three winding transformer is used to separate the two directions of transmission. It permits speech frequencies from the A direction to pass through the A—B amplifier and after amplification to pass to line B via the other hybrid. The hybrid coil in the latter case prevents the frequencies amplified in the A—B amplifier from passing to the input of the B—A amplifier except at very high loss thereby preventing "singing." A similar operation occurs in the case of frequencies in the B—A direction.

Balance Network.—A network usually consisting of capacity and resistance is arranged to provide a close electrical balance to that of the line. This is necessary to enable the hybrid coil to function satisfactorily. The degree of balance between the network and the line is the controlling factor in the amount of amplification which can be provided without "singing" occurring.

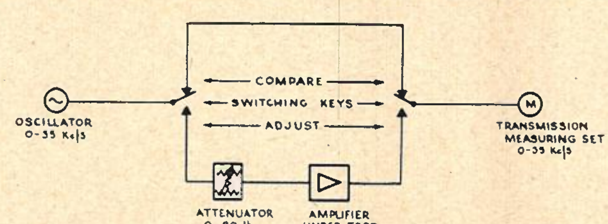
Gain Control.—A potentiometer at the input of each amplifier, which is used to regulate the overall gain of the repeater as required.

work design and allows a satisfactory compromise to be effected between the quality of transmission and the amount of amplification which can be inserted.

Monitor Facilities.—Additional windings on the output transformer of each amplifier enable each or both directions of transmission to be monitored and are also used for test purposes.

In addition, jacking facilities are provided to faciltate testing and patching arrangements.

Q. 2.—You are required to measure the gain of a transmitting line amplifier belonging to a three-channel carrier system. Show by means of a diagram the equip-



Q.2, Fig. 1.

ment you would use and briefly set out the procedure you would adopt in making the measurements.

A.—A suitable set up for measuring the gain of the amplifier is shown in Fig. 1.

The group of frequencies which the amplifier is required to transmit could be either 3-15 kc/s or 15-30 kc/s approximately depending on the direction of transmission of the amplifier.

Equipment Required.

Variable oscillator of 600 ohm output impedance suitable over range of frequencies 0-35 kc/s.

Balanced attenuator 0-60 db 600 ohm.

Transmission Measuring Set, 600 ohm, suitable up to 35kc/s (zero reference 1 mW = 0 db.)

Switching keys.

Patching Cords.

Test Procedure.

(1) Arrange set-up as shown in Fig. 1.

(2) Calibrate oscillator.

(3) With keys in "compare" position and oscillator on lowest frequency to be measured, adjust output of oscillator until T.M.S. reads 0 db when terminated in 600 ohms. (This value of test current ensures that there is no likelihood of overloading the amplifier.)

(4) With attenuator in maximum loss position throw keys to "adjust" position and reduce attenuator setting until T.M.S. reading obtained is the same as in (3). The loss in the attenuator is then equal to the gain of the amplifier at the frequency and is recorded.

(5) Repeat the procedure in (3) and (4) at frequency intervals of 1 kc/s within the range required and record results.

Q. 3.—What do you understand by the term "Signal to Noise Ratio"?

An oscillator is connected in series through an attenuator to the input terminals of an amplifier and the attenuator value is adjusted until the power measured at the output terminals at the amplifier is 5 milliwatts. If the output from the oscillator terminals is 10 milliwatts and the gain of the amplifier is 50 db, determine the insertion loss of the attenuator; given $\log_{10} 2 = 0.301$.

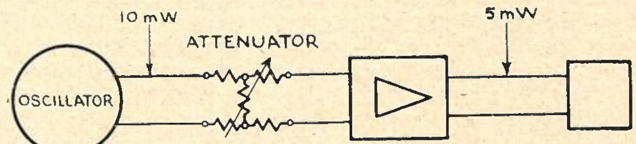
A.—The signal to noise ratio at any point in a communication circuit is the ratio of the signal voltage to that of the noise voltage.

Expressed in decibels, Signal to noise ratio

$$= 20 \log_{10} \frac{\text{USEFUL SIGNAL VOLTAGE measured at end of circuit terminated in 600 ohms pure resistance}}{\text{Psophometric voltage of noise measured at the end of the circuit.}}$$

The psophometric voltage of noise is used, as the effect of the noise on the ear is dependent on the frequency, e.g., a larger volume of noise at 50 c/s can be tolerated than at 1,000 c/s. The psophometer has a weighting network which takes care of the response of the ear and the telephone receiver. For telephonic communication, the signal to noise ratio should not fall below a value of approximately 58 db otherwise undue impairment of the signal may occur. To prevent the signal voltage falling below the required value, amplification is provided at appropriate intervals.

Likewise, it is necessary to confine the noise, which may be due to induction from other communication or electric circuits or caused by power equipment or thermionic valves, etc., within desirable limits.



Q.3, Fig. 1.

Power loss in decibels between the output of oscillator and the output of amplifier $= 10 \log_{10} 10/5$.

$= 10 \log_{10} 2$.

$= 10 \times 0.301$.

$= 3.01$.

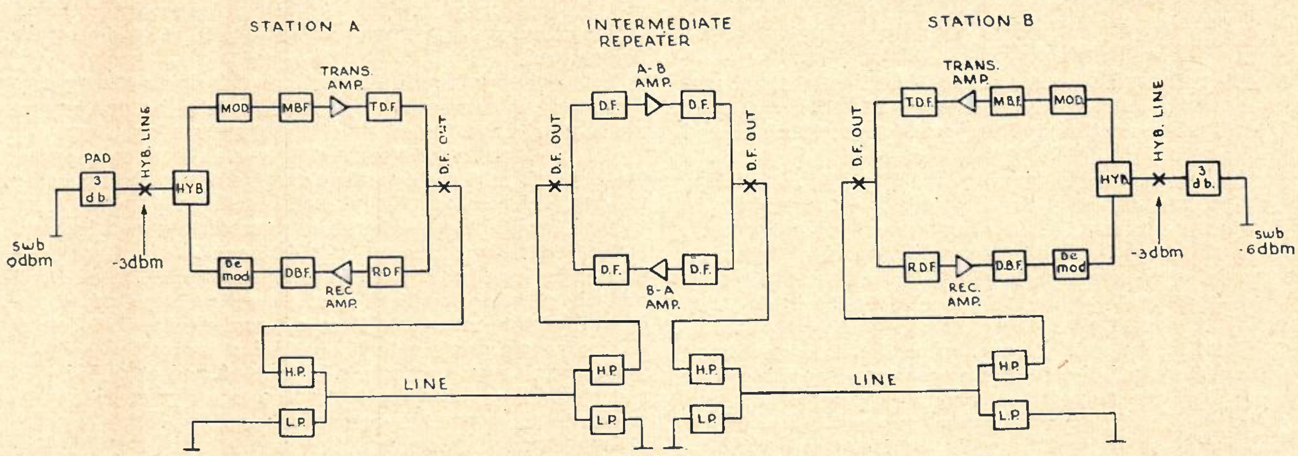
As gain of amplifier $= 50$ db the insertion loss of attenuator $= 50 + 3.01$ db

$= 53.01$ db.

SECTION II

Q. 1.—A three channel carrier telephone system is installed between centres A and B. The three channels at each end are connected to the local switchboard through 3 db switching pads. You are required to carry out a routine daily line up of the system. Detail the procedure and indicate by means of a simple block schematic diagram the point of measurement of each test.

A.—It is assumed that the system referred to is not equipped with pilot control owing to the necessity to carry out a daily routine line up. Fig. 1 illustrates a



Q.1, Fig. 1.

schematic arrangement of the 3 channel carrier terminals at A and B with details of only one channel shown in each instance. Although no direct reference was made to intermediate repeaters in the question one has been assumed for this answer.

As the channels are equipped with 3 db switching pads, which are generally remote from the system terminals, the test levels used for line up purposes should take these into account. Normally, with 0 db sent at one switchboard the level at the other switchboard should be —6 db with both switching pads in circuit. Therefore, when carrying out the line up between the hybrid line jacks, a sending level of —3dbm would be used and the receiving level at the corresponding point at the other terminal would be —3dbm.

Line Up Procedure.

Complete preliminary routine arrangements such as taking system out of traffic and establishing communication with distant terminal and repeater station over separate line.

Line up in A—B direction.

At station A send test level (800 or 1000 c/s) as —3 dbm at hybrid line jacks of middle frequency channel with the other two channels terminated in 600 ohms. Check the sending level at the Directional Filter out jacks and, if necessary, adjust the transmitting amplifier to obtain specified level, generally + 18 dbm, and then allow to pass to line. At the repeater station the level is checked at Directional Filter out jacks and if necessary the A-B amplifier is adjusted to obtain the specified level. If there were other repeaters on this system this process would be repeated in turn at each station after the previous one had adjusted. At station B the level is measured at the hybrid line jack of the channel with the demodulator amplifier control set at the centre of its range. Any adjustment necessary is made by varying the receiving amplifier control with perhaps a fine adjustment being made on the demod. amplifier. The "A" terminal then sends the same test level from the hybrid line jacks in the other two channels in turn and the "B" terminal checks correspondingly. Any adjustment necessary to obtain the specified level is obtained by varying the respective demod. amp. control.

Line up B—A direction.

A similar procedure is repeated for the B—A direction of transmission. After a speaking test is carried out over each, the settings of the various controls at the terminals and repeaters are recorded and the channels restored to traffic.

Q. 2.—You are required to synchronise one channel of any carrier telephone system with which you are familiar. Describe the procedure you would adopt.

A.—For this question the general method of synchronising three channel carrier telephone systems with jack or U link access to the modulator and demodulator band pass filters is described.

Under this method a tone of say 1000 c/s is fed into the hybrid line of one of the channels and the modulator band pass filters at the sending end are patched out, thereby allowing both side bands to pass to line. At the receiving terminal both sidebands are permitted to enter the respective demodulator by patching out the demodulator band pass filter. If the demod. oscillator at this end is the same frequency as the mod. oscillator at the sending end the frequency two tones produced at the output of the demodulator will be the same. If, however, they differ by say "X" cycles per sec. the principal demodulation tones will be 1000 + X c/s and 1000 — X c/s which create a beat tone equal to X c/s. The demodulator oscillator frequency control is then adjusted to eliminate the beat tone under which conditions both oscillators are synchronised. Having synchronised this direction the tone can be looped back from the receiving end and the sending end can beat the sending tone with the receiving tone. If a beat tone is heard which indicates non-synchronism in this direction the demodulator oscillator at the sending end is adjusted accordingly. Usually it is possible to send both sidebands on all three channels in one direction but where this is not possible on all three channels due to line or directional filters the method is used on two channels in one direction and the third channel in the opposite direction.

Procedure.

1. Remove the channel from traffic after notifying traffic section. As the synchronising interrupts all channels, traffic should be advised accordingly.
2. Select the most suitable direction of transmission in which both sidebands can be readily transmitted which we will assume to be the A—B direction.
3. The A terminal sends 1000 c/s at normal level to the hybrid line and patches out the modulator band pass filter allowing both sidebands to line. The B terminal patches out the demod. band pass filter of the channel and listens across the hybrid line jack. B adjusts his demod. oscillator until the beat note is less than 1 c/s.
4. The filters at A and B are restored and at B the demodulator output is patched to the modulator in jack, thereby looping the 1000 c/s back to the sending end. The A terminal now listens across the monitoring jack and adjusts the demodulator oscillator frequency until the beat note is less than 1 c/s.
5. Remove all patches, speak over channel and restore to traffic.

Q. 3.—A complaint has been made regarding a carrier telephone channel that transmission is faint in one direction. List the possible causes of the trouble and briefly outline the steps you would take to locate it.

A.—The cause and location of the trouble would depend on whether the channel concerned is a single channel carrier system or one of a multi-channel system. For the case of a single channel system faint transmission could be caused as follows:—

1. **Transmitting Terminal.** Faulty modulator, modulator oscillator or transmitting amplifier which might be due to faulty thermionic valve, dry joint or faulty jack spring contact. In the case of a dry joint it could be anywhere in the sending side of the terminal.
2. **Repeater.** Fault anywhere in the direction of transmission concerned; which might be faulty joint, filter, jack spring, amplifier or accidental alteration to amplifier control.
3. **Receiving Terminal.** Fault anywhere in the receive direction of transmission; which might be faulty demodulator, amplifier, dry joint or jack spring.

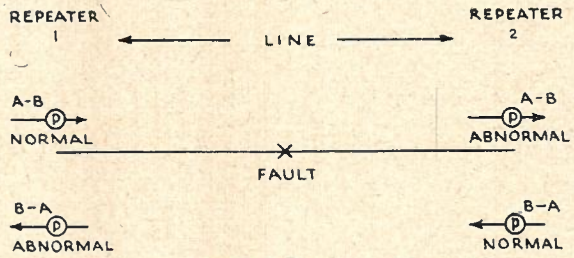
In some instances the trouble could be due to a line fault which might only affect one frequency group being transmitted particularly in the high frequency direction. In locating the trouble the best procedure would be send normal test level tone at hybrid line in the faulty direction. The level at the various points would be checked and the trouble localised first to which terminal or repeater and then which item of equipment. The faulty item of equipment is then checked electrically in detail until the faulty component is located and replaced. If the trouble was due to faulty line, arrangements would be made to patch the system if possible and clear the channel. In the case where the channel is one of a multi-channel system observations would be made on the other channels to see whether similar symptoms were evident on these. If this were not so the trouble would not be due to any item of common equipment such as transmitting and receiving amplifiers, and would be confined to the particular direction of transmission of the channel in either terminal. The troubles likely to be experienced would be of a similar nature as those for the single channel system, and the method of location would be on similar lines. If all channels of the system showed signs of faint transmission it is likely that the trouble could be due to a fault, along the lines already mentioned in some item of common equipment in that direction of transmission, such as the transmitting amplifier, repeater or receiving amplifier. Also if the direction of transmission concerned was the high frequency group it is possible that the trouble may be due to some fault on the bearer circuit.

Q. 4.—In the control station of a carrier telephone system equipped with automatic gain control, the pilot alarm relay in the terminal operates. You are required to investigate the trouble. State briefly what action you would take.

A.—The restore facility on the pilot control should be operated to ensure the alarm is not due to some momentary fault.

If this is not so the channels should be observed to determine whether they are working satisfactorily or not. If the channels appear normal it is likely that the trouble is due to a fault in the pilot equipment, such as the failure of the pilot oscillator at the sending terminal or a fault in the regulating equipment at the terminal. It is unlikely to be at any of the repeater stations if the channels are normal. Should the channels be abnormal it is likely that the trouble is due to some line fault, although it is possible to be due to faulty equipment in a repeater or terminal station.

In either case, the procedure would be contact the repeater stations and the distant terminal and note the conditions of the pilots at each in both directions to localise the trouble. Thus, if the trouble was due to a fault between two repeater stations the pilot would not be normal in one direction at one repeater station and in the other direction, at the other repeater station, as shown in Fig. 1.



Q.4, Fig. 1.

A check would be made of the bearer circuit in the section concerned. If the trouble was due to a fault in the pilot equipment only one pilot would be abnormal, and it is likely that the channels would be workable. Also, if either one or both directions of transmission were off completely the trouble could be due to some failure of common equipment, either at the repeater or terminal, e.g., power failure due to operation of fuse, faulty tube in amplifier, etc.

Having localised the trouble, arrangements would be made to either patch in a spare line in the case of line fault, or spare equipment in the case of equipment fault, which cannot be readily cleared. Should either of these courses not be available every effort would be made to keep the channels operating. It might even be necessary to patch out a repeater temporarily to provide service and adjust the receiver amplifier manually. Having provided service on the channels arrangements would be made to clear the fault, whether it be a line or some item of equipment, in order that the system may be promptly restored to normal.

Q. 5.—What is the function of a receiving relay in a voice frequency telegraph channel? Why is it necessary at times to make a readjustment of the relay? Briefly list the adjustments you would make.

(a) While the relay is in service;

(b) With the relay removed from the terminal and placed on a relay test table.

A.—The function of a receiving relay in a voice frequency telegraph channel is to convert the variation of direct current produced in the plate circuit of the amplifier detector by the incoming voice frequency signals to corresponding double current marking or spacing telegraph signals of a required voltage with a minimum of distortion.

Re-adjustment of the relay is necessary at times owing to the variations of the original adjustments by vibration due to constant operation and also from wear and pitting of contacts.

(a) The adjustments made while the relay is in service are to the bias control on the channel. This is a potentiometer which regulates the current flowing through the bias winding of the relay. No mechanical alteration should be made to the relay whilst in service. The adjustment to the bias is made by sending revs. at the correct speed from the sending terminal and adjusting the bias control until the meter in the telegraph receive leg reads zero.

(b) With the relay removed from the terminal and placed on a relay test table, the relay and armature contacts should be cleaned, burnished and reset to the correct adjustment. The relay should be adjusted in accordance with the procedure laid down for the particular type of relay used, and then checked by means of the facilities provided on the relay table for
   (1) Contact adjustment.
   (2) Transit Time.
   (3) Neutrality.

EXAMINATION No. 3101—SENIOR TECHNICIAN, TELEPHONE

C. J. Peady

(b) TELEPHONY I

Q. 1.—List separately the alarms used in a large 2,000 type Automatic Exchange—

(a) Those with delay period.

(b) Those without.

A.—(a) The following are the alarms with delay periods:—

(i) **Release Alarm** (9 secs.). Caused by a selector failing to restore to normal when its release circuit is energised.

(ii) **Line Finder Alarm** (6 secs.). Line finder fails to find calling line.

(iii) **Permanent Loop Alarm** (6 mins.). First selector or D.S.R. held for excessive period before receiving impulses.

(iv) **C.S.H. (Called Subscriber Held) Alarm** (3 mins.). Calling or called subscriber holding the connection for an excessive period after the other party has cleared.

(v) **N.U. Tone Supervisory Alarm (9 secs.).** A short-circuit or earthed negative fault in the exchange equipment associated with any of the 100 numbers connected to each N.U. tone relay.

(b) Alarms without delay:—

(i) **Fuse Alarm.** Caused by operation of an alarm type fuse.

(ii) **Ring Fail Alarm.** Failure of exchange ringing current supply.

(iii) **Machine Fail Alarm.** Failure of mains-driven ringing machine. This does not necessarily indicate a failure of ringing current since the battery-driven machine automatically starts.

(iv) **Voltage Alarm.** Voltage at main busbars outside prescribed limits.

(v) **Charge Fail Alarm.** Operation of circuit breaker due to overload or reverse current.

(vi) **N.U. Tone Overload.** A low resistance earth fault on a line temporarily connected to N.U. tone.

(vii) **Condenser Alarm.** Failure of uniselector spark quench condenser.

(viii) **Positive Fail Alarm.** Failure of positive battery voltage.

Q. 2.—(a) List the facilities provided by a P.A.B.X. of the Line Finder Type.

(b) Why are manual telephonists' positions necessary in such an exchange?

A.—(a) The following is a list of facilities provided by a Line Finder Type P.A.B.X.—

(i) Extension to extension calls are dialled direct.

(ii) Calls outgoing from the extension telephones are dialled direct by prefixing "O" to the directory number of the required subscriber.

(iii) Any extension may be barred direct exchange access. Outgoing exchange calls from such an extension may be made at the discretion of the manual telephonist.

(iv) Incoming exchange calls are received on a manual switchboard and routed to extensions by the telephonist.

(v) Information calls to the manual switchboard are made from extension telephones by dialling "9."

(vi) Exchange calls may be reverted, that is, set up by the telephonist and connected to any extension.

(vii) The telephonist may break-in on a busy extension to offer an exchange call. A warning tone may be provided, if required. (Trunk offering.)

(viii) An extension telephone may hold an incoming exchange call and make an enquiry call to any other extension. (Call back.)

(ix) Exchange lines may be night switched to selected extensions.

(x) Important extensions may be connected directly to the manual switchboard. (Executive lines.)

(xi) Up to six extension telephones can be connected together on one circuit for a conference call.

(xii) The manual telephonist or, if desired, any extension can set up a "Code Call" to locate a particular person. By dialling a special number, the person called stops the code call and is connected to the calling party.

(b) A Manual switchboard is provided with all types of P.A.B.X.'s, mainly to handle incoming exchange calls. There are other reasons, however, why a manual switchboard must be provided—

(i) Many subscribers calling a P.A.B.X. are not sufficiently acquainted with the business concerned to be able to choose the number of the particular extension required. If a manual board were not installed at a large P.A.B.X., therefore, the number of calls which would need to be transferred from extension to extension would be considerable, and much inconvenience would be caused. If the extension did not transfer the call to another extension the calling subscriber would find it necessary to make another call.

(ii) When all incoming exchange calls are answered at a manual board, the telephonist may be able to route calls to busy extensions to other disengaged extensions or ask the required extension to clear. This prevents delay to incoming calls and enables the public exchange apparatus to be cleared expeditiously. When all incoming calls are answered by a telephonist at the manual board, complaints of "No Progress" calls are minimised.

(iii) If subscribers could dial direct to P.A.B.X. extensions, all extension numbers would need to be listed in the Telephone Directory. This would entail an undesirable increase in the size of the directory.

(iv) If P.A.B.X. extensions were called direct by subscribers, it would be necessary to dial the P.A.B.X. number first, say, BF 4567, and then the number of the required P.A.B.X. extension, say extension 890. In this case, it would be necessary to dial BF 4567890 (a total of nine digits), and the possibility of wrong connections due to errors in dialling would be greatly increased.

(v) An information centre for the P.A.B.X. is necessary, and a manual board supplies this need. The manual board also provides exchange connections for extension telephones denied direct access to the public exchange.

(vi) The manual board also provides facilities for a telephonist to "Revert" a call, that is, to obtain a public exchange number and to connect or "revert" the call to a particular extension telephone.

Q. 3.—(a) What advantage is obtained by the use of Auto-auto Relay Sets (Repeaters) on junctions between 2,000 Type Automatic Exchanges and what functions do they perform?

(b) With the aid of a simple diagram show the connections, inside the Relay Set, of the circuit components in operation only when a conversation is taking place over the junction.

A.—(a) If outgoing selector levels were connected directly to the junctions and thence to an incoming selector at the distant exchange, it would be necessary to provide three-wire junction circuits in order that the holding and guarding functions of the private wire could be fulfilled. For economic reasons two-wire junctions must be used, and the use of Relay Sets (Repeaters) enables their use. The relay set repeats dialling impulses, thus avoiding the extension of the subscriber's calling loop to the distant exchange with consequent voltage drop and possible dialling distortion. The junction loop is fixed in value. The relay set and incoming selector are tied together and can be adjusted for best efficiency. For transmission purposes, it is necessary to provide a transmission bridge in the local exchange, and on junction calls the Relay Set (Repeater) feeds current to the calling party.

The general functions of an auto-auto Relay Set (Repeater) are as follow:—

(i) Connects guarding and holding earth to the P wire to hold preceding switches, and so allow the use of two-wire junction circuits.
(ii) Provides a transmission bridge to feed current to the calling party.
(iii) Repeats dialled impulses over the junction to operate selectors at the distant exchange.
(iv) When the called party answers—
 (a) Operates the calling party's meter.
 (b) Reverses the current on the calling line for supervisory purposes.
(v) When the caller clears, releases preceding and succeeding switches, and re-guards the junction to cover the release of the incoming selector.

(b) See Fig. 1.

for periodic testing. Connection to the line is made by plugs inserted into the M.D.F. protectors.

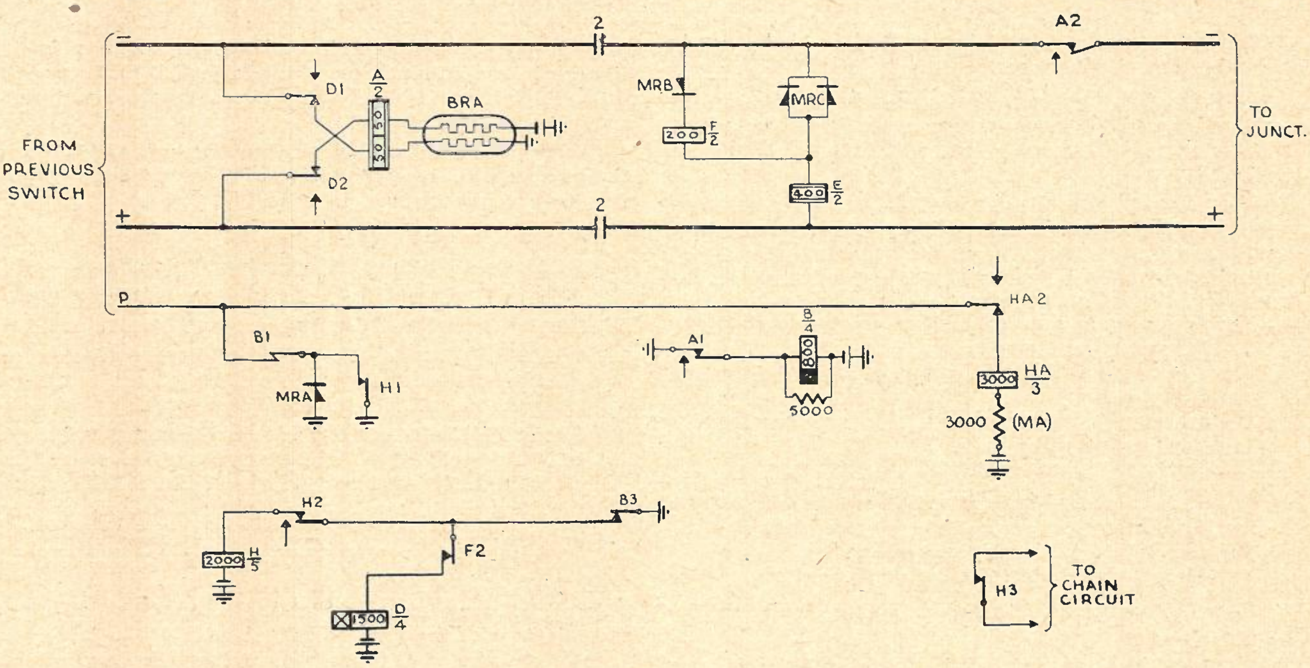
Q. 5.—An automatic exchange consists of uniselectors, first group selectors and final selectors.

(a) Draw a diagram showing the circuit elements in use on all ranks of switches for the purpose of registering an effective call on any system of call registration with which you are familiar.

(b) List the advantages and disadvantages of the system you show.

A.—(a)

The system of metering shown above is called "booster battery metering." The meter does not operate with the



Q.3, Fig. 1.

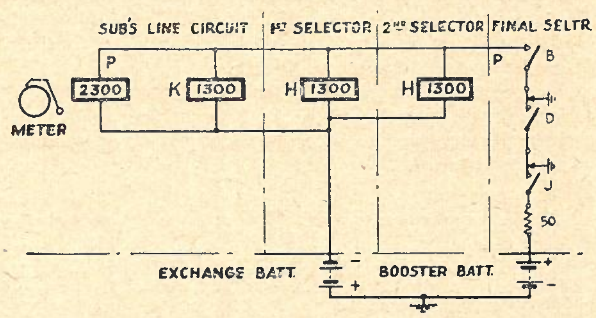
Q. 4.—(a) List the tests for which provision is made on a standard Test Desk in a large automatic exchange.

(b) What circuits are provided between the Test Desk and the M.D.F.?

A.—(a) The following tests may be performed on a standard Test Desk:—
(i) **Resistance tests,** loop and earth.
(ii) **Insulation resistance tests,** between wires, and each wire to earth.
(iii) **Capacity test,** between wires.
(iv) **Foreign Battery Test.**
(v) **Transmission tests.**
(vi) **Dial tests,** impulse speed, ratio and count.
(vii) **Calling Equipment tests.**

(b) (i) **Test Trunks to M.D.F. Line Side.** By means of a plug inserted into the fuse strip on the M.D.F., this circuit is connected to the line side of a service or to a cable pair.
(ii) **Test Trunks to M.D.F. Equipment Side.** This circuit is used to enable the test circuit to be connected to either side of a line by means of the "In" and "Out" key. Plugs inserted into the protectors on the M.D.F. make the necessary connections.
(iii) **Test and Plugging-up Iines.** This circuit enables a line which is out of service due to one of a number of faults to be plugged out of service, but available

normal 50 volts potential across it, but when the called party answers, operation of relay D in the final selector (relays B and J being previously operated) connects a 50 volt booster battery in circuit, raising the potential across the meter to 100 volts, allowing it to operate. Operation of relay D also opens the circuit of relay J, which is slow releasing, and after its release time (about 300 milliseconds) relay J contacts replace the booster



Q.5, Fig. 1.

battery with earth. The potential across the meter is reduced to 50 volts, but the meter remains operated until the end of the call, when relay B in the final selector releases. See Fig. 1.

(b) One advantage of this system is that there is no possibility with correct adjustment, of more than one operation of the meter for each effective call. This, however, is a disadvantage should "multi-metering" be required. Other disadvantages are:—

(i) Marginal adjustment of meters is necessary.
(ii) Special-metering battery is required.
(iii) The extra voltage imposes an extra strain on the insulation.

Q. 6.—Speed tests on two slow release 3,000 type relays gave the following results:—

Relay No. 1 released normally, but operated too slowly.

Relay No. 2 operated normally, but released too slowly.

What adjustments should be checked in each case to determine the possible cause of the trouble?

A.—Relay No. 1. The slow operation of this relay could be caused by excessive armature travel or excessive spring tensions, and these adjustments should be checked.

Relay No. 2. Insufficient residual air gap or light spring tensions could cause this trouble, and these should be checked. Sticking of the armature of a 3,000 type relay may also be caused by a black deposit at one or more of the following points:—

(a) On or around points of residual screw or stud and on the core face opposite,
(b) On the knife edge, and corresponding position on relay armature.
(c) On or around armature back stop and corresponding position on relay yoke.

If necessary these parts should be cleaned.

Q. 7.—In the central battery exchange, one side of the battery is connected to earth. Give the reasons for—
(a) the use of the earth connections, and
(b) earthing the positive terminal of the battery.

A.—(a) The reasons for earthing one side of the battery are—

(i) To provide a return circuit of negligible resistance for power leads to P.B.X's.
(ii) To provide a return circuit for signalling over junction lines.
(iii) To simplify the power switching circuit, and avoid the need for insulating the return conductor. Fuses and switches are required in only one of the leads (the negative) and not in both, as would be needed if the battery were not earthed.
(iv) To prevent crosstalk and other disturbances due to leakage and capacity currents between the circuits connected to the central battery. This is one important reason why the earth connection should be of as low resistance as possible.
(v) To ensure prompt indication of faults and assist in locating them. To assist in this respect, all mounting plates, racks, etc., in the exchange are connected to earth.
(vi) To assist in identifying line wires. The positive and negative wires may be readily distinguished by noting their potential in respect to earth.

(b) Earthing the positive terminal ensures that all lines and apparatus which differ in potential from earth are negative to earth, and any leakage currents flow from earth to the apparatus. This practically eliminates corrosion of the wires due to electrolytic effects. Also with the positive terminal earthed, partial earth faults show up more readily on test.

The power lead return current flows over the sheathing of lead cables, and with the positive terminal of the battery earthed, the cable is maintained at a potential negative to earth, and so the risk of electrolytic corrosion of the cables is reduced.

Q. 8.—(a) What are the advantages of the latest Standard Lamp Signalling Cord Type P.B.X. compared with the Eyeball Indicator Type previously the Standard?

(b) Draw a circuit diagram showing how a tie line is denied access to an exchange line. Show only the circuit elements in use for this purpose.

A.—(a) The advantages are—

(i) **Through dialling and clearing.** This allows—

(a) Reduced holding time of exchange switching plant.
(b) Improved accuracy in timing trunk line calls.
(c) If the P.B.X. is connected to a manual exchange, the extension may recall the operator at the exchange without the aid of the P.B.X. operator.
(d) If the P.B.X. is connected to an automatic exchange, extensions fitted with dials may make successive outgoing calls without the aid of the P.B.X. operator.
(e) The operation of the C.S.H. alarm at automatic exchanges, due to delayed clearing by the P.B.X. operator, is avoided.

(ii) The operator, when dialling a number, receives an indication of the progress of the call.

(iii) The use of lamp signals reduces the size of the switchboard cabinet. Association of the calling lamp with the jack facilitates the operation of the switchboard.

(iv) A V.F. termination during switching ensures balanced conditions for trunk lines connected to amplifiers.

(v) "Follow-on" exchange calls are trapped, and operate the exchange calling lamp.

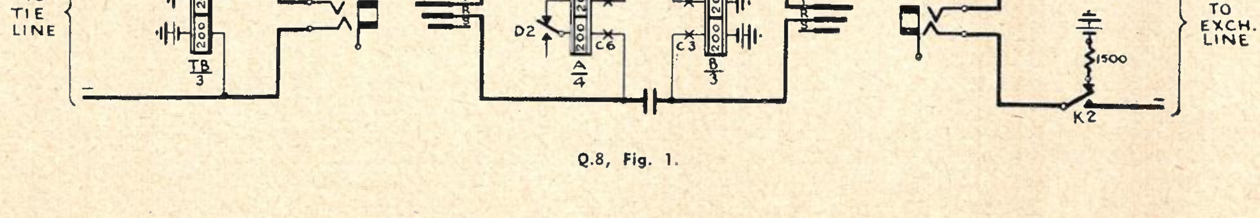
(vi) Any line may be night switched by normal cord circuits.

(vii) The use of plug seat switches is avoided, and when cords are not in use, battery is disconnected from plugs and cords.

(viii) "Call back" facilities may be given on any extension.

(ix) "Jacked in" equipment facilitates maintenance.

Fig. 1 shows the method used in the lamp signalling P.B.X. The front cord should be used to connect to an exchange or a tie line, and if an attempt is made to



Q.8, Fig. 1.

connect a tie line to an exchange line by inserting the rear plug into an exchange line jack, the battery from relay B in the cord circuit will be in opposition to that of the exchange line. The exchange line cannot be looped, therefore the call cannot proceed.

Q. 9.—(a) Explain what is meant by the term "Floating" as applied to an exchange main battery, and state what advantages are obtained by the practice.

(b) Describe with the aid of a sketch how the voltage applied to the exchange is automatically controlled when the battery is floated.

A.—(a) A battery is said to be floating if, when supplying a load, it is at the same time being charged. This means that the charging source is actually wholly or partially supplying the load, and the battery acts as a reserve supply in case of heavy load, or failure of the charging source. The arrangement has the following advantages.—

(i) More efficient, as the inefficiency of the battery is eliminated.

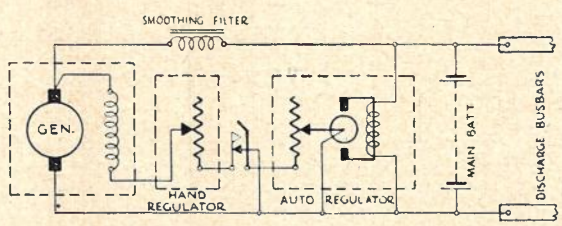
(ii) Voltage at busbars is more constant.

(iii) Battery is maintained in a fully charged condition, and gives its full capacity in an emergency.

(iv) Longer plate life is obtained.

(v) A smaller battery may be used thus reducing cost and saving space.

(b) The voltage at the exchange busbars is controlled within close limits by regulating the voltage output of the charging source. This may be either a rectifier unit or a motor-driven generator. In the latter case, a device called an "Automatic Voltage Regulator" is used to achieve the desired regulation. The principle of operation is shown in Fig. 1.



Q.9, Fig. 1.

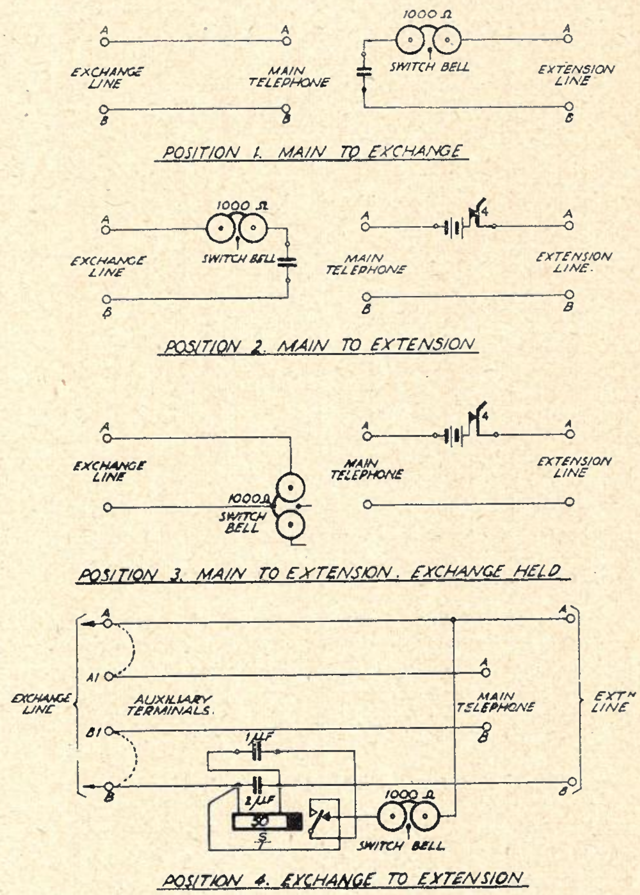
The automatic voltage regulator consists of two essential parts, (i) a torque producing device which may be either a solenoid or a moving coil, and is connected directly across the exchange busbars, and (ii) a variable resistance element actuated by (i), and connected in series with the generator field windings.

An increase in the exchange load results in a momentary drop in the busbar voltage, and the action of the voltage regulator is such that the resistance in the field circuit is reduced. The output of the generator is thereby increased to compensate for the increased load. Similarly, as the load drops off, so the generator output is decreased, and the voltage at the busbars is maintained within close limits.

Q. 10.—(a) Draw four schematic diagrams showing the circuit conditions in an Extension Switch, C.B. with the key in each position and indicate the position to which each diagram applies.

(b) State the functions of all components in circuit for the "Exchange to Extension" position of the key.

A.—(a)



Q.10, Fig. 1.

(b) (i) **Indicator relay** (S/1). This gives a visual indication at the main station when the line is in use. Its coil is shunted with a 2μF condenser to provide a low impedence path for speech currents, and its operated contacts connect an additional 1μF condenser in circuit, at the same time removing the switch bell from the lines to prevent distortion of impulses. It is fitted with a heel end copper slug so as to hold during dialling.

(ii) **Switch bell** receives signals from the exchange or from the extension telephone.

(iii) **Extension generator** allows the main station to be signalled from the extension. A 1μF condenser in the generator circuit prevents looping the exchange equipment and operating relay S while ringing.

(iv) **Switch generator** allows the main station to signal the extension.

EXAMINATION Nos. 3101, 3106 and 3107—SENIOR TECHNICIAN, TELEPHONE; RADIO AND BROADCASTING AND RESEARCH.

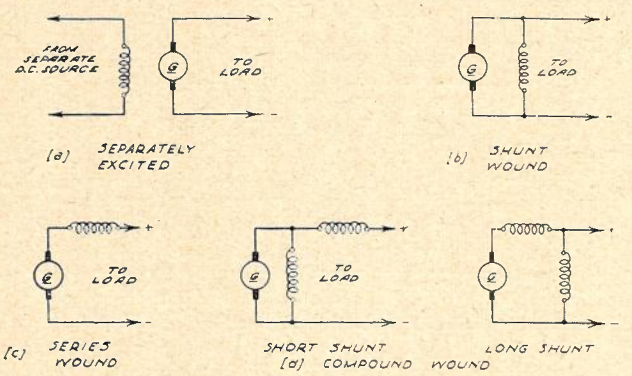
(a) ELECTRICAL THEORY AND PRACTICE

C. J. Peady

Q. 1.—(a) With the aid of a sketch describe briefly the various methods of field excitation of D.C. generators.

(b) Which method of excitation would you use in a generator which is required to charge secondary batteries. Give reasons for your choice.

A.—(a) Fig. 1 shows the various methods of exciting the field winding of D.C. generators.



Q.1, Fig. 1.

In (a), the windings are excited by current from a separate battery or generator.

The shunt-wound generator (b) has field windings of a comparatively large number of turns of light gauge conductor, which are connected in shunt with the armature coils.

In the series-wound generator (c) the field windings are of comparatively few turns of heavy gauge conductor, as they carry the full load current. The compound-wound generator is a combination of shunt and series type, and may be connected in "short shunt" or "long shunt" as shown in (d).

(b) In the charging of secondary batteries, an active opposing e.m.f. is set up, and if the generator e.m.f. should fall below the battery e.m.f., the latter sets up a current around the circuit in the reverse direction. This may be caused by a temporary slowing down of the prime mover, and in the case of a series generator, unless the machine recovers very quickly, this will result in the reversal of polarity of the machine. Operation of the circuit breaker should occur, otherwise the generator e.m.f. will work in conjunction with the battery e.m.f., thus setting up a very heavy current in the wrong direction, and endangering both generator and battery.

Such a state of things cannot occur with a shunt machine, as will be clear from Fig. 1 (b). If the battery e.m.f. does overcome that of the generator, the current in the field windings will still be in the proper direction, so that a reversal of polarity is not possible.

With compound machines there is some risk of reversal of polarity when used for battery charging, but not so much as with series machines; and the risk is slightly greater with short-shunt than with long-shunt generators.

For the above reasons, shunt machines are always best for use in charging secondary cells.

Q. 2.—(a) What is the meaning of the term "mutual" conductance as applied to a triode thermionic valve, and what is the practical significance of the term?

(b) The impedance of a triode is 20,000 ohms and its amplification factor is 30. What is its mutual conductance?

A.—(a) The mutual conductance (g_m) of a valve may be defined as the ratio of a small change in plate current (in amperes) to the small change in the control grid voltage producing it, under the condition that all other voltages remain unchanged. Thus it combines in one term the amplification factor (μ) and the plate resistance (r_a) and is the quotient resulting from dividing the first by the second.

Thus Mutual Conductance (g_m)

$$= \frac{\text{amplification factor } (\mu)}{\text{plate resistance } (r_a)}$$

$$\text{(b) } g_m = \frac{\mu}{r_a} = 30/20000 = 0.0015 \text{ mhos.}$$

or 1,500 micromhos.

Q. 3.—An iron ring of circular cross-section has a diameter of 2 centimetres and a mean length of 30 centimetres. If the permeability of the iron is 300 and the ring is wound with 200 turns of insulated wire through which a current of 0.25 amperes is passed:—

(a) What is the reluctance of the magnetic path?

(b) What is the flux density of the iron?

A.—(a)

Reluctance (S) $= 1/\mu \times l/a$.

where μ = permeability of magnetic circuit,
a = cross-sectional area of magnetic circuit, and
l = length of magnetic circuit.

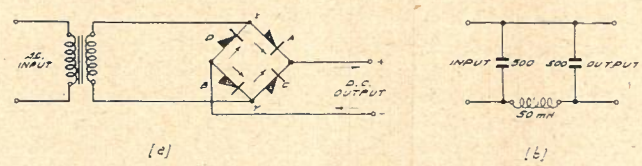
$\therefore S = 1/300 \times 30/(\pi \times 1)$.
$= 1/10$ reluctance units.

(b) Magnetic Flux Density (B)
$= 1.257 NI/Sa$.
$= (1.257 \times 200 \times 10\pi)/(\pi \times 4)$
$= 628.5$ Gauss.

Q.4.—(a) With the aid of a sketch outline the operation of a full wave rectifier of the metallic type, showing the direction of the currents in each component of the circuit.

(b) State the use to which this type of rectifier may be put and draw the circuit of a suitable filter for the use you nominate, showing the value of each of the components in the filter.

A.—See Fig. 1 (a). On those half-cycles of input current when point X is positive; current flows through rectifiers A and B in the direction shown. Rectifiers C and D are non-conducting, so that the current must pass through the load.



Q.4, Fig. 1.

On the alternate half-cycles when point Y is positive, rectifiers C and D conduct and rectifiers A and B block the current. Thus the current in the output circuit is unidirectional.

(b) This type of rectifier could be used to "float" the battery at a P.A.B.X. installation. To reduce the ripple voltage a filter circuit as in Fig. 1 (b) would be necessary.

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