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The New Melbourne Trunk Exchange

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Introduction

In January, 1938, the tender of Siemens Bros. & Co. Ltd., Woolwich, England, was accepted for the supply of a new trunk exchange for Melbourne, Victoria. Delivery of the material commenced some months ago, and installation work is in progress. The cutover will take place in two stages: (a) the interstate trunk lines not later than November next, and (b) the intra trunk lines, assuming normal progress, towards the end of 1940.

The work is one of considerable magnitude and with Melbourne as centre involves the whole trunk-line network of the State of Victoria, the interstate trunk lines to Sydney, N.S.W., Adelaide, S.A., and Hobart, Tas., and the trunk lines to several centres in New South Wales.

The new trunk exchange will be located in the City West Telephone Exchange Building, Melbourne, and will occupy three floors of this building, the allocation being:

(a) Third floor—carrier, repeater, testing and patching equipment, etc.;

(b) fourth floor—trunk line switching equipment, voice-frequency equipment, and associated apparatus;
(c) fifth floor—operating suites.
} Siemen's contract.

Switching System

The system is semi-automatic in principle in the sense that all traffic is routed and switched by automatic selecting equipment controlled by the telephonists on the various operating suites.

Incoming traffic is distributed automatically to the telephonists, and outgoing traffic is steered through the system by senders controlled from keysets on the positions.

Operating Positions

All positions in the main suite, irrespective of the type of traffic handled, are similar in appearance and are of the same size. The shelf equipment consists of keys, supervisory lamps, call-timing devices, ticket clips, pneumatic tube outlet and bulletin space. The face equipment consists of pneumatic tube inlet, bulletin space, ticket receptacles and a strip of lamps. All positions are not identical in respect of the equipment provided, as this is a matter which depends on the type of traffic to be handled.

The positions are of the cordless type, that is, cords, plugs and multiple jack field are absent.

Other equipment mounted on the positions has been kept down to the absolute minimum, and speaking broadly consists only of the telephonist's circuit and monitoring equipment.

Switching Equipment

The switches are of two types—Siemen's high-speed motor-driven uniselector and the British Post Office standard 25-point ratchet-driven uniselector. The former type of switch greatly predominates, but even then switches represent only a relatively small proportion of the total equipment. Only two types of relays are used—the British Post Office standard 3000-type and the Siemen's high-speed type.

The Siemen's high-speed switch[1] hunts at a speed of 200 to 220 steps per second. All these switches operate on the finder principle—that is, instead of impulsing being employed to step the switch to a required outlet, the outlet will be marked and the switch will hunt till this contact is reached. All codes or digits set up on the keysets are received by the senders, and translated by the latter into appropriate markings on the banks of the switches. The code translation and subsequent marking are practically instantaneous, and this combined with the high searching speed of the switches gives an extremely fast method of setting up connections. Furthermore, since the switches do not operate on a numerical or step-by-step principle, this means that numbering and trunking are independent of each other, and as the switch is a single motion type the outlets can be distributed over a number of groups ranging from one to something appreciably over ten, and the spare outlets can be pooled.

Ratchet-driven uniselectors are used in the transmission path in two instances where a small

[1] "The Motor Uniselector and High Speed Relay," by H. E. Humphries. P.E.S. of Vic., paper No. 25.

outlet availability is required: apart from this, these switches are employed mainly as sequence switches and for similar functions. In no part of the system are ratchet-driven switches subjected to heavy duty.

The switching equipment will be mounted on single-sided standard racks 10 ft. 6 ins. high and 4 ft. 6 ins. wide. Approximately 100 racks will be required for the initial installation.

Voice Frequency Signalling

The system adopted is termed a "simple frequency" system, and employs alternating currents of two frequencies for signalling, designated "X" and "Y" of 750 and 600 cycles per second respectively. These frequencies were allocated by the C.C.I.F.

The main characteristic of a simple system is that the signalling frequencies are always impressed on the line singly and never simultaneously, whereas the essential feature of a "compound" system is that the signalling frequencies are impressed on the line simultaneously as well as singly. These differences have rather far-reaching effects, but cannot be discussed at this stage.

The factors responsible for the adoption of voice frequency operation are—

(a) the number of carrier systems in operation;

(b) the use of intermediate and terminal speech amplifiers on a number of lines;

(c) the use of phantom or superimposed telephone or telegraph channels on a number of lines—

making the use of the speech channel essential for signalling. Furthermore—

(d) to secure maximum efficiency from the trunk-line network, a complete and efficient system of control and supervision is essential, and can be provided only by voice frequency operation. Then again,

(e) as the various country exchange telephonists will be given direct access to Melbourne metropolitan automatic subscribers, and as the main trunk exchange telephonists will have direct access to country automatic subscribers, the impulses received by the incoming selector must be practically distortionless. This requirement is very easily met by a correctly designed voice frequency system. Finally,

(f) transit working and the more complicated types of call routings cannot be arranged satisfactorily unless voice frequency operation is adopted.

The "X" and the "Y" frequencies impressed on the line at the sending end operate a receiver at the receiving end. The Siemen's receiver consists essentially of three thermionic valves, three tuned circuits and two relays. The incoming signal is fed to the grid of one of the valves, and the output from this valve is fed simultaneously to

(i) a circuit sharply tuned to 750 cycles per second, thence to the grid of a pentode which controls the operation of the "X" relay;

(ii) a circuit sharply tuned to 600 cycles per second, thence to the grid of a pentode which controls the operation of the "Y" relay;

(iii) a circuit broadly tuned to 375 cycles per second, thence to the grids of the pentodes referred to in (i) and (ii).

If the input is 750 or 600 cycles, the "X" or the "Y" relay will respond, but if the input consists of a mixture such as occurs in speech, even if 750 or 600 cycle components are present, most of this will pass into the circuit mentioned in (iii), the effect of which will be to cut off the "X" and the "Y" circuits. The output from the first tube remains appreciably constant over a wide input range, and, speaking broadly, if not altogether accurately, it can be said that speech immunity is secured, firstly, by limiting the output from the first tube, and secondly, by ensuring that this output must consist of either 750 cycle or 600 cycle tone before the receiver will respond.

The "X" and the "Y" relays are connected in the anode circuit of their respective pentodes, and are of the high-speed type. Both these relays are fitted with a single set of changeover contacts, and control a separately mounted relay set in which all the various circuit conditions are established.

The speech immunity provided by the receiver itself is insufficient since the "X" and the "Y" frequencies occur in speech and often predominate to an extent where false operation of the "X" or "Y" anode relay takes place, particularly as these relays are of the high-speed type. The relay set, therefore, is designed to discriminate between proper signals of either frequency and the transient operation of the anode relays by the "X" and the "Y" components of speech.

Trunk Line Network

Before going into further detail, it is necessary to describe the manner in which the trunk line network in Victoria will be arranged—an arrangement which primarily has been based on transmission considerations.

The State of Victoria, from a telephone standpoint, will be termed a region, and Melbourne will be the regional centre. The State will be divided into eight zones, and the principal telephone exchange in each zone will be the zone centre. In each zone there will be a number of group centre exchanges, which in turn will have access to terminal exchanges. The last type of exchange represents the final stage of subdivision. In this arrangement many of the group centre exchanges will be connected to the regional centre as well as the associated zone centre, and a number of terminal exchanges will be connected to the zone centre exchange as well as the associated group centre. The regional centre exchange—Melbourne—will also function as a zone exchange for its own area, mainly metropolitan and sub-metropolitan.

The trunk lines will be of three types, namely:

(a) **Interstate:** These lines connect the various capital cities in each State, that is, regional centres. For the new installation the routes involved will be Melbourne-Sydney, Melbourne-Adelaide and Melbourne-Hobart.

(b) **Main:** These lines connect the regional centre—Melbourne—with (i) the zone centres, and (ii) the group centres with direct circuits to the regional centre.

(c) **Minor:** These are lines of minor importance, and are confined mainly to the sub-metropolitan area and will be connected therefore to the regional centre.

The ultimate aim of the transmission scheme is to confine all trunk line connections to an attenuation of 15 decibels, and with this end in view trunk lines will be graded into three classes, namely:

CLASS 1: zero equivalent.
CLASS 2: zero to 4-db.
CLASS 3: 4-db to 7-db.

The interstate lines—RC-RC—will be class 1 circuits. The main trunks also will be class 1 in the ultimate scheme, although initially a number will be class 2, the latter being confined mainly to the RC-GC (regional centre-group centre) routes. The minor trunks will be class 2 and class 3 as well as the lines between terminal exchanges and group centre exchanges.

All class 1 circuits, with possibly a few exceptions, and a number of class 2 circuits will be carrier channels. Where required, class 2 and class 3 physical circuits are equipped with intermediate or terminal speech amplifiers.

Signalling on the interstate lines—RC-RC—will remain the same as at present, that is, 17 cycle between the carrier terminal and the switchboard, and 1000 cycle on the carrier section.

Signalling on all main trunk lines will be by means of voice frequency equipment. Minor trunk lines, in view of their relatively small importance, will be operated on a magneto or a common battery signalling basis. From this it will be seen that voice frequency signalling is being confined to main trunk lines only.

The circuits between the main trunk exchange (RC) and the various group centre exchanges (GC); that is, RC-GC routes will be provided on the basis that each such route will be able to carry only part of the busy hour traffic: the exact amount will probably be slightly less than the mean over the busier portions of the day. To take care of the "peaks," that is, the traffic which cannot be handled by the direct routes, a secondary route will be available via the zone centre exchange. Thus during normal periods the routing will be RC-GC, but if the primary route is congested the call will take the route RC-ZC-GC. By this means it is possible to ensure that the RC-GC trunks are fully worked, and greater efficiency is also secured in the RC-ZC route since this route, as well as carrying traffic for the zone centre itself, also carries the peak traffic for group centre and terminal exchanges in the zone, and it is unlikely that all "peaks" will occur simultaneously. Likewise all GC-RC traffic from the zones will have secondary access via the zone centre, that is, GC-ZC-RC.

In the main trunk exchange itself the secondary route will be selected automatically when the primary route is congested, and a telephonist calling a group centre exchange in a zone will not know the route taken by the call. This will be referred to later when call storage is discussed.

A point still to be decided later is whether the RC-ZC routes should be arranged as a single group carrying traffic for the zone centre itself as well as the peak traffic for the group centres, or alternatively to arrange these routes in two groups, and separate the direct and the through traffic. The first arrangement is the more efficient from a traffic standpoint, but has the disadvantage that it may react unfavourably on the zone centre. Probably a combination of both methods will be adopted.

Four Wire Switching

From a switching standpoint all the trunk lines will fall into one of the following groups:

(a) Straight-forward 2-wire circuits terminating in an isolating transformer;

(b) 2-wire circuits with intermediate speech amplifiers;

(c) circuits with or without intermediate speech amplifiers, but carrying terminal amplifiers;

(d) carrier circuits.

Although the lines referred to in (c) and (d) may be properly matched on the line side, the fact that many of the actual physical lines are lengthy and of aerial construction makes it difficult to retain accurate balance at all times, due to climatic variations, with the result that high repeater gains cannot be achieved owing to the risk of "singing" when these lines are switched. To obviate most of these difficulties, it was specified that the hybrid network pairs were to be disconnected from their networks and switched through also and a reversal introduced to retain proper phasing.

In this method of switching the hybrid coil losses disappear—3 db. per hybrid—and the gain which results is balanced out by the insertion of attenuation pads in the terminal switching circuits. The effect is that stability is greatly improved without degrading transmission.

When lines with 4-wire terminations are switched through to lines with 2-wire terminations the overall transmission equivalent may still be too low, and when this is so the attenuation padding will be removed. All discrimination as to whether a connection is to be 4-wire or 2-wire and whether pads are to be in or out of one or both circuits will be effected automatically immediately the two circuits are connected.

When a telephonist speaks on a 4-wire connection the circuit conditions temporarily revert to 2-wire, but return to 4-wire when the telephonist leaves the circuit.

Country Equipment

Ultimately the zone centre exchanges will be equipped for the automatic routing of trunk line traffic in conjunction with a manual trunk switchboard in the zone centre exchange. Initially all zone centre traffic—that is, direct and through—will be handled manually, excepting in one or two exchanges where automatic equipment is already installed for subscribers.

Most of the group centres will be manually operated, but there may be exceptions where the incoming trunk traffic will be routed through automatic switches. Terminal exchanges will be manual for the time being at least.

Excepting where automatic selecting equipment is installed, or power plant is available in an exchange, all country voice frequency equipment will be operated direct from the public electric supply mains. This arrangement saves the cost of batteries and their maintenance charges.

Where mains operated equipment is installed the whole of the equipment will be accommodated on small self-contained racks, each with a capacity for five circuits. There will be one V.F. receiver and one relay set per line, whilst common equipment such as tone generating equipment, power supply, etc., will be provided for each two racks—thus an installation of three racks will provide two sets of common equipment, with switch-over arrangements should one set of common equipment fail. Where an installation consists of one or two racks only, essential spares will be held.

Method of Handling Trunk Line Traffic, Facilities, etc.

As far as possible, trunk line traffic will be handled on a demand basis, with the exception that during the busy periods traffic passing over the interstate routes will be handled on a delay basis.

All the main trunk lines, that is, those equipped with voice frequency signalling equipment, will be arranged to provide direct access to Melbourne metropolitan subscribers by dialling subscribers connected to automatic exchanges, and by dialling the manual exchange for subscribers connected to manual exchanges.

Incoming traffic from the main trunk exchange at zone centre and group centre exchanges will be handled on a manual basis, excepting that where the trunk line is selector ended the services of the "centre" telephonist will not be required on calls to local automatic subscribers, rural automatic exchanges, branch trunks or combinations of all three.

Traffic between country exchanges which involve main trunk lines will be handled on a special suite of positions in the main trunk exchange. This is to ensure that the main trunk exchange will always have control of the circuits, as otherwise country telephonists might possibly monopolise trunk lines.

The main operating suites will be disposed as follows:—

(a) **Demand:** This suite will receive all demands for trunk line calls from Melbourne metropolitan subscribers, and will complete all such calls on a demand basis when possible. The only exception is demands for interstate subscribers, which are handled from the interstate positions.

(b) **Delay:** These positions form portion of the demand suite. During periods when trunk groups are congested and demand service cannot be given certain positions will be operated as delay positions and will attend to trunk groups in delay until the accumulation of calls has been worked off and demand service can be restored.

Incoming calls to the demand suite are queued and answered in their order of arrival. Each position is fitted with a strip of lamps mounted vertically on the face, and the number of lamps glowing corresponds with the number of calls waiting to be answered. Should a call remain unanswered for more than a predetermined period the waiting call lamp will flash on all positions. Waiting calls are taken out of the queue and answered by free telephonists, but during slack periods telephonists may set their positions so that incoming calls are routed direct to the positions. Trunk groups in delay are not accessible to the demand telephonists, and should a trunk group in delay be called by a demand telephonist a delay lamp on the position flickers, flashes or glows steadily to indicate firstly that the called group is in delay, and secondly that the delay is 15, 30 or at least 45 minutes respectively. The demand telephonist informs the caller accordingly and passes the ticket to the pneumatic tube distribution position, from where it is forwarded to the delay position operating the trunk group, where the ticket is dealt with in its turn.

(c) **Through:** This suite handles all traffic between the main trunk lines and the minor trunk lines. The minor trunk lines are worked from this suite, excepting for interstate calls. As stated earlier, the reason for main trunk-main trunk calls being set up on the through positions is to ensure that the circuits will be under the control of the main trunk exchange. All calls set up on these positions are under the control of the telephonist, even though she may be functioning in the capacity of an intermediate "B" telephonist.

Since a through connection may involve three or four telephonists, and two main trunk lines, various release conditions have to be taken into account, and the circuit designed to meet them. For example, assume that one group centre exchange has called another group centre exchange, and designate these exchanges A and B respectively. The call routing is, therefore, A-RC-B, the direction of the call is from A to B, and two main trunk lines are involved, that is, A-RC and B-RC. The final release of such a connection rests with the through telephonist in the main trunk exchange. Through supervision will be given between A and B, and these signals will also appear on the through position. When one of the subscribers has cleared, this normally will be followed by a clear from the other subscriber. Since the call will be timed by A, and A nominally will be the supervisory telephonist, the first trunk release signal should originate with A, and assuming it does this will show at RC and B. Assuming that B clears before RC, then two main trunk lines are tied up until RC breaks down the connection, and under these conditions the outgoing appearances at both A and B will be busied out until the lines are released by the RC and return to normal. If the RC releases before B, then the A-RC circuit returns to normal, but the circuit between RC and B remains busied out at both ends until B releases. This illustrates the principle followed, which is that no main trunk will test free unless it is clear at both ends.

(d) **Interstate:** This suite handles all traffic which involves an interstate trunk line. During the busy periods the interstate lines will be worked on a delay basis. Each telephonist normally will operate two circuits and will keep in continuous touch with the distant interstate telephonist at the other end of the circuit. During slack periods the interstate circuits will be operated on a ring-down basis with call queueing. Metropolitan subscribers asking for interstate subscribers will be answered by a demand telephonist, who will fill out a ticket and request the subscriber to hang up and wait. The ticket will be passed to the interstate suite, where it will take its turn, the subscriber being called by the interstate telephonist when the call matures. The delay on the interstate routes will be displayed by means of lamp indicator boards visible to all telephonists, and when a telephonist books an interstate call she will inform the caller when the call may be expected to mature.

The interstate trunk lines are accessible from the interstate suite only—that is, these circuits cannot be reached from any of the other suites.

(e) **Suspense:** This suite receives all tickets for calls which are held up on account of the called subscriber being unavailable, etc. Excepting when the calling party is interstate the call will be completed from this suite. Tickets for incoming interstate calls will be returned to the interstate suite when the called Victorian subscriber becomes available.

In addition to the main operating suites described in (a) to (e), the following special positions are also being provided:—

(f) Traffic Officer's Desk.

(g) Monitor's Posts.

(h) Pricing Positions.

(i) Pneumatic Tube Distributing Position (PDP) on which all tickets are received and distributed. The pneumatic tube arrangements will be the same as those followed by the British Post Office.

(j) Delay Supervisor's Position.

Metropolitan automatic subscribers desiring trunk-line service will dial "Y" and will be automatically routed to an incoming queue associated with the demand suite. Manual exchange subscribers will be plugged through on special circuits, or the "A" telephonist will route the call via the nearest automatic exchange. Incoming demand traffic will reach the trunk exchange over class 2 or class 3 junctions terminating on 24-outlet ratchet-driven uniselectors trunked to demand distributors, the latter being of the motor-driven type with 200 outlets, 10 of which are used for call queueing and 180 for access to the demand suite. When a call arrives one of 24 demand distributors is seized, and this switch searches over the first 10 contacts to find its queue position and remains there till the call is answered. As calls are answered new queue positions are not taken up, but the queue is rotated to avoid this. Waiting call lamps display on all demand positions and show the number of calls waiting to be answered, and, as stated earlier, flashing occurs on calls which have waited for a predetermined period. The number of waiting calls is displayed on the delay supervisor's position.

Trunk groups being worked on a demand basis may experience occasional periods of congestion, but not to an extent which justifies the introduction of delay working. Under the conditions stated, calls for congested groups will be stored, and delay working will not be introduced unless the number of stored calls becomes too great. The number of stored calls for each group will be shown on the delay supervisor's position, and under normal conditions delay working will be introduced automatically when the number of stored calls reaches a figure which can be decided for each group, and a group will then remain in delay, irrespective of its condition, till demand conditions are restored by the delay supervisor. Delay working can be introduced by the delay supervisor at any time, the matter being merely one of operating keys on the delay supervisor's desk. When a call goes into storage the approximate waiting time is signalled to the telephonist by means of tones, and she can then use her own discretion as to whether she holds the caller or not. When a line in the group becomes free the supervisory lamp on all stored calls will flash and will remain flashing till the circuit is seized by one of the waiting telephonists.

Another interesting point in connection with the call storage arrangements is that stored calls are always shown for their primary route, that is, where a secondary route is available, and both the primary and the secondary route is congested, the call goes into storage on the primary route. This applies to the secondary route, whether the outlets from the main trunk exchange are congested, or congestion has been encountered on outlets from a zone centre exchange. To make this point clear assume that a primary route RC-GC is congested: the sender in the RC immediately sets up the call via the secondary route RC-ZC-GC and on this routing congestion can be experienced at two points, (a) in the RC itself on the RC-ZC section, and (b) assuming that a circuit to the zone centre is available, then it is possible to experience congestion on the outlets from the zone centre, that is, the ZC-GC section, and whether (a) or (b) is experienced the call goes into storage on the primary route.

Senders

The senders are responsible for all call routing, and function as a common group available to all positions. In the trunk exchange itself the senders translate the trunk line codes into bank markings, and having steered a call to the required outlet, then transmit d.c. or v.f. impulses as required to complete the routing external to the trunk exchange.

Calls for trunk groups in delay and calls which go into storage do not go beyond the senders, as the condition of a trunk group is tested by the sender: selecting switches do not leave normal unless an outlet is available in the required group.

Concluding Remarks

The foregoing description is very broad and is intended to cover points of general interest only. In subsequent articles a more detailed technical description will be given.

Rural Area Telephone Systems

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Nowadays it is hardly necessary to emphasise the necessity to raise the telephone service for rural areas above the present-day results. All administrations are intent on stopping the exaggerated increase of the big cities and to distribute the settlement of an increasing population over the "country," where better living conditions may be found than in the cities. The increase of the present small settlements or the creation of new ones will, however, be successful, only if the new settlers are not cut off from the business life. That would be so if they could not conveniently use the nerves of business, i.e., telecommunication. The most practical telecommunication is the telephone. Today the small manual telephone offices give service only for a few hours per day. This is a serious inconvenience even for small business houses. One of the principal features of a modern rural area telephone system is a 24-hour service.

A plant, however, shall not only give a good service, it must be also "economical." The economy has two sides: the tariff shall be moderate and the owner of the plant should cover his expenses and have a small surplus.

The talking density in rural areas is usually small and mostly the "internal" traffic, i.e., the traffic inside the local tariff zone is smaller than the "external" traffic, i.e., the traffic using trunk lines with charges by time and zone.

For manual operation the 24-hour service requires at least two attendants whose working time is not well used. In all countries with high labour cost the salaries of these attendants are a heavy burden for the subscribers.

The geographical density (subscribers per sq. mile) is very much lower in rural areas than in cities. In order to cut down the operating cost the manual rural exchanges should be so large that the working time of the attendants is not too much out of proportion with their presence. But then the subscribers' lines become long and the annual charges for them become too large.

Three types of traffic must be considered for rural areas: the local traffic or calls within an area having a uniform tariff independent of zone and time, rural area traffic and trunk (or long distance) traffic. The latter distinguish themselves from the local traffic by the extra charges by zone and time charges on lines extending beyond the local tariff zone. In some cases short trunks are charged by zone only, not by time. A definite distinction of rural area and trunk traffic is impossible. It is not the diameter of the area. The German Railroad has subscribers dialling over 900 miles. This large system is for internal use and the costs of the connections are not charged to the subscribers. A practical dividing line may be established from the statistics. In Germany over 80 per cent. of the total trunk traffic lies inside of 50 miles. These distances are reached without amplification. The trunk lines being comparatively short, the number may be ample for "on demand" operation. The charges are moderate, so that simplified charging methods (no tickets) are justified. The rural area directly dialled traffic may be restricted to the features of local calls, omitting, e.g., person to person calls, charges reversed, appointment calls, messenger calls, etc. Such features cannot be suppressed entirely. Therefore one outstanding feature of rural area plants must be that every connection (except local calls) may also be set up by an operator in the usual way of recording the call on a ticket. Such a call may be finished semi-automatically by the on demand or delay method.

At the present time it seems practical to designate a rural area plant as one where the trunk connections have the features of local connections, the charges, however, being trunk line. In many existing rural areas almost 100 per cent. of the connections are dialled by the subscribers themselves.

A study of rural area telephony is to be based on a technical and an economical analysis. In a previous article (Automatic Telephone Plants, see page 136, Vol. 2) two genealogies show the extent of the problem. We proceed now by applying these genealogies to rural area systems.

Amongst the "generalities" the geography is the first study to be made. It is necessary not to confine the study to the one area under first consideration. The rural area operation will grow beyond a single district and a plan for the future should be developed so that the area first built will fit into the general layout.

Equipment

As a general rule for the equipment the simplicity and adaptability of the fundamental system are the controlling considerations. Small rural exchanges are not permanently attended. The requirements of trunk dialling possibly over lines influenced by high tension, the zone or time zone metering, the necessity to connect bad subscribers' lines, etc., bring many complications which are easiest embodied if the fundamental system has the possibly simplest design.

The fundamental system should be useful for exchanges of 10 or less lines up to unlimited sizes. It is not a good plan to use different types of operation (e.g., forward or revertive impulsing) for exchanges of particular sizes, the co-operation would unnecessarily complicate the fundamental circuits. The adaptability refers mainly to the feature of the system that future requirements (number of subscribers, new types of tariffs, new exchanges, advanced requirements of transmission, two and four wire trunk lines, etc.) may be added without fundamental changes in the existing plants.

Going into the details of the **apparatus,** preference should be given to the "self-contained" switches, i.e., switches with their own driving means, not depending on common drives. The safety then depends only upon the battery and the fuses in the current distributing wires. The driving motors of machine-driven systems are either run from the public power supply, which is not always very reliable in the villages, or they depend on the battery for their comparatively very large current consumption.

The **current supply** is difficult, if there is no public power available. The charging of a (non-attended) satellite battery over the trunk lines is possible if a sufficiently high voltage is available at the main office and if the resistance of the trunk lines is low enough to allow the transmission of the charging current. Otherwise a charging outfit with an oilmotor on a truck, or exchangeable batteries must be resorted to.

The **"line plant."** Subscribers' lines in country districts are sometimes long and expensive to maintain. It shall be possible to operate then with local battery telephones because the microphone receives the proper feeding current, as long as the dry-cells are in shape. The maintenance of the dry-cells is sometimes considered as an objection to local battery operation, but it must be compared with the maintenance of the subscriber's line. The trunk lines between the exchanges must be kept up in good order.

In rural areas the subscribers' lines and most of the trunk lines are overhead wires subjected to all climatic influences.

Rural exchanges of 20 lines or less need no **building** of their own. But it is not good enough to install them "anywhere." The room should be clean, dry, dust-free and free of insects. The installations in rented rooms are subjected to the danger of the cancellation of the rent.

The Circuits

We will discuss only the special requirements of the rural areas affecting the many circuit elements. The **dialling** is subjected to the properties of the lines: resistance, capacity, leakage. The principal problem is not the working of the driving magnets. They always are energised in local circuits, so that the line properties do not affect them directly. The connection between the lines and the system is the line relay. This relay refuses to pull up if the resistance is too high and refuses to drop if the leakage is too high. Resistance and leakage distort the impulses. Very often it is said that the line relay should be very sensitive to operate on "long lines." No—it should be insensitive. A sensitive relay will hang on over the leakages. But there are long and bad subscribers' lines, and for these the best solution is the "inductive" dialling. The "bad" line is closed at both ends by transformers. For dialling, a direct current supply (microphone battery) is closed and opened on the primary side of the transformer, the secondary transmits positive and negative peaks over the line. The transformer on the incoming side transfers these peaks again to the polarised line relay on the exchange side. So the line relay is not connected to a power supply and it cannot "stick over a leakage." A subscriber's line may be a loop of one wire and ground.

Any line may be subjected to high tension induction that may reach the danger point for the lives of subscribers and staff. They must be insulated by transformers at the ends, and inductive dialling is a safe way to operate them.

The engineers have the choice of d.c., a.c., inductive, voice frequency directly or with high frequency modulation and wireless dialling. A discussion of the merits of these methods would distract us too far into details.

The continued use of the many l.b. subscribers' stations with generators for signalling brought the development of the **"semi-automatic systems."** The turning of the crank causes the establishment of connection from the calling line over the local office and (possibly) several tandems to an operator's position in a main office, serving many local offices. This operator answers and, if necessary, dials back over the established ordering connection. After the introduction of this semi-automatic operation there came the demand to build "mixed systems," some exchanges to have fully automatic, some semi-automatic service. This "mixed" system complicates the circuits. The latest development tends to use only fully automatic service, including the dialling from l.b. stations after adding a condenser and a dial to these stations.

The **Guarding** is extended beyond the guarding in local exchanges, if two-way trunk lines are used. If such a line is engaged at one end it must be guarded at once at the other end to prevent a seizure in the opposite direction.

The **speaking circuit** has two principal problems: transmission and noise. The transmission is controlled by the "recommendations" of the C.C.I.F. It seems advisable to operate a rural area over non-amplified lines, but there are also developments bringing four-wire trunk lines far into rural areas. In some countries (Germany, Switzerland, Holland) the subscriber's dialling is extended across the whole country. The long lines have four-wire amplified service. It is the problem of how far into the rural areas these four-wire channels and their carrier systems should be extended.

The **power supply,** regarding the circuits, is a question of the safety of the impulsing relay. In a 60-volt system the impulsing bridge may have 1000 ohms. Taking the resistance of the subscribers' station to be 100 ohms, the maximum current is $60/1100 = 55$ mA, the energy is 3.4 watt and the impulsing bridge receives $3.4 \times 1000/1100 = 3$ watt. With a loop resistance of 1000 ohms the impulse bridge receives .8 watt. With 24 volt and an impulsing bridge, e.g., of 400 ohms, the impulsing bridge receives (at no resistance of the loop) .9 watt and with a 1000 ohms loop .1 watt. The operation with .8 watt certainly is safer than with .1 watt. For long subscribers' lines with C.B. stations the higher voltages are preferable in spite of the cost of the power supply. Microphones with high feeding currents restrict the lengths of the subscribers' lines.

The **release** in rural areas is subjected to interferences (thunderstorms, surges, high-tension induction) more than in cities. The interferences may "dial" or release. So the release over interfered lines should have a shape that cannot be produced by the interfering sources (e.g., 11 impulses in a specified sequence or as per recommendation of the C.C.I.F.).

The trunk lines in rural areas are usually limited in numbers. A subscriber should not hold it to the detriment of other subscribers. A connection is, therefore, usually automatically released after 9 or 12 minutes.

In rural areas numerous **accessory** circuits are incorporated beyond the needs of city exchanges. The multiple metering (time zone metering) will be discussed in a separate article. All the methods of dialling besides d.c. dialling require new circuits. Two-way operation of trunk lines usually do not pay in cities, because the city traffic is heavy enough for one-way junctions between city exchanges, but not so in rural areas. Local battery stations will hardly be found in automatic city offices. Multiparty lines are a matter for settlements along straight lines in rural areas. In cities the talking time is never restricted, but it is so in rural areas. All these features necessitate "accessory" circuits.

The "storing and translating" circuits are primarily introduced to adapt the decadal dialling to the non-decadal setting of the switches, resulting also in the revertive impulsing.

To **"store"** something means to put it up somewhere for future use. So some dialled digit or a whole number may be stored in a "register." Later on, they are transferred, e.g., to talking switches. Or, if an outgoing call from a satellite does not find a free trunk, the "order" is stored (not the dialled figure), and, after a trunk line becoming free, the "stored order" recalls the subscribers who will then set up the connection.

"Translation" means to change the numerical values of the digits or to add some digits that had not been dialled or to suppress some dialled figures.

These two elements, storage and translation, have then been used also for other deviations from the purely decadal setting up of the connections. It will be shown that the problems of the rural areas are solved without 100 per cent. storing and translation, i.e., by partial storage and translation and by other means.

Discrimination is a general term for methods to start the building up of a connection over some paths and then change it to some other paths.

Re-routing. Assume three exchanges A, B, C. The peak of the load A to B shall go over C. A translator directs this peak from A to C and inserts a digit to set the switch in C to the direction C to B. This extra digit is not necessary. If the switch in A does not find a free trunk to B it hunts up automatically a free trunk to C. At the incoming end at C a preselective uniselector parallel to the regular selector is attached standing on a free trunk to B. If the trunk line A to C is engaged for a call A to C the regular selector is engaged, if engaged for a re-routed call the uniselector is engaged. This change-over is enacted by a discriminating impulse sent after the engagement of the trunk line in the office A.

Another case of re-routing is the revertive connection to local switches in satellites. In automatic systems the originated traffic is first concentrated (e.g., by preselectors or call finders) on the first dialled switch stage (first selector or register), then distributed to different directions. In rural areas (also in satellites in cities) it would not be economical to put the first distribution into the small exchange. So the originated traffic of satellites, etc., is collected in the first distributing stage in a main office (first selectors). A **"discriminator"** in the satellite, etc., stores the code-number of the desired exchange. If the dialled code-number is the one denoting the local exchange it will free the trunk line and revert the connection to local switches for the rest of the number (partial storage and translation in so far as the finished connection "swallowed" some digits).

A **blind engagement** is an engagement of a switching stage and the consecutive freeing of it after a reverting action. The blind engagement is objected to as unnecessarily increasing the load on the always limited trunk lines. A storage and translation in the satellite will avoid the blind engagement. But the "registers" are always large outfits and one register for a small satellite is dangerous in case of a trouble in it. It is often found that the registers are placed in the main office, also causing blind engagements. With heavy internal traffic it may be advisable to give the subscriber's line first access to local switches and to dial a trunk digit, reverting the connection to a trunk, and freeing the local path. Sometimes the trunk digit is the first digit of the code-number of the main office.

Multiple number engagement. Assume a main office to have the ultimate subscribers' numbers 1000, 2000, 3000 and to have the recording position to be reached by dialling "0." The small rural exchange be connected by only two trunks. A translation in the small rural exchange will insert a digit to reach a trunk line and will then send the subscribers' number or "0." It is said that in systems without translation the subscriber has to dial the additional digit. The "multiple number engagement" of a trunk avoids the additional digit. The two trunk lines are connected to the levels 1, 2, 3 and 0 in the last selector of the rural exchange. At the incoming end in the main office each line ends in four preselective uniselectors. The number engagement "1" of a trunk line sends a discriminating impulse to the main office engaging the uniselector going to 1000. The number engagement "2" sends another discriminating impulse engaging the uniselector going to 2000, etc. The multiple number engagements are developed for eight discriminating signals.

Tielines. In State-wide plants several rural areas are formed. For geographical reasons two exchanges are connected in different rural areas, but they may have comparatively large common interests. The two exchanges are then connected over direct **"tielines,"** avoiding the roundabout way over the main offices of the two areas. The tielines usually will not carry the traffic peaks between the two exchanges. These peaks are routed over the main exchange.

Superior transmission. A long haul connection shall use lines with superior transmission. A translation may revert the connection to such lines, avoiding the lower grade trunks of the rural area. This is the question of "l.d. plains" (see later).

Non-attended **Public Telephones** (Coin Collectors) present the problem of informing the subscriber how much he has to pay and to supervise his payment. The information is given on printed cards in the booths. The "coin counting" consists of a special arrangement in the exchange. The subscriber takes the receiver off and receives the dialling tone. Then he inserts the coins. The different values send different impulses (e.g., ground over + lead or — lead or both leads) to a coin counter, setting it to the sum of deposited values. Then the subscriber dials. The code-number is stored in the exchange. If it corresponds to the setting of the coin counter the connection is switched through. If not, the connection is released and the busy signal is cut in. The answer cashes the total amount. The whole outfit is rather expensive. Another arrangement provides a coin collector with a "restricted" dial that allows only "0" or "00" to be dialled. This directs the call to the operator. The operator will dial over lines not used by the ordering connection and stay in the connections for time supervision.

Time allowance. The German rural area systems charge only a local fee if any dialled connection is broken inside of the first 10 seconds of the conversation. This is objected to as it would allow the caller to place an order by coded words. But the local fee, e.g., a penny for 10 seconds, is an amount corresponding to 18d. for the usual 3-minute period. These 18d. would cover a considerable distance. So the time allowance brings the same returns as a long trunk call.

Fee indicators. Hotels, clubs, etc., must know the charge at once after a rural area connection. A "fee indicator" is a meter at the P.B.X. (or station) set by the metering impulses at once after the end of the conversation so that the proprietor of the hotel knows what to charge to the guest.

The development of the rural area systems will bring more and more features with their "accessory" circuits. Again the importance of the simplicity and adaptability of the fundamental system may be emphasised.

Grouping Arrangements

The grouping arrangement is the co-ordination of the elementary connecting means (switches, lines, trunks, etc.) to form a plant ready to give service. It is primarily controlled by the traffic. The traffic is the product of five items:

s = past, present and future number, type, geographical location of all sources originating calls.

c = number of engagements, local, rural, long distance, etc.

t = holding time expressed in T.U.

k = concentration.

f = factor of community.

These items, being general for all plants, should need no discussion, but the special requirements of the rural areas justify some remarks.

s. The fast 24-hour automatic against the slow, restricted manual service often doubles and trebles "s" in small communities in a few years. The planning of the accommodation of the equipment should look out for this possibility.

c. The ratio of internal rural area to long-distance calls control the route of the first engagement of local or trunk paths. Surpassing trunk traffic should route the originated calls from satellites at once to the first selectors in a main office. Surpassing local traffic should route them firstly to local paths.

t. The advisability of the restriction of rural area connections to 9-12 minutes is mentioned above. But a subscriber may insist upon a "long" talk. He then orders the connection at the recording operator. These connections are not limited in time. Troubles and "no dialling" would seriously clog the trunk line, e.g., from a satellite. After an "empty" engagement of about 20 seconds the circuits clear all engaged components and revert the trouble to the line relays alone. These are cleared after the removal of the trouble.

k. It is difficult to predict the concentration, e.g., for summer resorts.

f. The known curves of the factors of community are valid for districts with a uniform tariff. As soon as zoned or time zone charges are introduced, special studies must be made.

The **grade of service** is explained in the previous article (page 136 of Vol. 2). Experience shows that a total loss from the calling line up to the final selector (i.e., not including busy reports on busy called subscribers' lines) across a rural area may be 10-20 per cent. The total loss is then distributed over the various links so that the expensive links (long trunk lines) show heavy losses, the cheap links low losses. The knowledge of waiting times is—sorry to say so —too limited at present time to allow any general statement.

Without giving definite figures it is often asserted that waiting times of a few seconds would materially improve the service against the "losses" in some systems. The short waiting periods would not be noticed by the subscribers.

The worst case is a satellite connected with one two-way trunk line to the next tandem exchange. Suppose it to carry (in the busy hour) two calls of three minute out and the same in, the load is 12 min. = .2 T.U. The loss is 50 per cent., i.e., two calls are successful and each third trial to reach the trunk (in or out) receives a busy report. From some curves now available the average waiting time for a delayed trial is 23 seconds. This period cannot be termed "short" if the subscriber has to wait with the receiver on the ear. A rural area system (of S. and H.) provides a convenient waiting arrangement. A subscriber will always be reverted to a local path (for finishing a local call) if the local code-number was dialled. If a foreign code-number was dialled and all trunks are busy, the subscriber receives a busy signal and replaces the receiver. The call is not lost, but stored in a relay in the set of line relays of the calling line. As soon as the trunk line gets free, this relay will pick up the trunk and re-ring the subscriber. So the subscriber waits without holding the receiver to the ear.

The **layout** of the plant shall cover the rural area itself and its connections finally to the world.

In the rural area itself the layout is "starlike" against "meshlike" in a manual layout. Fig. 1 is a diagram—not geographical—of a large layout for the former manual operation with many tielines in order to have only two operators in a connection. Fig. 2 is the same area with a layout for automatic switches. The many small traffic "rivulets" are collected and

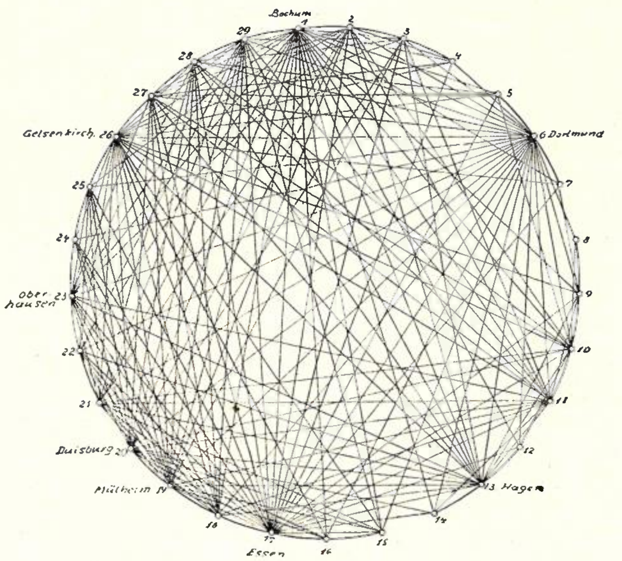


Fig. 1.—Manual Line Plant.

passed on in large "rivers" between the big towns. The carrying capacity of the many (former) small bundles caused considerable waiting times. The same number of trunks, now combined into big "river beds," have such an in-

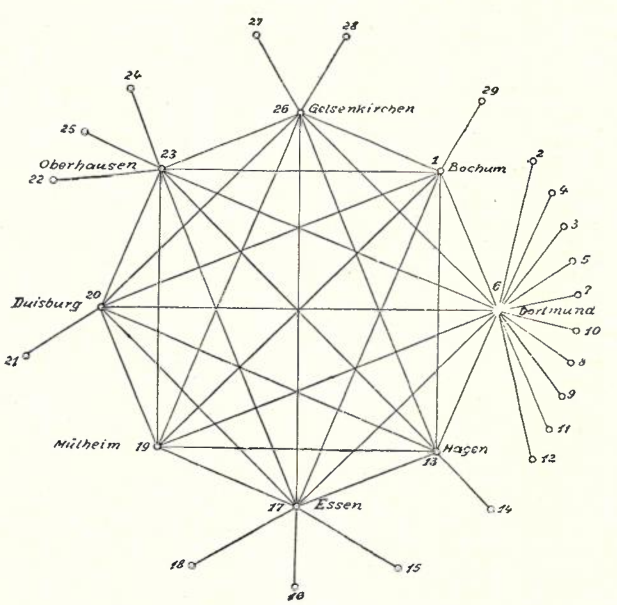


Fig. 2.—Line Plant for l.d. Dialling.

creased carrying capacity that a no-delay service is possible without increasing the numbers of trunks. The formation of one large "bundle" out of the existing small bundles in a trunk cable usually results in the possibility of on-demand service instead of delayed service.

The layout beyond the single rural area is shown in Fig. 3. It shows the world's telephony divided into "long-distance plains." The "element" or "nucleus" of the world's telephony is the rural area, as discussed in this article, not a single exchange and even less a single station. The Fig. 3 gives a diameter of a rural area as about 50 miles. This is the lowest plain. Each rural area has a "main office" or "primary outlet." Several rural areas are interconnected by trunks between the main offices, such forming the second plain with about 200 miles diameter, and also a main office in this plain. The third

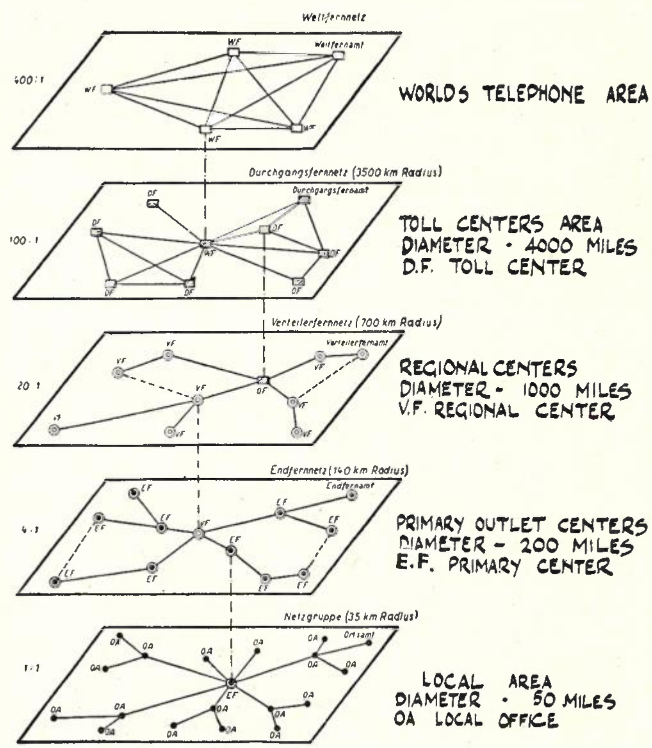


Fig. 3.—Long Distance Plains.

plain combines several 200-mile areas to one area of 1000 miles diameter. The fourth plain reaches over whole continents and the fifth plain finishes the world's telephony. It would be interesting to discuss the type of the channels (wireless, broad band, 4-wire and 2-wire channels) and the use of carrier waves in which plains the various types should be used. But this investigation would be far beyond the scope of this article. It is easily seen that the transmission problems are the simplest inside of a rural area. No amplification is required. But if a rural area trunk line is connected to the higher plains an amplification may be required. As there is no operator in the connection, this amplifier must be cut in automatically.

Another important question is the reach of the subscriber's trunk dialling and where to place the recording operator. This must be left to the gradual development of the subscriber's trunk dialling.

The layout of the rural area itself is primarily controlled by the equipment required to collect traffic of low density on as short routes as possible to large amounts. The lowest plain shows how this is done: small "end" exchanges, primary and secondary tandems and a main exchange. Certainly some areas may have several "main exchanges."

The planning of rural areas is furthermore closely related to the "numbering scheme." There are three types of traffic: local, rural area, and long distance. A "logical" scheme would separate them in this way:

(1) Small local numbers;

(2) prefixed code-numbers only dialled if outgoing calls are desired, and these may be—

(a) code-numbers beginning with "8" (i.e., the 8th level of the first selectors in the main office of the rural area) to call the exchanges of the local rural area;

(b) code-numbers beginning with "9" (from the 9th level of the first selector in the main office of the rural area) to call the main offices of other rural areas;

(c) the digit "0" to call the recording operator.

This method is called "open code-numbers," because the subscriber must know that he must prefix the code-number. But this "logical" numbering scheme uses too many levels. Another numbering scheme used "covered" code-numbers.

The numbers inside of a rural area are uniform (e.g., four digits) and the subscribers always dial these numbers even for local calls. To go outside of his own rural area an "open" code-number is prefixed, e.g., a "0." The "0" level of the first selector will be wired to a second selector in the main office of the rural area. An "00" will call the recording operator. 01-09 will call other rural areas. After dialling the open prefix 01-09 the subscriber will proceed to dial the number in the foreign rural area.

Operation

No general statement of operating methods can be made. It is closely related to the organisation of the general telephone service, which is different for the various administrations.

Economy

A new technical scheme will be successful only if it improves the service and lowers the cost for the same service as given before its introduction. The economical genealogy of the previous article shows the complexity of the problem. There are two special points for the rural areas:

(1) The cost of the line plant of a manual rural area network with its many tielines amounts to 70-75 per cent. of the total cost. The systematic collection of the small traffics and the avoidance of ill-used tielines (except in special cases) reduces the first erecting cost and the maintenance very decidedly.

(2) The avoidance of many operators reduces the "service" cost.

A quick answer to these statements is always that the price of automatic exchanges and subscribers' stations is higher than the price of manual equipment. This is correct. But the price of the exchange equipment and the stations is considerably smaller than the price of the line plant. Then the maintenance of the automatic equipment is supposed to be a high charge. Certainly the maintenance of the switching equipment is higher than for local battery exchanges. But the principal maintenance cost goes into the upkeep of the lines, which is very much lower for a line plant, as shown in the lowest plain of Fig. 3, than for a manual "mesh" layout.

A proof of the economical superiority of the automatic rural areas lies in the fact that all large administrations of the world have adopted or contemplate the introduction. And a world-wide interest could not grow up if there were doubts about the economy of automatic rural areas.

To close the study, some historical data may be of interest. The first semi-automatic rural exchanges, connected to the nearest manual office with 24-hour service, was erected 1906 in Germany. The first rural area scheme, as defined in this article, was erected in 1923 in Weilheim, Bavaria.

UNISELECTORS

D. F. Burnard, B.E.

The uniselector is defined in British Standards Association, Specifications No. 204—1930, and No. 205—1936, as "a selector having unidirectional motion." Prior to December, 1930, this switch was generally known as a preselector.

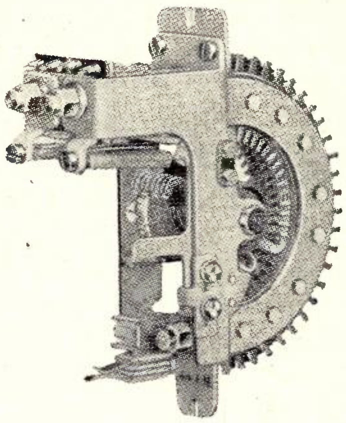


Fig. 1.—B.P.O. Standard Uniselector.

The uniselector is well known in telephony because of its extensive use in main exchanges as a line switch, both primary and secondary, line finder, allotter or assigner and junction seeker or outgoing secondary. It is also used in P.A.B.X.'s, R.A.X.'s and U.A.X.'s as a line switch, line-finder and allotter and in miscellaneous recording, ringing and alarm circuits.

There are different types of uniselectors manufactured by the various telephone manufacturing companies. The principal types in use in Australia are illustrated in Figures 1 to 5.

The B.P.O. Standard uniselector is manufactured by five British telephone manufacturers to detailed working drawings and a specification prepared by the B.P.O. This standardization was completed in 1928 after a close examination of switches supplied by A.T. & E., Liverpool; G.E. Co., Coventry; Ericssons and Siemens. The switch in service in the B.G.E. exchanges in the Adelaide network, with a few minor modifications, is similar to the B.P.O. Standard. Line switch units recently supplied are equipped with this uniselector.

The first uniselector used extensively in Australia was the A.E. Co. Chicago switch. It was used as a local secondary line switch with Keith type primaries. Our first automatic exchanges were equipped with Keith type primaries only. As these switches have only 10 outlets and cannot be overloaded without serious risk of double plunging, it was necessary to provide a comparatively large number of first selectors. The average traffic occupancy per first selector was in the neighbourhood of 0.30. Exchanges opened prior to 1915 were trunked in this manner.

Subsequently 10 point local secondaries of the Keith type were obtained and the average traffic occupancy of the first selectors was thereby increased to 0.60. The Siemens No. 16 system in use in the Brisbane network is trunked generally on this basis, but 10 point uniselectors of the type shown in Figure 5 are used as primaries and as secondaries instead of the Keith type switches.

In 1919, 25 point three level non-homing rotary secondaries were introduced. These switches increased the average traffic occupancy of the first selectors to 0.85 and reduced the risk of double plunging. Uniselectors are in use as local secondaries in City North (Sydney), Carlton (Melbourne), Central (Perth), as well as in other busy A.E.C. Chicago exchanges.

About this stage four level non-homing 25 point uniselectors were used in junction groups between selector levels and the repeaters to improve the traffic efficiency of these groups.

Uniselectors as local secondaries did not come into general use because the tendency in exchange design was to use uniselectors of the 24

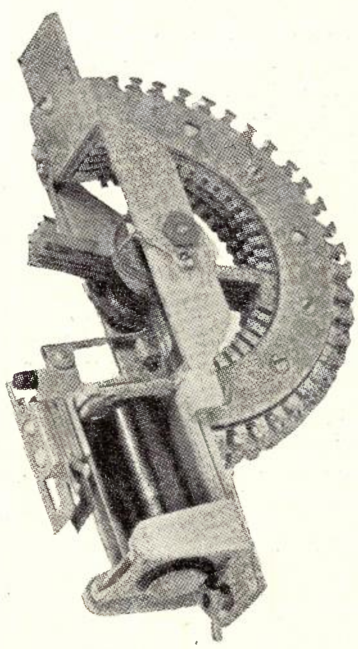


Fig. 2.—A.E.C. (Chicago) Uniselector.

point homing and 25 point non-homing types as primary line switches, giving a traffic efficiency which rendered the use of local secondaries economically unsound. The average traffic occupancy of first selectors reached from 25 point primaries is in the neighbourhood of 0.60.

Since 1924 many exchanges have been installed and extended on this basis, with equipment supplied by A.E.C., Chicago; A.T. & E., Liverpool; G.E.C., Coventry; S.T. & C., and Ericssons. All line switch units supplied by Ericssons have been equipped with the B.P.O. standard uniselector.

Mounting.—A comparison of the main mounting details of various types of 25 point uniselectors in use in Australia is given in Table I.

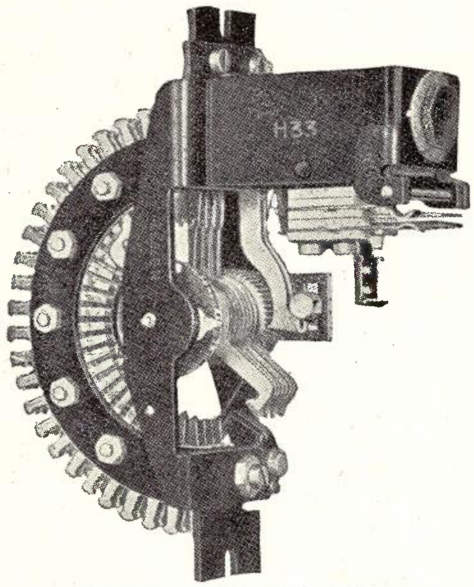


Fig. 3.—A.T. & E. Uniselector.

The uniselectors used in the Siemens No. 16 system are 10 point and have therefore been omitted from the comparison.

The type C.3100 uniselector manufactured by the G.E.C., Coventry, represents a recent development, and economizes in mounting space. The two additional shelves have been obtained by using B.P.O. 600 type relays for the L & K's. The B.P.O. 600 type relay is a small compact relay and if used with the other switches listed, it would enable additional shelves to be mounted on each rack for these also.

The Siemens Halske switch listed above is their standard 26 point. This is added as a matter of interest. It is similar to the 17 point switch which is used on type "C" P.A.B.X.'s of their manufacture.

Where economy of mounting space is desired, it is interesting to note the limitations imposed by the mechanical design. The B.P.O. standard switch and the G.E. Co. C.3100 switch use what is known as the wire brush wiper feed. The brushes bear on rings between each pair of wipers. This requires a certain clearance between pairs of wipers, and consequently it is impracticable to reduce the width of this type of uniselector to the same degree as the other types. The centre to centre spacings of adjacent bank levels on the standard B.P.O. bank is 7/32nd ins. (See Table I.) This dimension is 5/32nd ins. in the A.T. & E. Co.'s, Liverpool's bank and ⅛ in. in the Siemens Halske's bank. Comparing the B.P.O. standard bank with the A.T. & E. Co.'s bank, the comparative level spacings are 7/32nd in. and 5/32nd in. In the existing 3-5 level uniselector frame, five pairs of wipers are the maximum number that can be accommodated on the B.P.O. switch. The A.T. & E. Co. accommodate six pairs of wipers in this frame. From the point of view of the uniselector as a rotary line switch, where no more than five pairs of wipers are wanted, the tendency might well be to reduce the size of the frame. A saving of 20 per cent. would be practicable in the A.T. & E. Co.'s switch and in those switches which do not use the wire brush wiper feed.

TABLE I.

	A.E. Co., Chicago	A.T.E. Co., Liverpool	G.E. Co., C.3100	S.T.C.	Siemens and Halske	B.P.O. Standard
Horizontal Mounting Centres	2⅛"	2⅛"	1¾"	2⅛"	2⅛"	2⅛"
Overall width	1-13/16ths"	1 15/16ths"	1¾"	1-13/16ths"	2-1/16th"	2"
No. mounting on 4 ft. 6 in. shelf	20	20	25	20	20	20
Vertical spacing between mounting centres	7"	5⅜"	5⅜"	7"	6"	5⅜"
Overall height	7⅜"	5-11/16ths"	5⅝"	8"	6⅝"	5⅝"
No. of shelves per 10 ft. 6 in. rack	9	10	12	10	10	10
No. of switches per rack	180	200	300	200	200	200
Bank level spacing, centre to centre	11/64ths"	5/32nds"	7/32nds"	5/32nds"	⅛"	7/32nds"

Types.—There are six general types of uniselector in use in Australia:—

(a) B.P.O. standard;
(b) G.E. Co. C.3100;
(c) A.E. Co., Chicago;
(d) (i) A.T. & E. Co., Liverpool; (ii) S. T. & C.
(e) Siemens, No. 16.
(f) Siemens and Halske.

The B.P.O. Standard is generally similar to the original G.E. Co. uniselector and has the following main features:—

(i) Double coil driving magnet. Two magnet coils each 37.5 ohms are connected in series.

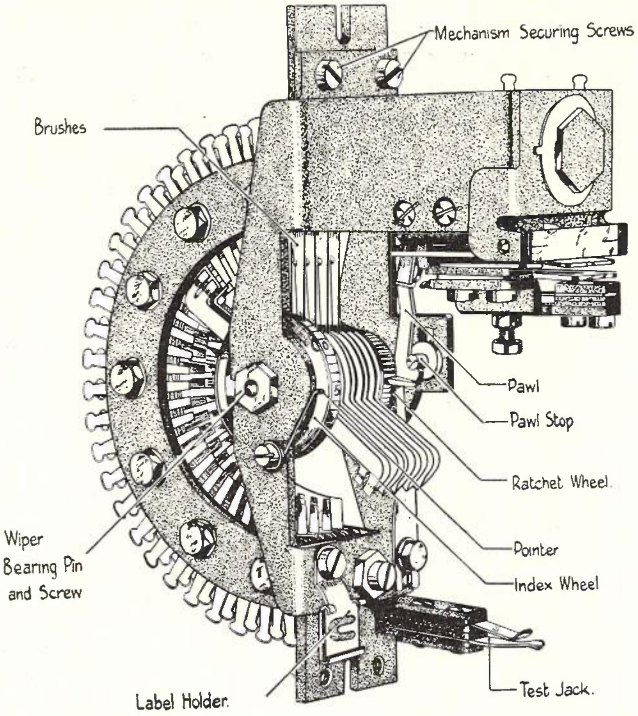


Fig. 4.—S.T.C. Uniselector.

This supersedes the early arrangement of two 150 ohms magnet coils connected in parallel.

(ii) Two armature restoring springs of the spiral spring type.

(iii) Wire wiper feeder brushes.

(iv) $\frac{1}{2}$ M.F. Spark Quench Condenser with inherent resistance.

(v) Flat trailing edge on wipers.

This uniselector is in common use, and the various types are listed in Table II.

The frame for this switch is made in two sizes, the smaller takes 3-5 pairs of wipers and the larger takes 6-8 pairs. The larger frame will accommodate 10 pairs of wipers if modifications are made to the wiper assembly. The bank must also be modified.

Twenty-five outlet switches can be converted to 50 point switches by using single ended wipers instead of double ended wipers. S.E. wipers are sometimes found in the smaller frame but they are more generally used in the larger switches. The practice is for adjacent pairs of S.E. wipers to be set with 180 deg. phase difference. This means that as one pair of wipers is leaving its bank, the adjacent pair is about to come into use. In an eight level switch with S.E. wipers, four pairs of wipers are on the bank contacts at any one instant.

The bank used with the homing switches has one continuous bank level, broken only for the home contact. This is usually a single metallic arc, but for special circuit facilities a twin homing arc can be used. This consists of two metallic arcs insulated from each other but forming one level. The City West uniselector working to Drawing C.491, sheet 2, uses a twin homing arc.

The G.E. Co. C.3100 uniselector has the following main characteristics:—

(i) The horizontal mounting centres are reduced;

(ii) A single, small driving magnet coil is used and mounted vertically;

(iii) The spiral restoring springs are mounted vertically and pivoted in the armature;

(iv) The wiper tips are specially shaped to avoid catching in contacts when backlash develops;

(v) The L & K relays are of the B.P.O. 600 type;

(vi) The magnet is mounted in the lower portion of the frame to facilitate inspection. In the standard B.P.O. switch the magnets are fixed in the upper portion of the assembly and a wiper and bank inspection of switches located on the lowest shelves is very difficult.

A full description of this switch is given in the "Telecommunication Journal," Vol. 2, No. 2, October, 1938, page 66.

The C.3100 switch is in service in City West, Melbourne, and primary line units equipped with

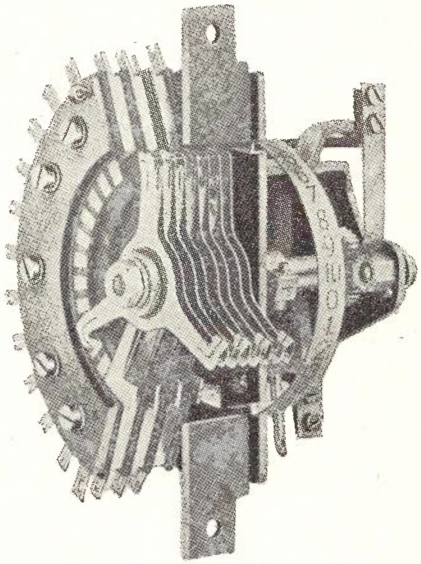


Fig. 5.—Siemens Uniselector.

this uniselector are on order.

The A.E.C., Chicago, uniselector can be identified by the following:—

(i) The driving magnet is mounted vertically below the wiper assembly.

(ii) Extended insulation pieces are fitted between pairs of wipers in later deliveries.

(iii) Round head screws with American thread are used.

Three and four level switches are used in

TABLE II.

Wipers			Homing or non-homing	No. of points on bank	B.P.O. code	Where used
No. of pairs	Double-ended or single-ended	No. of bridging pairs				
3	D.E.	0	N.H.	75	—	Siemens R.A.X. Assigner circuit L.S. Switch.
3	D.E.	1	N.H.	75	33 A N	P.L.S. Drawing C.529. Outgoing secondary. Siemens R.A.X. Alarm circuit. B.G.E. R.A.X.
3	1 D.E. 2 S.E.	1 (D.E.)	N.H.	75	—	B.G.E. R.A.X.
3	D.E.	2	N.H.	75	—	Siemens R.A.X. Time delay circuit.
4	D.E.	0	N.H.	100	—	Delayed alarm Drawing C.1048, Fig. 9.
4	D.E.	1	N.H.	100	41 A N	P.L.S. Drawing C.530 Siemens & B.G.E. R.A.X.'s. O.G.S. with S.S.R.S. Drawing C.519.
4	D.E.	2	H.	77	42 A N	P.L.S. C.491 Sheet 1.
4	D.E.	2	N.H.	100	42 A O	Delayed alarm circuit Drawing C.1048, Fig. 4. Siemens R.A.X. Assigner circuit. A.S. Switch.
5	D.E.	1	N.H.	125	51 A N	Type C P.A.B.X. S.T.C.
5	D.E.	2	H.	102	50 A O	S.T.C. R.A.X.
5	D.E.	5	N.H.	125	53 A N	Type C P.A.B.X. S.T.C.
6	D.E.	1	N.H.	150	62 A N	Siemens R.A.X. L.S. and D.S.A. switch.
6	D.E.	0	N.H.	150	61 A N	Sec. Allotter, Drawing C.1185.
8	D.E.	8	N.H.	200	—	B.G.E. R.A.X. Code ringing circuit.
8	D.E.	4	H	177	—	S.T.C. R.A.X.
8	D.E.	2	N.H.	200	86 A N	S.S. Switch Siemens R.A.X.
8	D.E.	1	N.H.	200	81 A N	D.S.B. Switch Siemens R.A.X.
8	D.E.	0	N.H.	200	84 A N	Allotter Drawing C.1211 & C.1185, D.F.A. & D.F.B. switches (Siemens R.A.X.)
8	S.E.	8	N.H.	200	—	S.T.C. R.A.X.
8	S.E.	4	N.H.	200	—	S.T.C. R.A.X.
8	S.E.	2	N.H.	200	—	S.T.C. & B.G.E. R.A.X.'s.
8	S.E.	0	N.H.	200	85 A N	S.T.C. R.A.X. and Sec. Finder, Drawing C.1185.
10	S.E.	4	H	203	—	S.T.C. R.A.X.
10	S.E.	2	N.H.	250	—	S.T.C. P.A.B.X.

Sydney, Melbourne and Perth networks. A three level non-homing switch is used as a local secondary associated with Keith type primaries. Outgoing secondaries trunked from group selector levels and non-homing rotary primaries are also three level switches. A four level non-homing outgoing secondary is used with switching selector repeaters and there is a four level homing primary line switch. The recent rotary primaries can be distinguished by the L. & K. relays, springsets being mounted on the side of the relays and covered by three small bakelite covers. The early rotary primaries have L. & K. relays and springsets located under one cover.

The A.T. & E., Liverpool, uniselector has the following characteristics:—

(i) A single coil driving magnet is mounted horizontally, sometimes at the top and sometimes at the bottom of the mechanism.

(ii) The wipers are much wider at tips.

(iii) The ratchet wheel is rather small in diameter.

An examination of the wiper tips will safely distinguish this switch from the S.T. & C. switch, switches to give greater clearance. The extra projection in the original armature back stop facilitated adjustments.

(iv) Hexagon head adjusting screws have replaced cheese head screws.

(v) The test jack has been raised above the frame to avoid possible short circuits to frame.

In this switch and in several other types, the wiper feed forms an extra contact which is passed over by one end of a pair of wipers, while the other end is on the 25th contact. This increases the load for the armature restoring spring at this contact. Ordinarily the action of the switch is not affected, but sticking and chattering may result, and it is partly to avoid this trouble that the B.P.O. standard uniselector is equipped with a wire brush wiper feed. The extra load is appreciable in a five level switch with a twin homing arc. In the latest model, the A.T. & E. uniselector has an extended, tapered or wedge shaped first contact and the additional load on the restoring spring is much reduced. The A.T. & E. switch is used extensively in Sydney, Melbourne and Perth networks.

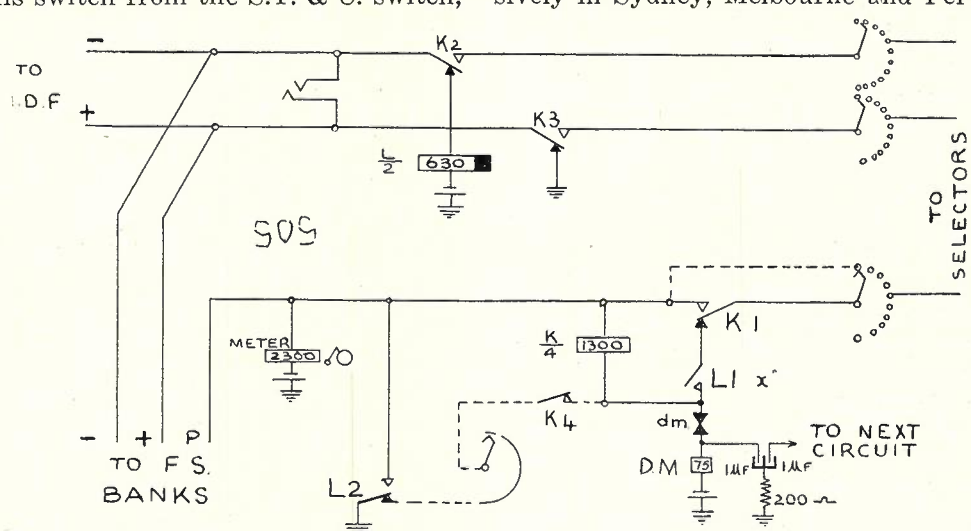


Fig. 6.—SUBSCRIBER'S LINE CIRCUIT.
Drawing C530, Booster Batt. Metering (full lines), Non-Homing, combined with C491, Sheet 1 (full and dotted lines), Homing.

which is otherwise very similar. From time to time the A.T. & E. Co. have made several minor changes in the design of this switch. Some of these are:—

(i) A flat armature restoring spring is used. Originally the tension adjustment was made by bending this spring. A rocker adjustment was subsequently developed and is the present standard.

(ii) A wide ratchet wheel was originally used and both pawl and detent engaged in the same tooth. The detent now engages two teeth behind the pawl.

(iii) The armature back stop is a cam with an extended arm. Originally this arm protruded below the magnet. It is shortened in later

The S.T. & C. uniselector is very similar to the original A.T. & E. switch, but may be distinguished by its split wiper tips. It is sometimes provided with a leather mounting to absorb vibration. This switch is in use in Sydney and Adelaide networks.

The Siemens No. 16 uniselector is a 10 point switch used as a primary and secondary preselector in Siemens No. 16 exchanges. The primary preselector is a homing switch and the secondary preselector a non-homing switch. The former has four levels and the latter, three levels. The driving magnet is not self-interrupted; it is driven by pulses supplied from machine driven interrupters. The pulses give a speed of 32 steps per second for preselectors. Triple ended wipers spaced at 120 degrees are used giving 30 steps per revolution. This uniselector is in use in exchanges in the Brisbane network and in certain P.A.B.X.'s and early R.A.X.'s. These R.A.X.'s have been installed in N.S.W., Victoria and Queensland.

The Siemens and Halske uniselector is used in type "C" P.A.B.X.'s supplied by this company. The types used are 17 point homing and non-homing switches with single ended wipers giving 34 point switches and a 10 point switch used as an auxiliary call finder. The construction of the switch is radically different from the others. A noteworthy point is that a forward drive is used, i.e., the wipers are driven by the pawl as the armature operates. In the reverse drive used in the various 25 point types, the armature is pulled up against the tension of the restoring spring, which rotates the wipers when the magnet circuit is opened and the armature is released. The Siemens and Halske 26 point switch is similar to their 17 point switch.

Besides the 25 point uniselectors briefly described above, other types have been developed for special purposes. Some of these are:—

(a) A.T. & E. Co.'s, Liverpool, 12 point switch used in their R.A.X.'s.

(b) Siemens No. 1100 type to be used on the Melbourne automatic trunk board. This has a 52 point bank and rotates at approximately 200 steps per second.

(c) G.E. Co.'s two way 25 point switch which rotates in both directions.

Light and Heavy Duty. — The majority of three to five level uniselectors are light duty switches. Heavy duty switches use nickel silver instead of brass bank contacts and wipers. In some cases phosphor bronze wipers are used. The pawl of the heavy duty switch is also much stronger. The six to eight level switch is designed as a heavy duty switch.

Circuits.—The two main subscriber's line circuits for uniselector exchanges are the homing and the non-homing circuits. Figure 6 shows the subscriber's line circuit. The full lines show a typical non-homing circuit and the additional connections required for a homing circuit are shown in dotted. The circuits are well known, but a brief description may be of interest.

The subscriber's line loop operates relay L. Contact L1 closes before L2 to avoid premature operation of relay K. The homing switch immediately drives off the home position to the first outlet. The non-homing switch will drive on if its wipers are resting on a busy outlet. The drive in each case continues while an earth is encountered on the P bank. When this earth is lost, K relay operates in series with the driving magnet to earth at the L2 contact. The driving magnet does not operate as the current through the magnet is reduced to approximately 40 milliamps. The operation of K relay cuts the subscribers' lines through to the wipers and opens the circuit of L relay. Before L relay releases, an earth is returned from the switch ahead to hold K operated. The subscriber's line is busied on the final selector bank by means of the earth on the P. wire.

On an incoming call the subscriber's line is tested on the P contact of the F.S. bank. If the line is disengaged, the final selector cuts through and extends an earth over the private to operate K relay. K disconnects relay L.

In the non-homing circuit, the wipers of the called subscriber's uniselector will be resting on an outgoing trunk. The full operation of K would extend the called subscriber's line through to this trunk and to avoid this it is necessary to provide a mechanical latch on the L and K relays

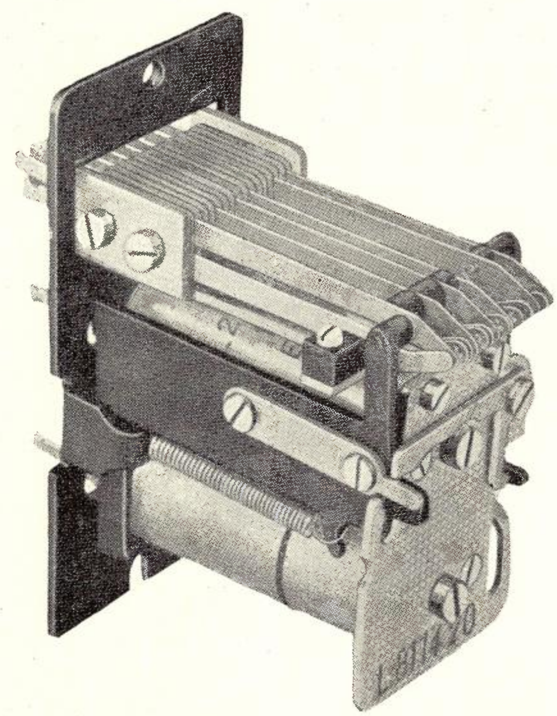


Fig. 7.—Mechanical Latch and Face Plate on L and K Relays.

which prevents the full operation of the armature of K relay unless L relay is first operated (see Figure 7). K pulls up far enough, however, to disconnect relay L. In the homing circuit the connection of the called subscriber's line to the uniselector wipers does not matter because the wipers are resting on open contacts in the home position.

When an open trunk is encountered, the drive stops because there is no earth on the P wiper. K operates and its contacts K2 and K3 disconnect L relay which also releases. As the trunk is open, the subscriber's loop is not extended to a switch ahead and an earth is therefore not returned via the private to hold relay K which releases. In the homing circuit as K releases with L at normal, a momentary impulse is given to the driving magnet via K4 normal and L2 normal to earth on the homing bank. The wipers are thus driven on to the next contact.

In the non-homing circuit, the driving magnet does not receive this kick on and the wipers remain on the open trunk, while the L and K relays chatter. A second attempt to call may also prove unsuccessful unless another subscriber busies out the open trunk at the critical moment.

Mechanically, the uniselector used is identical for both circuits except that an extra pair of wipers is required for the homing switch. The two banks are also identical but a continuous homing segment is necessary on the homing switch. In each case there are 25 bank contacts per level.

The associated relays are identical electrically, but the non-homing switch has the mechanical latch feature mentioned in the circuit description.

There is a difference in the trunking to the 1st selectors or equivalent switch. The homing uniselector has 24 effective outlets, the 25th being used as the home position; the non-homing uniselector has 25 outlets. The fundamental difference from the trunking viewpoint is that each outlet on the non-homing switch carries the same amount of traffic whereas in the homing switch, the earlier choices carry the bulk of the traffic. The 2nd outlet only takes traffic when the first is engaged. Similarly, the 3rd takes traffic only when the first two outlets are engaged. For example, a group of 24 trunks will carry 12.4A (traffic units) if one lost call in 1000 is allowed. The first trunk carries .93A, the 2nd carries .91, the 3rd .88A and so on to the 24th, which carries a very small amount of traffic. But because the homing switch commences its search at the same point for each call, it is possible to grade the outlets. The outlets from each uniselector are multipled over three or four units, according to the density of the traffic, the multiple forming a group. Each outlet is taken to a first selector, or equivalent switch. The purpose of grading is to common the later choices of several groups, leaving the early choices which carry the heavy traffic, connected to individual trunks. The traffic peaks are taken by the common groups and the result of this grading is a reduction in the number of first selectors required over several groups to an extent of approximately 20 per cent.

The grading of the outgoing trunks from the uniselector banks is arranged on a trunk distributing frame so that variations can be made readily whenever necessary.

For each call made, the homing switch makes 25 steps, which includes the search and return to home position. The non-homing switch only steps until a free outlet is found. For this reason the amount of wear on moving parts is considerably less in the non-homing switch. The wear on first selectors served from non-homing uniselectors is slightly reduced also as a result of the traffic being equalized over all outlets.

The advantages of the homing uniselector are:—

(i) The outlets can be graded.

(ii) It will step over open trunks.

(iii) A circuit can be designed to allow the wipers to stand on the 25th contact if all outlets are busy. The arrangement sometimes used with non-homing switches is not so satisfactory.

(iv) The mechanical latch and face plate on the L. & K. relays is not required.

The stepping speed of a uniselector is on the average 60-70 steps per second. The specification requires a minimum speed at 50 volts of 65 r.p.m. for the small switch and 55 r.p.m. for the larger switch. Sixty r.p.m. is the same as 50 steps per second.

The specifications also requires that a switch should complete 100,000 half revolutions without any readjustment and one million half revolutions without any appreciable wear.

As a result of the extensive research work done by the B.P.O. prior to the standardization in 1928, and also by the various manufacturers, the uniselector is now a robust switch, complying without difficulty to the specification. In service it is found to be very reliable, and satisfaction is given with a minimum of maintenance attention.

AUTOMATIC TRAFFIC RECORDING

THE EQUIPMENT, CONTROL AND METERING CONNECTIONS OF THE AUTOMATIC TRAFFIC RECORDER

B. Draper, A.M.I.E.E. (General Electric Coy., Coventry, England)

General.—The automatic traffic recorder for automatic exchanges has been designed to overcome the disadvantages and limitations of the manual method of traffic observation. Since the basis of traffic recording lies in the observation of the number of simultaneous calls in progress during regular short intervals, it follows that the manual method requires a large number of observers to enable accurate results to be obtained. The automatic recorder, which needs no attention once it has been set up, makes a complete survey of all the switches under observation every 30 seconds, thus enabling the traffic to be computed with considerable accuracy.

It is not the purpose of this article to deal with circuit details as this aspect has been fully covered elsewhere[1]; but the essential parts of the recorder are reproduced in Fig. 1 to give a reference to the method of associating the various sections of apparatus. The bank contacts of the access switches (T1 to T8) are connected to the exchange circuits to be tested by means of jumpers. A description will be given of the method of determining the best possible arrangement for this jumpering. The meter connections, which are specially set up by means of plugs and cords for each portion of the record, will also be dealt with.

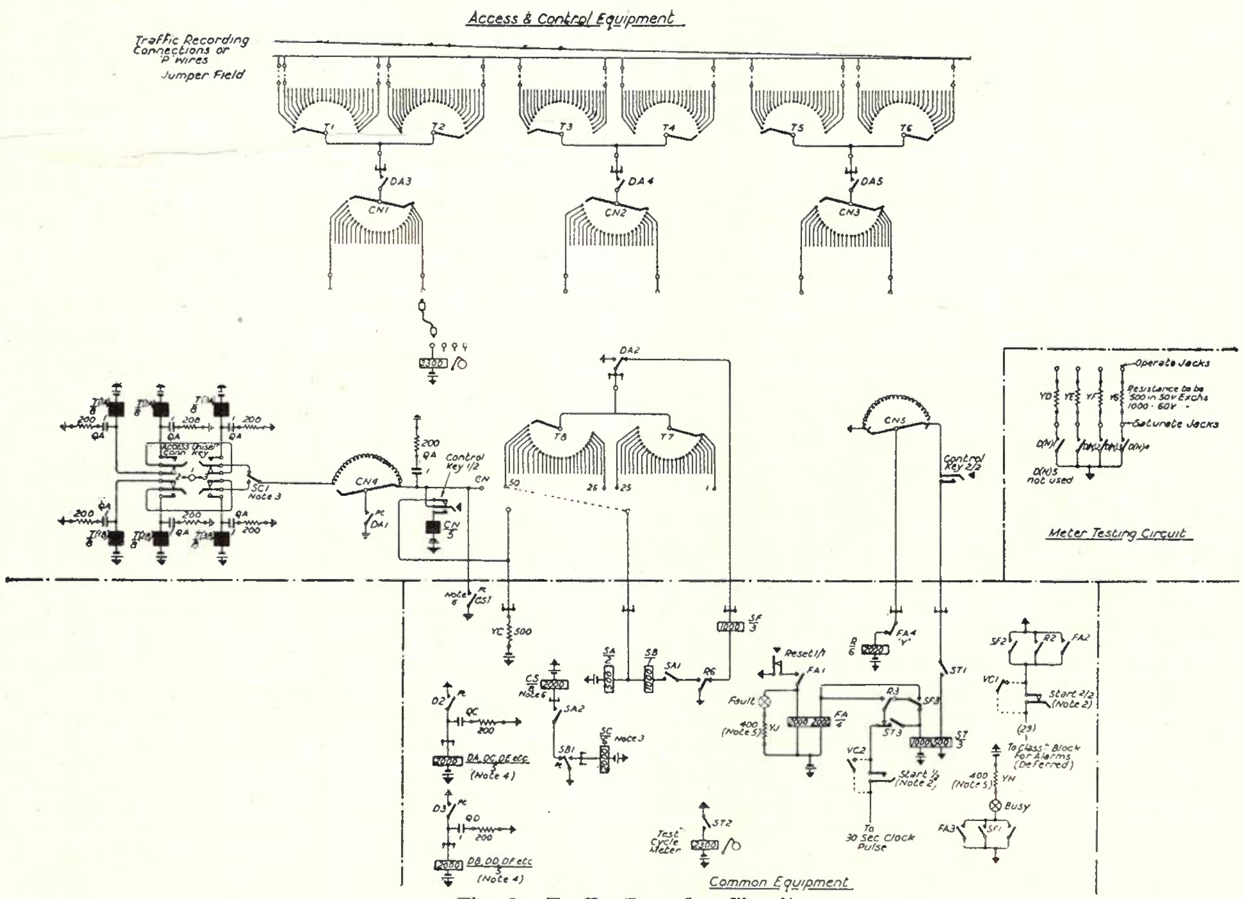


Fig. 1.—Traffic Recorder Circuit.

Allocation of Exchange Equipment to Access Uniselectors. — The access uniselectors are mounted on racks which are conveniently located to facilitate cabling of the recording leads from the exchange equipment. The standard rack is 10 ft. 6 ins. high and carries 12 access uniselectors, giving a total of 1764 possible access points which are wired out to terminal strips for the purpose of cross-connecting to the exchange apparatus. The first step towards the allocation of exchange equipment to access uniselectors should be to prepare a form of the type shown in Fig. 2, which provides sufficient space for

[1] The P.O.E.E. Journal, Vol. 28, Part I.

recording the connections from the exchange equipment to two access uniselectors. The access uniselectors which are "paired" are those which operate as a pair on the access Uniselector Connecting key and are generally Switches 1 and 2, 3 and 4, 5 and 6, etc., on a particular rack.

The recording leads should be allocated to two similar levels of the pair of uniselectors (the recording sub-unit) in turn; for instance, levels 1 and 2 of the first access uniselector should be allocated first in the order mentioned, levels 3 and 4 of the first and then levels 3 and 4 of the second, and so on.

ACCESS SW.	ACCESS CONTACT	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	LEVEL 5	LEVEL 6	LEVEL 7	*	LEVEL 8	*
1	1	HOME CONTACT	AC 5	HOME CONTACT	DD 1	HOME CONTACT	GA2	HOME CONTACT	1	B	7
	2	RS. AA1	AC 6	1ST DA1	DA 2	2ND AA 2	GC 2	B		B	
	3	AA2	AC 7	DD2	DH 2	AC 2	GE 2	B		B	
	4	AA3	AC 8	DE 2	DE 3	AE 2	GG 2	B		CN	
	5	AA 4		DH 3	DD4	AG 2		CN		B	8
	6	AA 5		DA 4		BA2		B	2	B	
	7	AA6	AD1			BC 2		B		B	
	8	AA 7	AD2			BE 2		B		CN	
	9	AA 8	AD3		DE 1	BG 2		CN		B	9
	10		AD 4	DB1	DH 1	CA 2		B	3	B	
	11		AD 5	DC2	DA3	CC 2		B		B	
	12	AB1	AD6	DF 2	DD3	CE 2		B		CN	
	13	AB2	AD 7	DG 3	DE4	CG2		CN		B	10
	14	AB3	AD8	DB4		DA 2		B	4	B	
	15	AB4				DC 2		B		B	
	16	AB5				DE 2		B		CN	
	17	AB6	AE1		DF1	DG2		CN		B	11
	18	AB7	AE 2	DC1	DG1	EA2		B	5	B	
	19	AB8	AE 3	DB2	DB3	EC2		B		B	
	20		AE 4	DG2	DC3	EE 2		B		CN	
	21		AE 5	DF3	DF4	EG 2		CN		B	12
	22	AC1	AE6	DC 4		FA 2		B	6	B	
	23	AC2	AE7			FC 2		B		B	
	24	AC3	AE 8			FE 2		B		B	
	25	AC4				FG2		CN		S	
2	1	HOME CONTACT		HOME CONTACT	DE 5	HOME CONTACT		HOME CONTACT	13	B	19
	2			DA 5	DE6			B		B	
	3	AF1		DA6	DE 7			B		B	
	4	AF 2		DA 7	DE 8			B		CN	
	5	AF 3		DA8				CN		B	20
	6	AF4						B	14	B	
	7	AF5			DF5			B		B	
	8	AF6		DB5	DF6			B		CN	
	9	AF7		DB6	DF7			CN		B	21
	10	AF8		DB7	DF8			B	15	B	
	11			DB8				B		B	
	12							B		CN	
	13				DG4			CN		B	22
	14			DC5	DG5			B	16	B	
	15			DC6	DG6			B		B	
	16			DC7	DG7			B		CN	
	17			DC8	DG8			CN		B	23
	18							B	17	B	
	19							B		B	
	20			DD5	DH4			B		CN	
	21			DD6	DH5			CN		B	24
	22			DD7	DH6			B	18	B	
	23			DD8	DH7			B		B	
	24				DH8			B		B	
	25							CN		CN	

* : CORRESPONDING METERING POINT OF CONTROL SWITCH LEVELS
ø : SWITCH BUSIED. NO JUMPER TO BE RUN
ẋ : " UNBUSIED

Fig. 2.—Allocation of exchange equipment to access uniselectors.

Large groups of equipment should be allocated first and in such a manner that they are confined, as far as possible, to similar odd and even levels on the pair of access uniselectors. This will enable one meter to be used for recording the traffic on the whole group, if below 98 circuits, and a minimum if above.

Referring to Fig. 2, it is seen that the access points are associated with the meter points in groups of four (except at the end of the even numbered levels on the access switches, where there are five points associated with the 12th or 24th meter points). Thus it is possible to associate up to 24 meters with each pair of levels on a pair of access uniselectors.

The stepping of the control uniselector in relation to the access uniselector to which it is connected is governed by the connection of the B and CN points to the contacts on level 7 and 8 of the access uniselectors. For the sake of simplicity these are made the same for all access uniselectors. The S connection on the 25th contact, level 8, of the first uniselector in a pair controls the change over from the first to the second uniselector.

Before proceeding with the allocations, it is necessary to determine in which of the following four forms the traffic record is required:—

1. Measurement of total traffic via a grading.
2. Measurement of traffic via each group of a grading, i.e., an analysis record.
3. Measurement of traffic via incoming selectors.
4. Measurement of traffic via line-finders.

The first method is usually adopted for all gradings other than subscribers' uniselector gradings, since the standard method of switch allocation on gradings ensures an even traffic loading on each of the groups of a grading which is beyond the first switching stage. In this case the outlets from a grading should be allocated on the access uniselector in shelf order, spare contacts being left for spare positions on the shelves. An example of this is shown in Fig. 2 on the first recording sub-unit, which is a typical arrangement for outgoing junction relay sets.

In the case of outlets serving uniselector gradings it is very desirable to record the traffic in each group separately so that the distribution of subscribers' lines on the uniselectors may be periodically reviewed. The individual outlets in a grading carry by far the greatest proportion of traffic in their respective groups and it may therefore be said that, for any grading the relation between the traffic in one group to that in any other is equal to the relation between the traffic carried by the individual outlets in the one group to that carried by the corresponding outlets in the second group. Thus, if a meter is provided to register the total calls carried by the individual outlets in a grading group and a further meter or meters to record the traffic on the remaining outlets, satisfactory analysis and total readings may be obtained as follows:—

Total traffic via grading = sum of all meter readings.

$$\text{Traffic through any group} = \frac{\text{Traffic via individual outlets in that group}}{\text{Traffic via individual outlets in all groups}} \times \text{Total traffic via grading}$$

When proceeding with the allocation of recording leads on the access uniselectors, one meter group should be used when there are up to four individual outlets per grading group and two meter groups for five to eight individuals. This will be more clearly demonstrated when reference is made to Fig. 3, which shows a typical uniselector grading with five individual

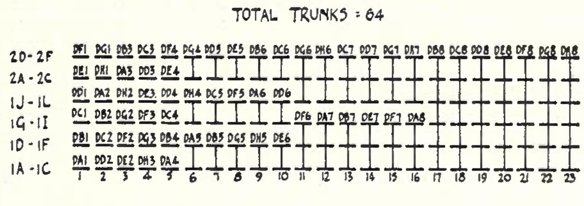


Fig. 3.—Grading of uniselector banks (typical).

outlets per group, the allocations for which are shown on the second recording sub-unit in Fig. 2.

Where there are five individuals there will be three access bank contacts left spare, and the control uniselector will step before the whole group has been recorded upon. The two control uniselector bank contacts concerned will, however, be joined together by a U-link, and one meter used to record on the five switches.

All outlets other than individuals should be allocated in shelf order, the traffic on these contacts being measured in bulk. Spare contacts should be left for spare positions on the shelves.

Incoming first or second selectors must be allocated on the access uniselectors in exchange order so that the total traffic via a particular group of junctions may be recorded on one meter. In this case, sufficient spare contacts on the access uniselectors must be left to provide for increases in the number of junctions. A typical case for incoming junctions from B Exchange is shown in the third recording sub-unit in Fig. 2.

In line-finder schemes with partial secondary working the recording may be carried out by either of the following methods:—

(1) By allocating the first selector recording leads on the access uniselectors so that the traffic via the directly-connected finders for each group may be measured. Similarly, the traffic carried by the secondary groups can be determined by allocating the indirectly-connected first selectors so that the traffic carried by each secondary group can be measured.

(2) By allocating recording leads direct from the primary line finders to the access uniselectors to measure the traffic in each group. The primary finders should be allocated in shelf order and spare contacts left for spare positions on the shelves.

Allocation of Access Switches to Control Switches.—Having allocated the recording leads to the access uniselectors on each of the racks, it is now necessary to determine the best arrangement for the leads between the access switch wipers and the control switch wipers.

As it is not essential that the traffic passing through all switching stages should be measured simultaneously, an economy may be effected by connecting six access switches to each control switch. Since two access switches constitute a single unit so far as the recorder is concerned, it is only necessary to provide a 3-way key, known as the access uniselector connecting key, in order to switch in a particular pair to the control switch.

These connections between the access and control uniselectors are carried out by means of flexible jumpers on the I.D.F., thus facilitating their re-arrangement at any future date.

In order to determine the best arrangement for a particular exchange a table should be set out as shown in Fig. 4, the vertical columns indicating control switches and the horizontal columns access connecting key positions. In setting out the allocations care must be taken to see that complete groups of traffic such as outgoing or incoming junctions can be measured simultaneously, that is, they must be allocated to different control switches, although, preferably, the same access connecting key position should be used.

CONTROL	1	2	3	4	5	6	7	8	9	10	11	12	KEY POSN.
	← O/C. JUNCS. FROM 1ST & 2ND SELECTORS →									← INCOMING 1ST SELS. →			
		RK.10 3&4	RK.10 5	RK.9 1&2	RK.9 3&4	RK.9 5&6	RK.9 7&8	RK.9 9&10	RK.9 11				2
	← INCOMING 2ND SELECTORS →									← "M" 3RD SELS. →			
	RK.4 1&2	RK.4 3&4	RK.4 5&6	RK.4 7&8	RK.4 9&10	RK.4 11				RK.5 1&2	RK.5 3&4	RK.5 5&6	1
	← "MU" 4TH SEL. →		← "MOT", "MO9" 4TH SEL. →		← "MY" FINAL SEL. →		← "MU" FINAL SEL. →						
	RK.6 3&4		RK.6 1&2		RK.7 7		RK.7 1&2	RK.7 3					3
CONTROL	13	14	15	16	17	18	19	20					
	← INC. 1ST SEL. →	← LOCAL 1ST SELS. →				← LOCAL 2ND SELS. →							
		RK.2 1&2	RK.2 3&4			RK.3 7&8	RK.3 9&10	RK.3 11&12					2
	← "M" 3RD SEL. →		← "MU" 3RD SELS. →		← "MY" 3RD SEL. →								
	RK.5 7&8		RK.5 10&11	RK.5 12		RK.3 1&2							1
			← "M1" - "M4" FINAL SELS. →										
			RK.8 1&2	RK.8 3&4	RK.8 5&6	RK.8 7&8	RK.8 9&10						3

Fig. 4.—Chart showing typical allocation of access switches to control switches.

In the typical case shown in Fig. 4 it is seen that Position 2 on Control Switches 1 to 9 is reserved for traffic on outgoing junctions and Position 1 on the same switches for traffic on incoming second selectors. These traffic measurements would not be required simultaneously, consequently it is quite in order for them to be connected to the same control switches. A further consideration is the desirability of being able to measure the traffic into and out of a particular rank of selectors at the same time. For this to be possible, succeeding ranks of selectors must not be allocated on the same control switches. In the example shown, traffic into first selectors (local and incoming) can be measured simultaneously with traffic out via repeaters and second selectors because they are all connected to different control switches. Similarly, traffic on M 3rd Selectors can be observed at the same time as traffic on M1-M4 final selectors. It will be appreciated that this facility provides a ready means of detecting any serious loss of traffic at a particular switching stage.

When the complete lay-out has been determined the relative control uniselector numbers and the access uniselector key positions should be inserted on the form shown in Fig. 2.

The actual jumpering for the CN, TW1, TW2, TW3 and TW4 wires is usually carried out on the I.D.F., access switch wipers appearing on the multiple side and control switch wipers on the local side. Jumpers must now be run from each access switch to the corresponding control switch in accordance with the arrangement decided upon. The access switch driving magnets are usually cabled direct from the access racks to the control racks and terminated on a strip marked with the control switch number and access uniselector connecting key position. For example, the driving magnet connections for Control Switch 1 as shown in Fig. 4 would be:

Rack 4 Switch 1 to Control 1 Position 1A.
Rack 4 Switch 2 to Control 1 Position 1B.
Rack 6 Switch 3 to Control 1 Position 3A.
Rack 6 Switch 4 to Control 1 Position 3B.

It is advisable to leave a good length of skinner at the Control Rack end in case a re-arrangement is required at some future date.

In the case where an odd number of access uniselectors is provided, it will be necessary to strap the access uniselector connecting key spring appropriate to the missing selector to the corresponding spring of one of the other pairs connected to the key, so that the timing of the odd uniselector will not be interfered with when used with other pairs. The last bank contact of the odd access uniselector should be connected to the S terminal. The second uniselector of one of the other pairs, to which the access uniselector connecting key spring is strapped, will be stepped to take the place of the missing uniselector, so that the control uniselector will be stepped to the home position. In these circumstances, meters should not be associated with the second half of the control uniselector bank.

The actual strapping may be conveniently performed on the terminal strip previously referred to in connection with the termination of access uniselector driving magnets on the control rack.

Preparation of Schedules showing Meter Connections for Analysis and Complete Traffic Records.—The bank contacts of the control switches are wired out to a large terminal field on the lower part of the control rack, which is suitably designated to facilitate metering connections. Connections to meters from control bank contacts are made by means of a single flexible cord carrying a plug No. 24 at each end, and U-links are used for strapping the bank contacts together.

Since each control switch may be connected to three separate pairs of access uniselectors, it follows that the bank connections will have to be varied to suit the particular grading under observation.

It is necessary, therefore, to prepare a schedule which will give direct information of the metering connections, the control uniselector numbers, and the access connecting key position required for either analysis or complete records. The information for its compilation is derived from the forms prepared as shown in Fig. 2.

The meters recording traffic on exchange equipment allocated to levels 1 and 2, 3 and 4, 5 and 6 of the access uniselectors are connected to contacts on levels 1, 2 and 3 of the control uniselectors respectively. Hence an examination of Fig. 1 will show on which control uniselector bank contact metering conditions for any group of circuits will be obtained. For instance, a group of circuits allocated to contacts 2, 3, 4 and 5 on level 1 of access uniselector 1 would give metering conditions on level 1, contact 1 of the appropriate control uniselector; and circuits allocated to 13, 14, 15 and 16, level 6, access uniselector 2, would give metering conditions on level 3, contact 22 of the control uniselector. The meter point for each group of circuits is thus obtained and inserted in the schedule, an example of which is shown in Fig. 5. The control uniselector number and access connecting key positions are obtained by reference to the form shown in Fig. 2.

AUTOMATIC TRAFFIC RECORDER

METER CONNECTIONS

EXCHANGE - TYPICAL SHEET Nº - 1

MEASUREMENT OF TRAFFIC		CONTROL SWITCH Nº	CONNECTING KEY POSN	GROUP IN GRADING	CONNECTIONS FOR METERING		METER
FROM	TO				STRAP POINTS SHOWN BY U-LINKS OR PLUGS & CORDS	CONNECT FOLLOWING POINTS TO METERS	
1ST SELECTOR LEVEL 3	"F" EXCHANGE	1	1		1.1 PTS. 1-15	1.1 PT. 1	A1
SUBS UNISELECTORS	1ST SELECTORS	1	1	1	1.2 PTS. 1-2	1.2 PT. 1	A2
				2	1.2 PTS. 3-4	1.2 PT. 3	A3
				3	1.2 PTS. 5-6	1.2 PT. 5	A4
				4	1.2 PTS. 7-8	1.2 PT. 7	A5
				5	1.2 PTS. 9-10	1.2 PT. 9	A6
				6	1.2 PTS. 11-12	1.2 PT. 11	A7
				COMMONS	1.2 PTS. 13-24.	1.2 PT. 13	A8
B EXCHANGE	INCOMING 2ND SELS.	1	1		1.3 PTS. 1-7	1.3 PT. 1	A9

Fig. 5.—Typical meter connections.

The meter connecting points are specified thus:
3.1 Pt. 5—Control Switch 3, level 1, Contact 5.
2.3 Pt. 3—Control Switch 2, level 3, Contact 3.

For an analysis record a meter will be connected to the control bank contacts appropriate to the individual choices for each group of the grading with further meters to record the traffic on the common choices. For measurement of total traffic in a group or grading only one meter with U-link strapping will be necessary for each recording sub-unit, that is, for one arc of the control switch bank.

In the extreme right-hand column in Fig. 5

the meter number should be shown, allocations being made in order starting with A1 to control uniselector 1, level 1, contact 1, and so on. When more than one control rack is supplied care should be taken to see that the control switches on rack 2 are allocated to meters on rack 2 in order to keep the connecting arrangements as straightforward as possible.

General Remarks.—When trunking changes are made in the exchange equipment, the connections to the recorder should be altered at the same time. Failure to do so may lead to confusion and unreliable records.

It is also important that the meters be given an electrical test just prior to operating the recorder. For this purpose an arrangement is incorporated for transmitting one hundred and one impulses to any desired meter under normal operate or saturate conditions at the usual speed of operation of the recorder.

THE TELEPHONE IN NEW GUINEA

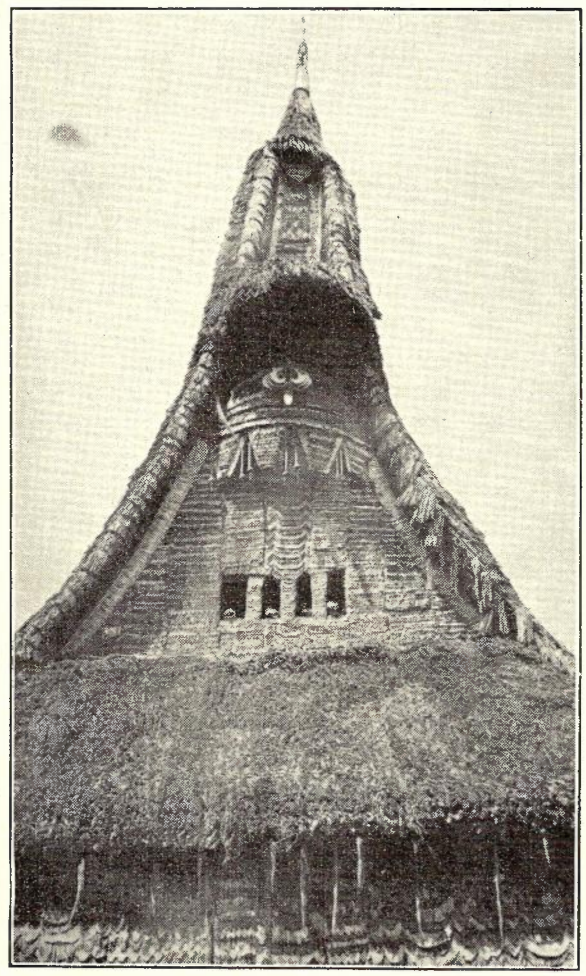
S. Kensett

The first Englishman to set foot on New Guinea soil was that famous explorer, William Dampier, in 1700. Captain Cartaret, also an Englishman, was next to write discovery on the map of this portion of the Pacific in 1767, and it was this man who named many of the landmarks around Rabaul. His description was mainly of the magnificent Mother and Daughters, three volcanic cones which lend distinction to the harbour, now known as Blanche Bay. Since this discovery a few more cones have appeared around our harbour and, I might say, not so beautiful, but distinctive nevertheless.

In the year 1884 the German flag was hoisted at New Ireland, New Britain and that part formerly known as German New Guinea. Germany retained possession until the annexation of the Territory by Australia on 13th September, 1914. Readers can visualize the difficulties which confronted the military administration in reorganizing and operating all public services, particularly in connection with our telephone work. A careful selection was made from the military administrative staff, a few highly qualified officers were borrowed from the Commonwealth of Australia and others were gathered from various sources.

Re-organization after re-organization proved to be necessary. It was difficult to obtain men with tropical experience and of a character suited and trained to public service. However a highly efficient service is now being rendered and compares very favourably with other tropical administrations.

In the year 1917, an officer of the Postmaster-General's Department was sent to Rabaul to maintain telephone services and, as it was military administration, this officer took the rank of Warrant Officer in charge of telephones and later of postal services. This officer, Mr. E. M. Hawnt, who, no doubt, is known to the older section of Sydney mechanics. In 1921, civil administration took over the reins of government, Mr. E. M. Hawnt retaining the position of Officer-in-Charge of Telephones and Postal Services. This gentleman then set to work in an endeavour to bring the telephone service into line with Australian standards. At this time it was not known whether cables would be suitable, mainly because of foreign substances in the soil of Rabaul. However, an experimental cable was laid and in 1926



Meeting House, Sepik District.
Note human skulls at windows.

a new telephone exchange was built and the whole town cabled. This was brought about by the recommendation of Mr. Hawnt and the concurrence of Mr. N. V. Hayes, an engineer in the P.M.G. Department, Melbourne. Prior to the cabling, Mr. Hayes made the remark that Rabaul was a telephone mechanic's nightmare, and I can quite believe that it was.

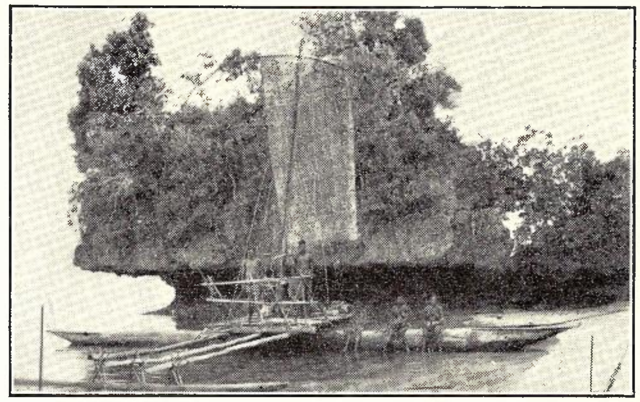
During the removal operations service was maintained, meaning of course paralleling of cables, but unfortunately, when all was ready to cut over, the wrong exchange was cut off, much to the disgust of the Foreman Mechanic. This was remedied as quickly as possible and the service carried on smoothly once again. Great difficulty was experienced with poles for distribution to subscribers' premises. It was found to be too expensive to install wooden poles, as the portion which was in the ground rotted very quickly.

Native village.

The system ultimately decided upon was the three iron poles coupled at the base, middle and top with an iron ring, a cooks terminal fitted at the pole top and subscribers' lines flying off from three cross arms fitted at a rakish angle to the poles.

Open wire was used at subscribers' ends and breakages in these wires were numerous owing to coconut bom-boms falling across them. Prior to the eruption of May, 1937, this method of feeding was to be changed, to that of stranded steel wire used as carrier wire and the standard V.I.R. fastened on to it by means of tape and wire, but before it could be completed, rumblings were heard and felt from the volcano and from Friday, 28th May, 1937, until 2 p.m., Saturday, 29th May, 1937, severe earth tremors were felt almost every two minutes, and at 2 p.m. on the Saturday a tiny island in Blanche Bay was seen to be rising and exploding, and by 4 p.m. this same small island was a huge mountain belching forth pumice, rocks and steam. On Sunday the other volcano, Matupi, situated on the other side of the Bay, commenced operation.

No doubt you read of these happenings and there is no need for me to explain further. At this time I was stationed at Longreach, Queensland, and when I received word to travel to Rabaul, I did so with many misgivings, and on arrival what I saw was really amazing, and my thoughts were centred on catching the next boat back to Australia. However, Mr. Hawnt, Mr. Tom Walsh and self had several talks and to work we went, and it was a heart-breaking job for a long time.

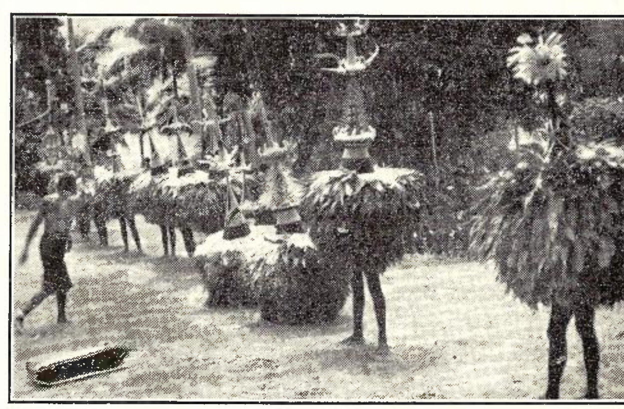


Sailing katamarang, New Ireland.

The pumice had choked the ground around Rabaul, making a huge water shed of the mountains, and the phenomenal rains that followed did more damage than the actual eruption.

Every morning we would go to the office wondering just what had happened overnight. Every day cables were broken and the great gullies left by the water made it a hard task to maintain any sort of service.

The Public Works Department was making every endeavour to drain the town with drains

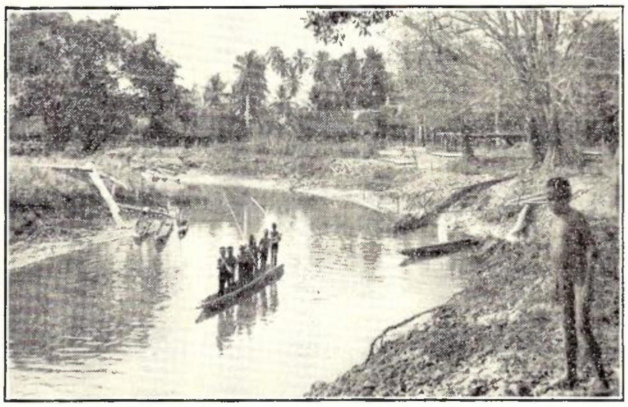


The Duk-Duk and Tamarangs at a sing-sing (dance).

measuring about 10 feet wide and 4 feet deep. Many annoying incidents occurred whilst this draining was in progress. All work, of course, is done by natives and, on one occasion, a gang of natives whilst digging a drain, came across one of our main cables. This cable meant nothing to the natives, so they promptly cut it off on both sides of the trench and nicely smoothed the ground over the ends.

As the eruption had written finis to all cable plans and records, we were kept busy, to the amusement of others, running up and down the trench looking for the cable, particularly as the natives had told us, "me pella no pindem, Master," meaning that they had not seen any cable.

At long last, some semblance of order was achieved. We then set out to re-erect the trunk line to Kokopo, approximately 12 miles of which had disappeared entirely. To erect this line, we had to run our poles right over the side of Vulcan crater. This was no mean task, as the



Sepik River natives in canoe.
These natives always stand in canoes.

only time we could work within two miles of Vulcan was from 6 a.m. to 11 a.m. and only then with sun goggles and masks; after 11 a.m., it was almost impossible to see further than 20 yards owing to the wind blowing loose pumice along the track of our line. The line was finally completed and we used iron poles with 200 lb. copper wire.

For several months, the maintenance costs were high as the ground was continually shifting and being washed away and, in some places, we found that our poles were entirely covered with pumice. Fortunately, this ground has now settled down and a good service is maintained with Kokopo.

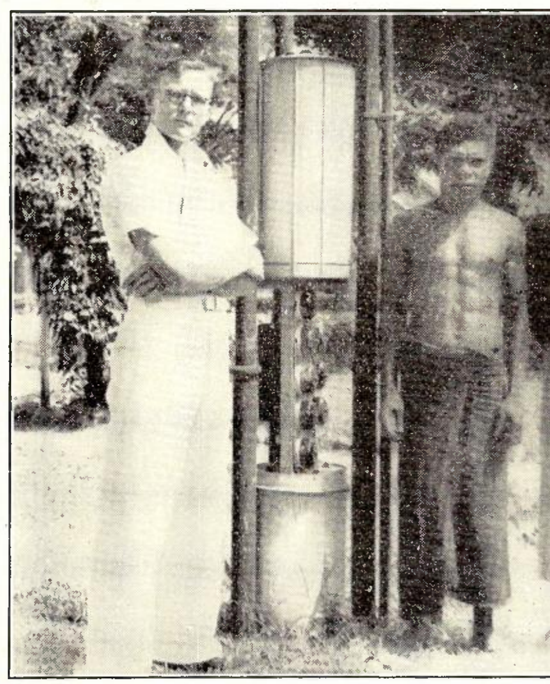
One interesting point is that, on both ends of this line, we are working superimposed E.C. telephone lines, one for a distance of 16 miles from Rabaul, and the other for six miles from Kokopo. This scheme was adopted as we did not want to risk further wire on our poles.

At present there are 208 subscribers working off a 200-line switchboard in Rabaul, and new equipment cannot be installed until some decision is made re the new capital of New Guinea.

On top of the hills surrounding Rabaul, is that part known as Namanula, which has 12 subscribers, previously fed by a 15 pair U.G. cable. Washaways on this mountain roadway caused us great trouble until we erected a hand-rail and placed the cable on top of it, but the natives travelling up and down this road used to hold competitions to see who could cut the cable with a knife first. We put up with this for a while, until forced to erect an aerial cable on iron poles for a distance of one mile and this is now giving satisfaction.

Owing to daily cable breakdowns, we ran short of paper jointing sleeves. We had plenty on order, but we were praying nothing would happen before they arrived; however, this was not to be, as the main 150 pr. cable broke down and we were then in a quandary, but necessity is "the mother of invention," and we canvassed the town for drink straws, which we cut down to sleeve lengths and completed a good temporary joint. Whilst doing this job, a very amusing incident occurred.

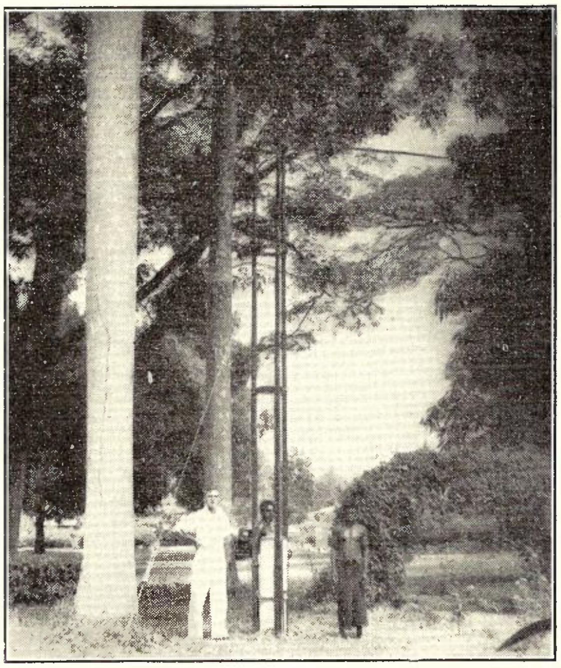
I worked all night, but at 11.30 p.m. went home for a cup of tea. Rain started to fall and, as I had two 110 W. lamps over the exposed joint to keep it as dry as possible and the joint



Author with native Boss Boy showing 10-pr. cable head and method of distribution to pole head.

being just outside the Crown Law Office, I was slightly nervous of the rain on the joint and lamps, so back I went, and on turning the corner, saw a large blaze at what I thought was the Crown Law Office. My thoughts were indescribable, and you can imagine my relief on finding that this was not the case, but Burns Philp & Co.'s store was burnt to the ground.

The Cooks terminal boxes used here were not a success as the humidity is always about 90 per cent. and we found leakage between lines with resultant cross-talk. We then set out to eliminate this, and Mr. Hawnt designed the terminal boxes now in use, a photograph of which appears here. In these boxes, the P.I.L.C. cable is taken in through a hole at the base and fanned out,



Showing complete pole as used throughout New Ireland.

the box is then filled with Berry Wigins compound. This system has proved very satisfactory, easy to work and can be kept clean by natives.

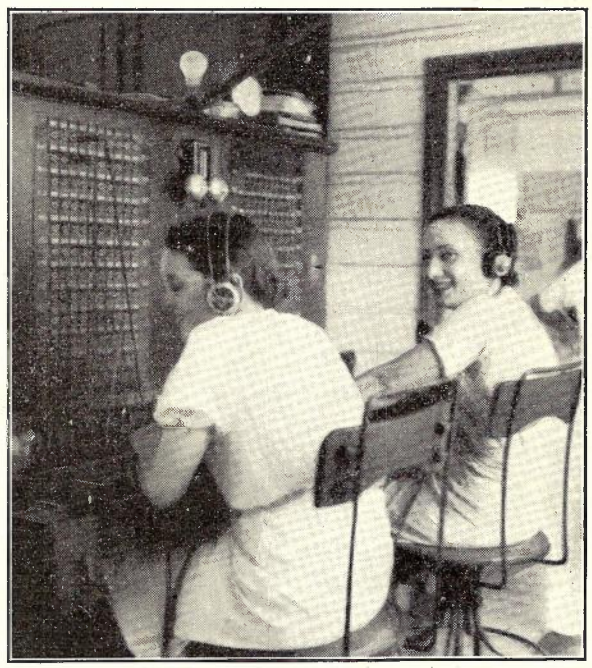
Besides being public servants, we are also endeavouring to instruct the natives and, although in the main, this appears to be somewhat of a job, there are several instances of natives with ability to grasp these teachings. At present, they cannot reason, but do their jobs blindly and, provided a fault is not too intricate, they manage very well. For instance, if a subscriber cannot be heard, they change batteries. If a subscriber reports C.G.X., they know whether its o/c or s/c by the switchboard generator and so on.

We have two boys at the moment who can use a standard magneto test desk and install handset telephones. These boys are a great asset, but cannot be trusted on their own as yet.

Recently I installed a telephone system at Kavieng, New Ireland. U.G. cables were put down, and in all about two and a half miles of cable was laid. This particular town is situated on a coronous (coral) ridge, and, as this coronous is mainly composed of lime, it will be interesting to watch the action on these cables.

On one occasion, whilst digging cable trenches, I found it too hard to use picks or crowbars, so decided to use dynamite. In loosening the coral with an iron bar later, the bar disappeared altogether into a huge cavity in the coral, consequently, I did not persevere with dynamite. I had often seen the natives burning coral to get lime, so I decided to try lighting fires to soften it, and found this to be quite a success.

The switchboards used throughout the Territory are of the self-restoring indicator type. This type is used as it is foolproof for native operators. It is unfortunate that a unit fee system



Switch girls in attendance, Rabaul Exchange.

cannot be brought into being, but such a system is impossible with native telephonists. All subscribers are charged a flat rate of £15 per annum, but, I believe, a concession will shortly be made to private houses. Their rental will then be £10 per annum.

To provide a more efficient service between 7 a.m. and 6 p.m., we have replaced the native telephonists with girls, and this is greatly appreciated by the public.

The staff at Rabaul consists of a foreman mechanic, two mechanics, three lady telephonists, four native telephonists and six native line boys. When the number of natives is insufficient, we can easily obtain boys from the Government labour line. In comparison with Australian telephone networks, the staff at Rabaul would appear to be rather large, but such a comparison is impossible, as a mechanic's duties here include cable joining, line work, overseer to native labour line, general telephone work, and the maintenance of Kokopo and Kavieng exchanges.

It has been our aim for the past two years to install the Standard Handset telephones throughout the whole Territory, and at the end of this year it will be an accomplished fact. A new telephone exchange will shortly be installed at Madang with 36 subscribers as a starting point, and when this is completed a mechanic will travel from Rabaul to inspect Salamaua, Madang and Kavieng on a round trip every three months.

The greatest source of trouble in the coastal towns of New Guinea is the heavy humid atmosphere, which causes mildew to form on covered wire, even inside switchboards. A constant watch has to be kept and all wiring heavily shellaced frequently. Even on the dryest of days the greatest care has to be taken in jointing cables, and before fitting the sleeve, the joint has to be thoroughly dried with blowlamps, etc. Earth tremors are another source of annoyance as a particularly severe shock often causes cable breaks.

As I previously explained, all labour is carried out by natives, and the medium of speech between master and native is pidgin English. This medium is not perfect but is much more easily acquired than English for the natives, or native language for the white man. It is very noticeable even now that the natives who have been under white influence for a long time can understand and, in some cases, speak perfect English, but strangely enough, it is the boys who, in their endeavour to emulate the white master, causes that white master to keep his personal belongings under lock and key. There is a strange fascination about the tropics that makes one want to return, and even though things seem different, somehow everyone seems happy and contented, but that three months' leave is a silver lining for me, so cheers, Australia, until we meet again.

BROADCAST STUDIO EQUIPMENT

H. R. Adam, A.M.I.E. (Aust.)

General.—Before considering the primary factors it would be well to study what is meant by a studio group. The studio group comprises not only a number of rooms specially allocated for the purpose of being the place where artists, bands and others perform before a microphone, but also such outside temporary locations as may be used for this purpose. Within a group one or more programmes may be proceeding at the same time and, in addition, rehearsals requiring the use of microphones and control facilities may be in progress.

A group of studios serves directly a number of broadcast transmitters generally located within the State and, indirectly, via similar groups in other States, transmitters in these States. Flexibility must be maintained so that any group of transmitters may be fed from any studio in any arrangement.

The technical equipment of a studio must provide for the setting up of at least two broadcasting channels which may be directed without pause from one studio to another to outlets which may also vary. The channels must meet the requirements in regard to the amplification and control of very weak microphone currents to values suitable for transmission to the broadcasting station.

With this general definition of a studio group, the primary technical factors to enable requirements in respect to amplification will be considered.

The common sources of programme—speakers, bands, etc.—possess two characteristics of particular interest—a frequency range and a volume range.

Our ears can detect sound, if of sufficient intensity, in the frequency range from 30 to 20,000 cycles and components of these frequencies are present in many sources, but it is doubtful if the final octave of this range contributes a change of quality which affects the value of the sound heard. I am not sure but that this octave does not include all the more unpleasant sounds which the best instrument makers and players strive to eliminate. With a range of 50 to 8,000 cycles per second, the important parts of practically all programmes can be reproduced, and it has become customary to specify a uniform response from 35 cycles to 10,000 cycles per second as being adequate at least for a monoral reproducing system, uniformity being defined by a range not exceeding $\pm$ 1 decibel.

Volume range, i.e., from ppp. to fff., has a significance which, while not overlooked, has been discussed and appreciated less than it ought to have been. It is clearly desirable to avoid tampering with the volume range of the source, but two factors impose a need to restrict the normal range. One arises from competitive noises introduced into the circuit subsequently to the volume control, and the second is due to a need for maintaining a reasonably high aver-

Lecture delivered before The Postal Electrical Society of Victoria on 10th October, 1938.

age modulation of the broadcast transmitter.

Allied with volume range is the question of noise, and as noise is a technical factor which largely determines the amount of gain and its location, its mode of entry into a broadcasting channel is described in detail.

The first source of noise in the electrical system is the molecular movements in the conductors. This noise is approximately 130 db below a zero of 6 milliwatts and, therefore, if a 30 db margin be accepted as the minimum ratio between signal and noise, the minimum useful output from a microphone must not be less than 100 decibels below zero. As this molecular noise is irreducible, it determines the minimum sensitivity of a microphone, and also such points as the minimum distance a microphone can be placed from a performer. On account of the low sensitivity of modern microphones, the additional loss introduced by faders makes it necessary to employ preamplifiers, i.e., amplifiers between the microphone and the faders. In the design of subsequent stages of the channel, the introduction of loss through the use of a pad or fader may reduce levels below the minimum permissible.

The second source of noise is the electron stream between the cathode and anode of the first tube in the amplifier system. This stream is to a certain extent random and may give rise to noise, but with an adequate space charge to draw upon for the anode stream the effect may be reduced so as to be negligible in comparison with earlier molecular noise. As the signal is now amplified no further noise arising from this source need cause worry.

A third source of noise is the switching contacts in keys and mixers. In key contacts noise arises from the impulsive discharge of a charge that has accumulated on the pair to which connection is made. All parts of a circuit have a capacity to store electrical energy, and when two parts are connected a sharing of charge must take place. This source of noise can be reduced by ensuring that no static charge accumulates on either circuits to be connected or, alternatively, that no movement of charge takes place when a switch is closed. A method of doing this is to ground through high resistances each side of the circuit, and drain away to a common point any static charges. Another method would be to cross-connect with high resistances each side of the circuit across the key, and to make common the centre point of this connection. Noise arising from mixers may be regarded as arising from contact potentials due to the movement of the switch arms. With choice of metals, it may be considerably reduced. Dirt is a source of noise, and all contact surfaces must be kept carefully cleaned. The use of preamplifiers as required for present-day microphone work increases levels to such an extent that little trouble is now met in overcoming the noise difficulties due to keys and faders.

The above sources of noise are the determining factors in the design of microphones, and the first amplifying section of the transmission channel. There are other sources of noise in this section—crosstalk from external electric fields and microphonic tube noises. The methods and ideas that can be employed against these forms of disturbances are open to some discussion, and it is sufficient to state in general terms, the principles employed.

Protection against varying magnetic fields is provided by avoiding loops, i.e., with twisted pairs, by canning transformers in heavy cases, and by winding them so as to be at least partially immune from external fields (astatic winding)—for example, on a ring. Protection against electrostatic fields is provided by using short leads in the low level sections, and by enclosing all parts of the circuit in copper or metal screens and/or by balancing each conductor with respect to ground so that the charge arising in a pair does not produce a circulating current, but merely a longitudinal one. Faulty tubes which are microphonic or subject to irregularities in the cathode-anode stream may be cured usually by the selection of a satisfactory make.

The above sources of noise all occur prior to the volume control of the channel and should the microphone output not be sufficient to override the noise, manipulation of the control can achieve nothing of value in respect to the signal to noise ratio. Owing to the existence of a threshold of hearing, an increase of loudness brought about by increasing the gain may make such noise as is derived from the sources mentioned more noticeable and objectionable.

As the volume control itself introduces a loss usually in the neighbourhood of 20 decibels, but ranging in accordance with the volume input, it is necessary to provide amplification between the faders and the volume control—otherwise, the level would fall too low for competition with molecular noise in the conductors. The amount of amplification between the fader and the master volume control should be limited so that the level input to the master volume control is well below the power capability of the amplifier stage inserted. For this reason, the amplifier between the faders and the line is divided into two sections rather than carrying it out all in one step.

The fourth source of noise arises in the lines connecting the studios to the broadcast transmitters. Noises enter lines mainly from neighbouring circuits and atmospheric disturbances. These, in general, cannot be reduced below a certain datum, although, in special cases where precautions have been taken, very quiet lines may be obtained. The determining level for transmission from the studio is that of the speech levels arising from the ordinary telephone, for if the transmission level is made much higher, annoying crosstalk may occur between the programme channel and the comparatively weak received signal from a remote source. The transmission level adopted is approximately 6 milliwatts, and in the majority of cases this provides an adequate margin between signal and line noise. In some cases, it is desirable to employ higher levels.

These comments will suffice to indicate the importance of noise, and how imperative it is to combat its introduction. The necessary requirements are summarised as follow:—

(1) Microphones whose input on minimum signals is not less than 100 decibels below zero.
(2) Preamplifiers whose gain is sufficient to raise the minimum signal to a value such that, after passage through the mixer, the level will still be above the datum of 100 decibels below zero.
(3) A volume control that will enable the average level from a variety of different sources to be adjusted to equality, and also to permit of the maximum levels being restricted to avoid overloading and overmodulation of subsequent equipment.
(4) Sufficient amplification to permit of the output of the microphone being raised to approximately zero level for transmission to a line.
(5) Adequate screening and protection against electromagnetic, electrostatic and radio fields, together with the location of amplification so that long circuits carrying low level programmes are avoided.

These requirements are met by providing a total amplification of 70 decibels, with the possibility of 100 decibels maximum through use of a volume control (this amplification includes the losses in faders and gain control) and locating the amplifier as close as possible to the microphone so as to reduce the possibility of noise introduced from foreign sources being troublesome.

Other technical factors are impedance and power capability. Wrapped up with the general circuit arrangements is that of the normal impedances in various sections. Of these, the outgoing line approximates to 600 ohms, and this figure has been adopted for all parts of the circuit subsequent to and including the volume control. For mixers a figure of 200 ohms was adopted some years ago, presumably on account of the early types of microphones having this value. Subsequently, preamplifiers have been designed to operate into this impedance, and in consequence the impedance has been maintained. It may be preferable to adhere to 600 ohms throughout, matching, where necessary, with transformers. In connection with matching, it is of interest to note that in Europe there is a tendency to make all amplifiers have an input and output impedance of 40 ohms, irrespective of the impedances into which they operate. The basis of this arrangement is:—

(1) Such an amplifier with a constant input will deliver a constant voltage to a wide range of normal line impedances.
(2) The normal microphone has an impedance of 30 ohms.

The scheme is open to the objection that some power is lost on account of the mismatch to lines. Against this, it should be noted that to meet the same difficulty it has become customary to place a small pad subsequent to amplifiers with a similar loss. The loss due to mismatch 40 to 600 ohms is approximately 6 decibels.

The power capability of an amplifier is largely determined by the type and arrangement of tubes employed, and it is important that any amplifier should have an adequate margin over the maximum possible level at the point of the circuit in which it is inserted. In practice, as it is not necessary to exceed a level of approximately zero, it is not difficult to achieve this requirement. A margin of 14 decibels between the normal output level as determined by the level meter is adequate to avoid distortion on a transmission on account of studio amplifier overloading. With an average power of 6 milliwatts, a power capability of 150 milliwatts will provide a satisfactory margin. As outputs having a power capability of 250 milliwatts are readily available, this figure has been chosen for recent equipment.

To define this overload point, the total harmonic content of the output tube is specified not to exceed 4 per cent., this figure being chosen as at the overload point a sharp rise of harmonic content occurs. To avoid the possibility of harmonic content being excessive, below the overload point it is usual to specify that the harmonic content at half this output should not exceed 1 per cent.

Having outlined some general observations on the basic structure of any studio system, and before proceeding to the more complex facilities required to meet the needs of the group, a few observations on control are desirable. The functions of the control are:—

(1) To adjust the average level for various classes of source to a common value.
(2) To limit the maxima so as to avoid overmodulation of transmitters.
(3) To raise quiet passages so as to avoid trouble due to noise arising subsequently to the control.

The real difficulty of determining how to manipulate this control arises from the wide range of sound volume, which is part of the effect aimed at. The operator has to determine how much of the peak intensities he must cut down and how much of the low passages he must bring up. For example, if he maintains the general level high, the effect of crescendos is lost, and no doubt emphasis is placed on pianissimo passages. Alternatively, if he arranges the control to avoid much manipulation when loud passages occur, the average signal or depth of modulation is lower, and listeners may be troubled with noise.

As far as I am aware, no specific guide to the operator has been laid down, at least for orchestral concerts. Such rules as have been employed tend to lead to an excessive restriction of loud passages — for example, the rule that in any piece the volume indicator should kick to zero approximately every ten seconds, or that the overmodulation indicator should operate at least once in a specified period. It may be more desirable to operate on a basis of the amount of restriction necessary on peaks—thus, during a rehearsal the normal or general setting of the gain control should be ascertained. This normal setting should be the datum about which compression is based. Peaks should not require more than four or five decibels of restriction, and low level sections should not be increased by more than this amount. Actual control should only occur during the really loud passages as the prime requisite is reproduction of the item concerned with as close a copy of its volume range as possible. The transmitter is not designed to make as much noise as possible, but to broadcast as faithful a copy of the production as is possible.

In regard to the raising of the level of the lower portions, it is doubtful if any real merit can be obtained by doing this. If it is necessary to over-ride noise, the noise is usually too much of a nuisance in any event, and nothing much is achieved. If to compensate for the habit of a listener in adjusting a set at too low a volume and thereby losing the low passages, it seems to be unfair to the man who operates at a proper level and who, therefore, probably really listens. A point of interest in regard to control is the contrast in level that should exist between a full orchestra and the announcer. It is suggested that in these cases, even at the expense of reduced modulation depth, the control should be brought back at least 5 decibels below the normal orchestral level. At present a full orchestra is frequently followed by an announcer at the double fortissimo level.

The technical factors discussed determine what might be regarded as the backbone of a studio system. It is the programme factors which enable us to determine the system as a whole.

There are two major factors, namely, the multiple production of programmes within a studio group, and the maintenance of continuity of each programme. Continuity must be such that changes can be made on scheduled cues without doubts, and without such changes being apparent to the listener, either through pause or noise.

These two factors involve means for handling within a group two or more programmes, and means for an unambiguous transfer from city to studio or to an outside source. In addition to at least two programmes, provision must be made for rehearsals which must be carried out with microphones and loud speakers for observation in the same manner as during the actual broadcast. When it is realized that for every hour of a programme that is broadcast at least four hours' rehearsal are necessary, it will be appreciated to what extent rehearsals occupy time and space in a studio. Another factor is means for the production of items. The production necessitates control over balance of two or more sources, the control of artists in relation to microphones, and the timing of entry of effects and artists, in addition to the direction of artists in regard to the effect the producer strives to achieve. As the technical control enters into this, facilities must be available for co-operation between the producer and the technical control. Means for effects reproduced from discs must be available, and also the closest contact between the producer and all taking part.

Another factor of importance arises from the need for broadcasting from outside points — halls, racecourses and inter-State studio groups —and for effecting smooth transfer to and from these sources with a standby programme instantly available.

Other necessities are facilities for playing records, both for programme purposes and for programme building prior to use; loud-speakers for observation purposes; and cue lights of various classes.

In addition to this brief outline, further requirements arise from time to time, and flexibility of arrangement to meet the growth of new facilities must be available.

The ideals to be aimed at in meeting these programme factors are:—

(1) A scheme which permits of using every studio simultaneously.
(2) A clean-cut method of transfer from one studio to another without ambiguity, and with the responsibility of actual transfer in the hands of one man.
(3) A system which caters for expansion by the addition to existing units—for example, a unitary and standardized system.
(4) A flexible arrangement that permits of special requirements being readily set up with a minimum of equipment.
(5) An adequate intercommunication system.

From the elements of the studio system as just described, a variety of arrangements might be employed, and before entering on the details of the system being adopted here, two different systems that are being employed in England and America are described briefly.

The system employed by the British Broadcasting Corporation is outlined in Figure 1. In this system control points are provided in the studio listening room, in the announcer booth and in the main control room, with additional

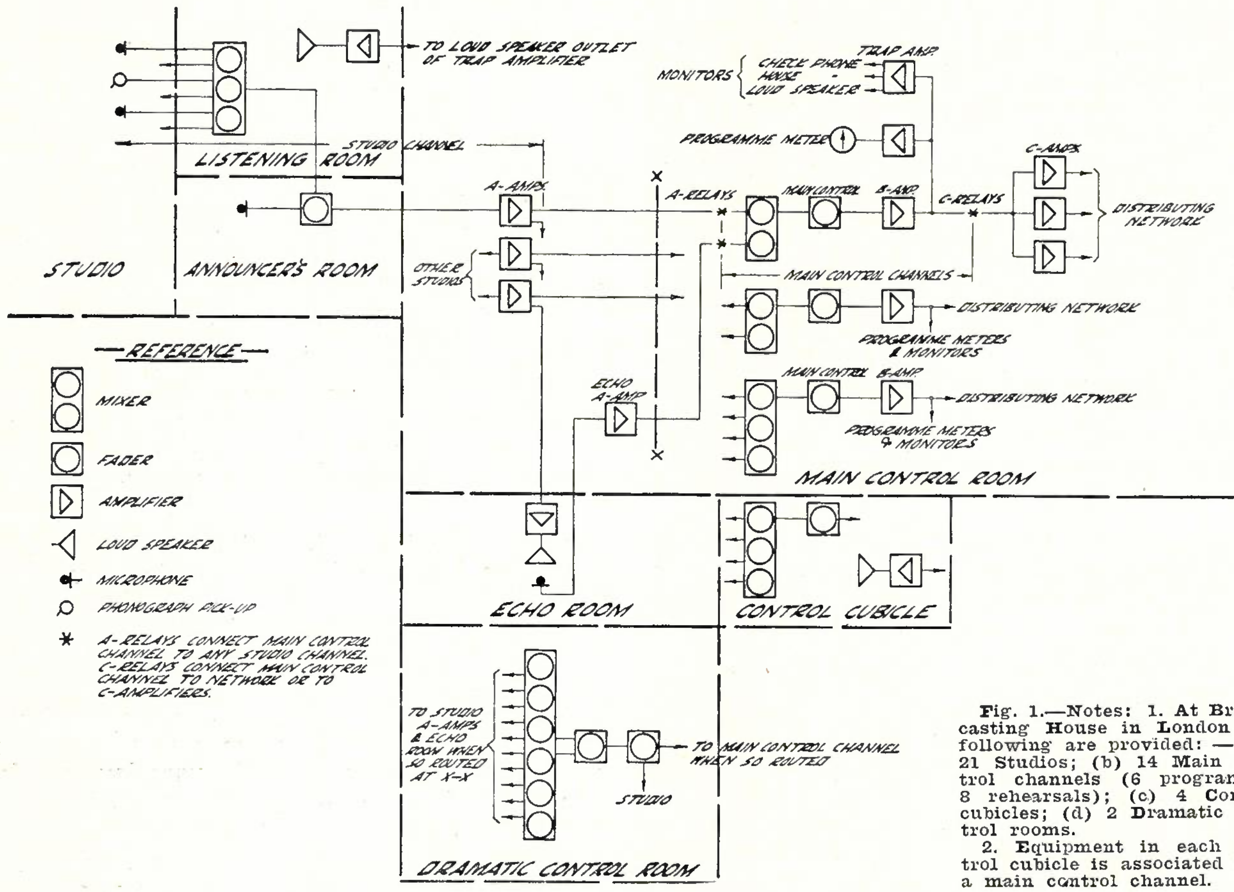


Fig. 1.—Notes: 1. At Broadcasting House in London the following are provided: — (a) 21 Studios; (b) 14 Main control channels (6 programme, 8 rehearsals); (c) 4 Control cubicles; (d) 2 Dramatic control rooms.
2. Equipment in each control cubicle is associated with a main control channel.

positions for multi-studio operation and special control. The system is characterized by the number of points at which programme may be fed into a programme channel, and another feature of the system is the centralization of engineering control in one room, a system which involves headphone monitoring at the level controlling position.

The B.B.C. scheme also centralizes all amplifying equipment and an extensive system of low level wiring is necessary. The main outline of this system was evolved when Reiss microphones and microphones of similar output were standard. As microphone sensitivities have decreased it is possible that a different outline would have been adopted under present conditions.

The scheme lends itself to a very comprehensive mixture of sources by use of a dramatic control panel. It is possible to mix, through faders, the output from a number of studios in the same manner as the number of individual microphones within the studio. This feature offers a solution to the problem of cross-fading sources in a dramatic production—the fading in and out of non-recorded effects and the balance of such effects as may be desired by the producer. Effects are not only mechanical but also vocal, and it would be difficult to obtain a proper balance between, say, a choir and a solo performer if the microphones were in the same room. If performers are in separate studios, the question of synchronization must be set against this difficulty, and an elaborate cue system becomes necessary.

The major features of the system employed in America by the N.B.C. are outlined in Figure 2. This system associates with each studio a group of equipment that makes each studio self-contained. Each studio can be used either for programme or rehearsal simultaneously with any other studio in the group. This arrangement permits of full loud-speaker monitoring at the control point, a feature of some merit, and in addition close contact may be maintained between the dramatic control and the artistic control in the studio.

As all low level circuits are confined to the studios, they may be located anywhere with respect to each other. Should growth demand the location of studios at some distance from the original group, no technical difficulty would arise in respect to their provision. This scheme contains the essentials of the system described later. Arrangements could be readily made to operate other studios as satellites of one particular studio, and in this way dual studio operation similar to the multi-studio methods of the B.B.C. could be carried out. Other embellishments such as echo rooms, etc., may be readily added to the scheme.

In both these systems the two major switching positions occur normally between studios and a programme channel, and between a programme channel and outlets. Except when the dramatic control panel is inserted, the first switch is interlocked so that only one studio can be connected to a programme channel. Outlets may be connected in multiple across a particular programme channel. The systems differ in the place of location for equipment. In the B.B.C. method, the main amplifier is associated with the programme channel, whereas in the American system this channel is merely a link. In both, outlets have associated with them branching amplifiers of low gain, which isolate the various outgoing lines so that impedance variations in one line do not affect what is transmitted on others.

Australian System.—The system, which is being adopted here in our comparatively small groups, is similar to the American with the exception that direct connection is effected between studios and outlets without the intervening programme link. This scheme is suited to our conditions, particularly where studios are located in widely diverse locations as in Melbourne.

In the ensuing details the simple amplification channel should be borne in mind: microphone-preamplifiers-volume control-line amplifiers-branching amplifiers, as this is the backbone of the system. Variety is introduced by two points of commutation: at the output of the first preamplifier (mixers and selector keys), and between the line amplifier and the branching units (switching relays). The first point is solely concerned with sources in or being controlled in the studio—for example, microphones, disc players and outside programme fed to the studio. The second point is solely concerned with the connection of studios to one, two, three or almost any number of outlets. Each studio is self-contained, and may be used for rehearsal, audition or programme independently, and without interfering with any other studio—thus, if nine studios exist, nine separate programmes may be broadcast simultaneously. The facilities required in the studio, the booth, and in the switchroom, are:—

In the Control Booth:

(1) Selecting and mixing of a number of sources.
(2) Control of level with supervisory facilities such as a level meter and overmodulation warning.
(3) Effecting the switching of outlets to the particular studio channel at the same time removing these outlets from the preceding studio in use.
(4) Monitoring on a loud-speaker and also on headphones programme originating in the studio and also, if desired, programme originating in other studios.
(5) Switching off loud-speakers or adjusting them to a low volume.
(6) Switching outside lines into the programme, and feeding programme back to outside points when they are not broadcasting.
(7) Communicating with the switchroom, outside points and other studios, and the announcer within the studio.
(8) Giving a warning light to the studio prior to the commencement of programme, and lighting the "on air" signals in the studio and outside the doors when broadcasting.
(9) Indicating when circuit conditions depending on operations elsewhere are suitable for the operation of the above facilities—for example, outlet switching and outside line switching.
(10) Talking back to the studio.

In Studios with an Announcer's Table:

(1) Selecting and mixing one of two microphones (announcer and speaker) and the output from two record players.
(2) Effecting the switching of outlets subject to permission of the technical control.
(3) Monitoring on a loud-speaker and also on headphones programme originating within the studio or elsewhere, including all incoming inter-State programmes and programme from outside points.
(4) Switching outside lines and time signals into the programme.
(5) Communicating with the control booth, and in some cases with the general telephone system via the P.B.X.
(6) Giving a lamp cue to a talker within a studio.
(7) Indicating the broadcasting outlets connected to the studio.

In the Switchroom:

(1) Presetting circuit arrangements for switching outlets from one studio to another.
(2) Effecting the switching of outlets if required.
(3) Testing and equalizing outside lines prior to a broadcast, and routing these to a studio.
(4) Communicating with studio booths, broadcasting outlets, recording rooms, trunk equipment and test positions.
(5) Routine tests on all studio equipment—for

example, frequency response, distortion and noise, and also on outside line connections.

(6) Monitoring and observation on all outgoing programmes as may be required. These facilities are more in the nature of a check on the observations made at programme control points, as continuous observation is not required in the switchroom.

(7) The control and distribution of automatic signals such as time signals.

The facilities for selecting and mixing sources are provided by a group of four faders and a number of keys, the keys selecting four out of eight possible sources which may be microphones, record players, or a group of six outside lines. With the exception of the record players, all mixer controls are in the booth, key switching being employed in the studio.

Level control is provided by a fader between the second and third amplifiers.

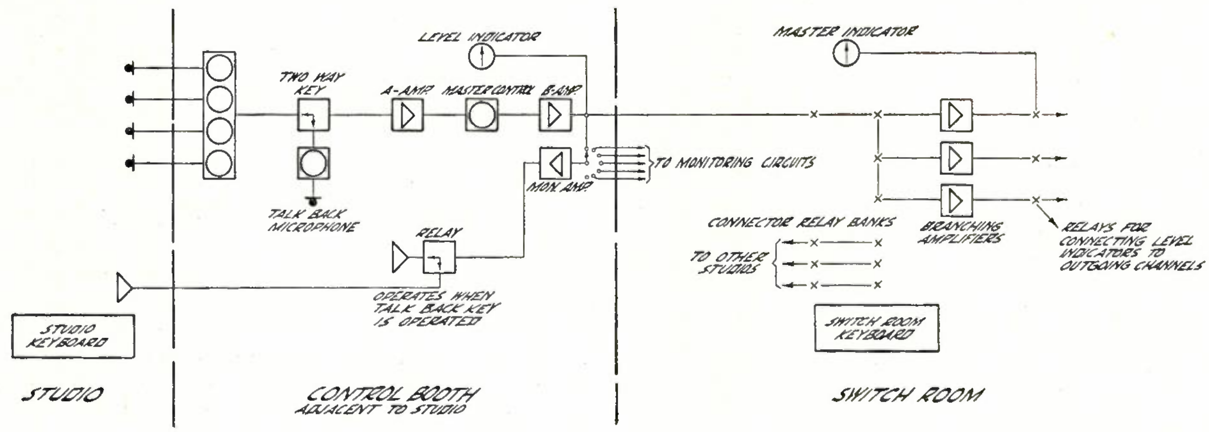
A meter having a rapid action is bridged across the output of the third amplifier, through which the level transmitted may be observed. An overmodulation warning is provided by automatically leading back from the studio transmitters an impulse. When overmodulation occurs, the impulse may operate a buzzer in the booth or cause a lamp to flash.

The switching of outlets is provided for by a non-locking key which places a ground on the switch relay operating circuits, or in some cases via an intermediate relay. The relay system is arranged so that the operation of a relay pertaining to an outlet automatically releases another relay pertaining to the same outlet but to another studio. The switching can only occur after the connecting wire has been extended to the booth from the switchroom, an operation which lights a supervisory lamp in the booth. The booth operator is primarily not concerned whether the correct outlets have been selected, this being the duty of the operator in the switchroom. When switching occurs, the "on air" signals in the studio and booth automatically light, and thus provide proof of the completion of the operation.

Monitoring is catered for by the provision of two or more channels feeding programme to all studio booths at zero level. A high impedance bridging amplifier, in conjunction with a key, enables the studio output or these two programmes to be listened to. Similar facilities are available on headphones which also may be used to listen to incoming programmes on outside lines.

The switching of outside lines is provided for by a group of six keys, the operation of one of which routes the incoming line to the outside line fader. The line is extended from the switchroom and, when routed, a lamp lights in a position appropriate to the key. When switched to the transmission circuit another lamp lights, and also one in the switchroom, at a position which associates it with the equalizer feeding the programme.

Communication over these lines is by a ringing and listening key in series with the keys switching on to the fader. The other keys are arranged so that when the line is routed to the



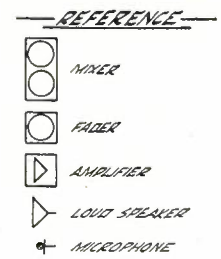


Fig. 2.—Studio Keyboard provides keys for operating switch room relays, signalling to other control points and jack terminations for headphone listening.
Switch Room Keyboard provides keys for setting up the circuit for operation of relays to connect a studio to any one of eight relay banks and other keys for selecting relays associated with the outlet branching amplifiers mounted in these banks. Where the number of studios is small each studio may be connected permanently to one bank and then only one bank of keys is necessary.
Monitoring Facilities other than local are supplied to the control booths and studios from the switch room via a selector switch.
"A" Amplifiers are frequently located between the microphone and mixer instead of as shown.
Studios and Control Booths. In the N.B.C. building in New York. 27 studios are provided and there is generally one control booth to each studio.

fader, all subsequent keys are disconnected, so that ringing on the wrong line will not affect the broadcast. Programme is fed back on these lines by tapping a portion of the programme output, and feeding it to the line across the ring relay. Communication with other points is provided by a simple key arrangement.

The warning light facility is provided by a manually operated key. The "on air" signal is automatic, being lit whenever a broadcast outlet is connected to the studio. To economize in battery, and to provide a bright light, A.C. is employed for these lamps, the switching being carried out with mercury contact relays.

The talk-back facility is obtained by switching with a relay, the transmission circuit at a point between the programme mixer output and the first main amplifier, so that a microphone is connected at this point. The same relay cuts in the studio speaker. The booth speaker is cut out when the talk-back key is operated. This key is a non-locking key protected by a presetting key on the technical position. With this arrangement and a suitable timing of the talk-back relay, it is possible to avoid even a momentary period

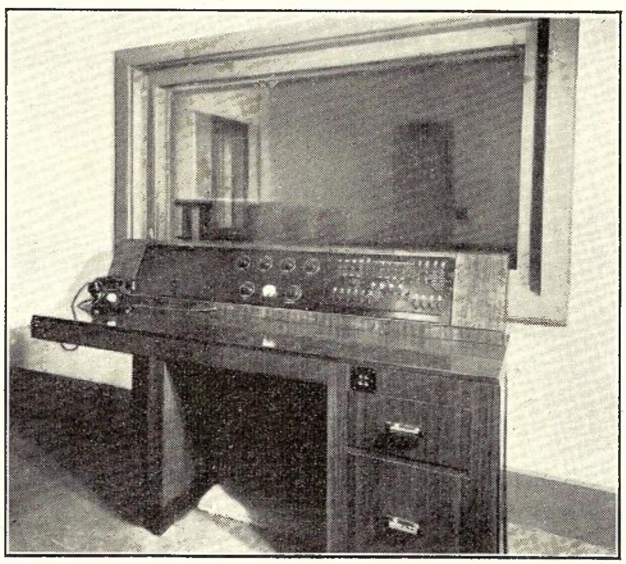


Fig. 3.—5 C.L. Studio Control Desk, Booth 4.

when microphone and speaker are alive simultaneously. In the studio the opening of a microphone is automatically inter-locked with the studio speaker so as to avoid the same trouble.

These facilities are mounted on a desk designed for the dual working of a producer and technical control. Three panels are mounted on this desk in a frame which is hinged to permit of inspection. On the left-hand side terminal strips and relays, and the talk-back key are mounted. In the middle, opposite the technical position, the mixer and level control panel are mounted, while on the right-hand side the key panel for the above facilities is assembled. This general arrangement is shown in Figure 3. The remaining equipment in the booth comprises an amplifier rack, distributing frame and power panel, with which are associated the A.C. cue light relays.

In the studios the facilities are mounted on a desk which also incorporates two record playing machines and space for keeping log papers and programme notices. The facilities comprise keys and lamps and two faders for the mixing and control of the output of the record players. The switching of outside lines and headphone monitoring arrangements are similar to those employed in the booth, but are subject to correction at this latter position. Time signals are fed into programmes through a fixed pad which presents a high impedance to the transmission circuit so that disturbances cannot affect the transmission, and impedance relationships are unaltered. A key is provided to select observatory time signals or chimes. Other automatic signals could be conveniently fed into the system by this means.

The table for the announcer is designed to permit of ready access to all facilities with convenient space for log keeping. The control panel is approximately 19 inches in front of the announcer, and the turntables are located as close to the centre as is consistent with the width of a log sheet. The record players are provided so that the left-hand arm rests across the back of the left-hand turntable, while the right-hand one rests along the right-hand side. This arrangement offers the best compromise for operation by the announcer. In earlier models the left-hand unit was provided to rest along the left-hand side, but the larger units now in use make it desirable to adopt the method stated. Two removable notice boards to the left and right of the control panel, and arranged to face the announcer, are provided for programme notices, and a number of shelves are located on the extreme left for filing papers. Provision is made for pens and ink, the wells being chosen to minimize the chance of staining the table.

In the switchroom the facilities for presetting circuit arrangements comprise a group of keys. Each key belongs to a studio and to an outlet—thus, the operation of, say, key 12 would select outlet No. 12 to be connected to Studio 1. The total number of keys is equal to the product of the number of studios and the number of outlets as for each studio there corresponds a key associated with each outlet.

The operation of one of these presetting keys connects the operating winding (15 ohms) of an associated relay to a common which is associated with the studio. Thus, if five outlets are preset to Studio 1, the five relays are connected to the Studio 1 common.

The battery side of all the relays pertaining to a given outlet are common, and fed through a common resistance of approximately 100 ohms.

Operated relays are held through a holding winding (1000 ohms) and one of the relay contacts. The relays have four make contacts, two of which connect the studio circuit to the outlet branching amplifier, one holds the relay operated and one provides a ground for signal lamps, and also four additional relays copying the action of the main switching relays for routing incoming signals such as the overmodulation impulse and a monitoring circuit from the transmitter.

The operation of the relays preset takes place by grounding the studio common. The ground may be provided by a relay whose operating circuit may be extended to the studio by a key which lights a lamp in the studio to indicate that this operation has taken place.

The grounding of the studio common causes current to flow through the relay to be operated, and a resistance common to all the relays associated with the outlet concerned and reduces the voltage across the holding coil of any relay of this group already held and thereby causes it to release—thus, with a 12 volt battery, the holding current would be 11 milliamps. When a ground is placed on the operating end this current is reduced to 1.3 milliamps, say slightly less than 12 per cent. of the normal holding current, a reduction that is adequate to ensure release.

This switching system is extremely simple, and has the marked advantage that its introduction involves merely the addition of relays without modification of existing relays. As changes can only occur when the studio common is grounded, presetting keys may be left operated so that rapid transfers back and forth between two studios may be effected without presetting, but as this procedure reduces working margins, this practice should not be general.

Facilities for testing and equalizing outside lines are provided by a link circuit containing an equalizer and an attenuator, and a group of routing keys. Outside lines may be patched to these link circuits and tests carried out using the switchroom amplifying channel and loud-speaker. After equalizing these tests to adjust level and to check line conditions, the circuit would be directed to the studio control booth. To enable the link circuit to be spoken over and rung through from the studio, a relay is associated with each link and when not operated the relay routes the line direct. When operated via the equalizer the operation is effected from the studio when the line is switched to the transmission circuit. The relay also provides a ground for the supervisory lamp to indicate when the link is being used for broadcast.

Testing facilities in the switchroom comprise a beat-frequency oscillator, together with distortion and noise measuring equipment and line testing equipment. With these it is possible, by using lines to studios, to check equipment daily from this central point in regard to frequency response, distortion and noise. Such tests may be carried out rapidly, and ensure confidence in the equipment.

The correctness of operations arising from action elsewhere is checked by signal lamps. Whenever a relay connecting an outlet to the studio operates, a lamp indicates the operation. When an outside line is connected to a programme another lamp is lit.

The observation of outgoing programmes is provided for by level meters on each channel or, alternatively, by the provision of means to connect such a meter. Facilities are provided to enable a loud-speaker to be used across any circuit by patching. Supervision of overmodulation on the City stations is given in a manner similar to that employed in the studios.

Automatic signals, such as time signals, arise from various sources, and facilities are provided to adjust the level of these to a value suitable for superposing on a programme originating in the studios. To enable one signal to be fed to programmes without coupling the programmes, these signals are adjusted to approximately zero level and faded down in the studio booth. This provides a high degree of attenuation between the programme channels.

The facilities for the switchroom are mounted on racks, and include the following units:—

A line terminating rack;
A facility and a control rack;
A switching relay rack;
An amplifier rack similar to the studio racks but including also a volume control and level meter;
Branching amplifier racks, each rack of which mounts 10 units having a high impedance input;
A test equipment rack; and
A power distribution bay.

This outline has dealt with the general features of the studio system, but, in addition, special facilities are sometimes required — for example, facilities for conducting sporting broadcasts on a Saturday afternoon, of such a nature that frequent changes of source may be carried out without undue formality by the announcer within the studio. Another special facility which has not yet been tried, but which appears to be desirable, is provision for the handling of transfers of Regional outlets between the two major programmes originating or being handled in a studio group.

The system outlined employs a unitary system, and it is desired to deal briefly with a few of the components employed. In a previous section, the announcer's table and control table for the booths were described. An amplifier rack and loud-speakers are common to all studios.

The amplifier rack, which is repeated in all studios, consists of an 8 ft. 6⅝ in. rack with bays mounting terminal strips for floor cabling. On it are mounted four preamplifiers having a gain of 25 to 30 decibels, an A amplifier (gain 45 decibels), a B amplifier (gain 45 decibels and power capability of 250 milliwatts), a C amplifier for monitoring (gain 30 decibels and power 3 watts), jack strips, a meter panel, distribution panel, and a power unit for all the amplifiers, together with space for mounting of relays controlling the loud-speakers. The form of construction employed in these amplifiers is of interest as it provides accessibility to all components very readily. It consists of a depressed panel with a cover plate or, in other words, a radio set turned on edge. The small components and wiring are contained within the recessed portion, while transformers and tubes project from the back. Apart from this feature, the circuit design of the amplifiers is of the conventional type, using an input transformer-output transformer with resistance capacity coupling between stages. The input transformer in each amplifier is astatically wound, and provided with an electrostatic screen between the primary and secondary windings.

Loud-speakers, which repeat themselves in all studios and also in offices and other situations, present some problems of mounting. To obtain good quality at low frequencies, it is impossible to avoid a considerable bulk, and to permit use anywhere the actual output should be independent of the position of the unit with respect to walls. To overcome these difficulties, a cabinet form of unit embodying a folded horn construction loading the rear of the loud-speaker and arranged so that the low frequencies issue from the front was devised. Dual speakers were employed as it was found that one was insufficient adequately to cover the frequency range.

The loud-speaker is the measuring stick of all performances, and it is essential that the speaker employed should reveal faults clearly to those concerned. A loud-speaker is a form of radiator, and the cabinet or mounting is the acoustic equivalent of an aerial in a broadcasting set-up. However good the speaker, its radiation efficiency at low frequencies is largely dependent on its mounting.

Other components, while the detailed working out of their form must be carefully considered, do not present any special problems. These are, for example, effects machines, record testing equipment and miscellaneous studio furniture. In the switchroom the only components that need be mentioned are the switching relays. The operation of these has been fully described, and their mounting employs the scheme commonly used in automatic telephone practice, i.e., the relays are mounted on a base which may be plugged into a shelf jack. Each base mounts up to 10 relays, all of which are associated with an outlet. The base also mounts the common resistance in the battery feed. Additional outlets simply require an additional relay base, and up to 10 studios may be catered for by one base.

THE BEVERAGE WAVE ANTENNA

E. W. Anderson

Theory of Operation

The wave antenna in its simplest form consists of a horizontal wire in the order of one wave-length long pointing towards the transmitting station to be received.

When the signal reaches point "A," Figure 1, an E.M.F. is induced in the horizontal wire due

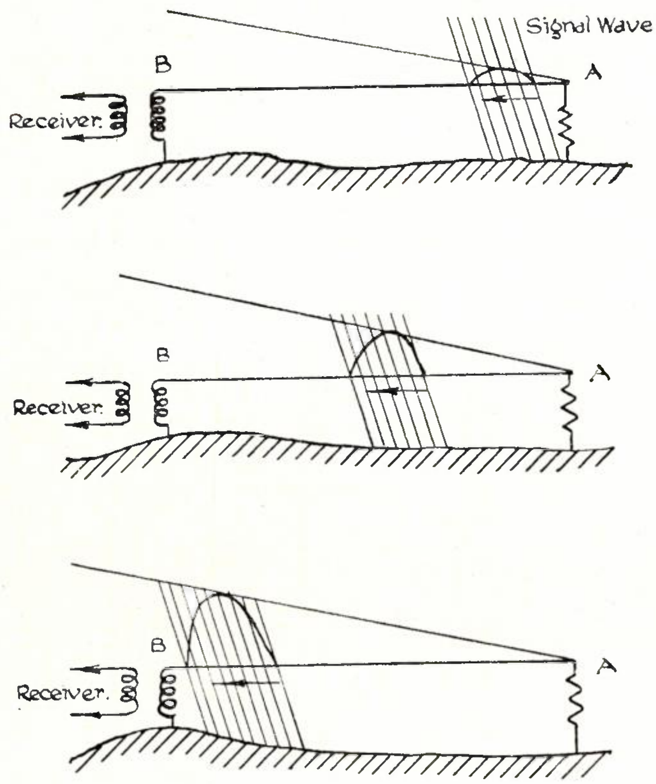


Fig. 1.—Building up wave on wire as space wave progresses.

to the fact that the wave front of the received signal is not perpendicular to the ground but has a tilt forward of 1-10 degrees depending on the wave-length and also upon the character of the ground. Thus, at the end "A" a wave of small magnitude starts to move down the antenna towards the receiving station, and if it travels with the same velocity as the radio wave in space, the space wave follows right along with it, supplying energy to it and building it up until at the end "B" it has reached a magnitude many times that which it had at "A." This is illustrated on Figure 1, which shows a single wave at successive intervals.

If the velocity of the wave on the wire is not equal to the space wave (which has a velocity equal to light), interference effects develop, the wave on the wire building up for a certain distance and then decreasing in amplitude. The velocities on the actual antenna, however, are nearly equal to that of light, so that for considerable lengths the wave on the wire builds up as it would on a line having a velocity equal to that of light.

A signal coming from the opposite direction to that which we have been considering will build up a wave on the wire in a similar manner, from a small value at "B" to a large value at "A." If, now, the line were open or grounded at "A" the wave would be reflected back over the antenna to the receiver at "B." On the other hand, if we damp the end "A" in such a manner as to prevent reflections, the antenna becomes unidirectional. A non-inductive resistance having a value:—

$$R = \sqrt{L/C}$$

Where R = Resistance,
L = Inductance per unit length,
C = Capacity per unit length,

constitutes practically a perfect damper.

Analysis has shown that when a wave antenna is a multiple of half wave-lengths long, that is 1/2, 2/2, 3/2, etc., a greater signal is built up on the antenna than at any other lengths; also the higher the numerator the greater the signal output and also, what is more important, if the antenna is terminated in its correct impedance to earth at the transmitter end, the better the directional properties of the antenna. Theoretically, the antenna should be unidirectional but, due to the values of earth resistance, this is seldom obtained in actual practice. However, if care is taken to keep the values of the earth resistance as low as possible and also to ensure that no R.F. pick-up occurs in any other part of the system but the antenna, the theoretical condition is very nearly obtained.

The surge impedance is determined by its height above ground and by the soil conditions with regard to moisture, etc. By erecting the conductor at a minimum height of 10 ft. above ground, the surge impedance remains more nearly constant during all seasons than when erected at a lower level. However, raising the height of the antenna has a serious disadvantage—namely, the end terminations, one to earth and the other to the receiver, become in themselves vertical antennae, and as a vertical antenna has a circular polar diagram this would tend to spoil the directive property of the wave antenna. By careful shielding of both these leads so as to ensure that no direct pick-up takes place, this disadvantage can be overcome.

There are two main methods of "balancing out" or damping the "back end" disturbances:—

(a) Figure 2A shows a single wire wave antenna using resistance and inductive network equal to $\sqrt{L/C}$ to prevent reflections—this type of antenna has been explained above.

(b) Figure 2B shows a two-wire antenna with one wire left open at the far end and the other wire connected directly to earth. The two wires work in multiple as an antenna, but as the far end is not correctly matched the wave will be reflected back to the receiver end using the two wires as a normal transmission line. Any signal coming from the opposite direction will balance out in the receiving transformer and can be absorbed in the terminating network from the centre tap to earth.

It can be said, therefore, that the Beverage wave antenna has the following desirable features:—

(i) Delivers a stronger signal over the entire band than a good simple antenna.

(ii) Unidirection.—By means of R.F. transformers the direction of reception can be chosen as desired, i.e., direction from A to B or B to A.

(iii) Atmospherics and industrial electrical interference considerably reduced, especially when the source is in a direction other than that of the received signal.

(iv) Low initial cost, long life and unlikely obsolence.

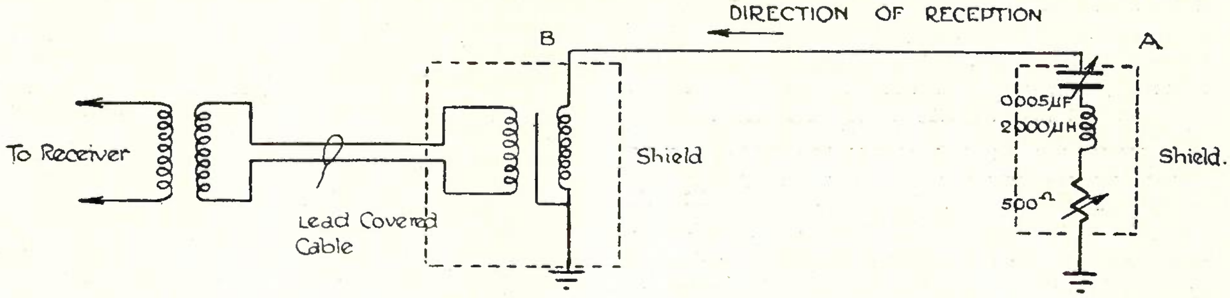


Fig. 2A.—Single Wire Antenna.

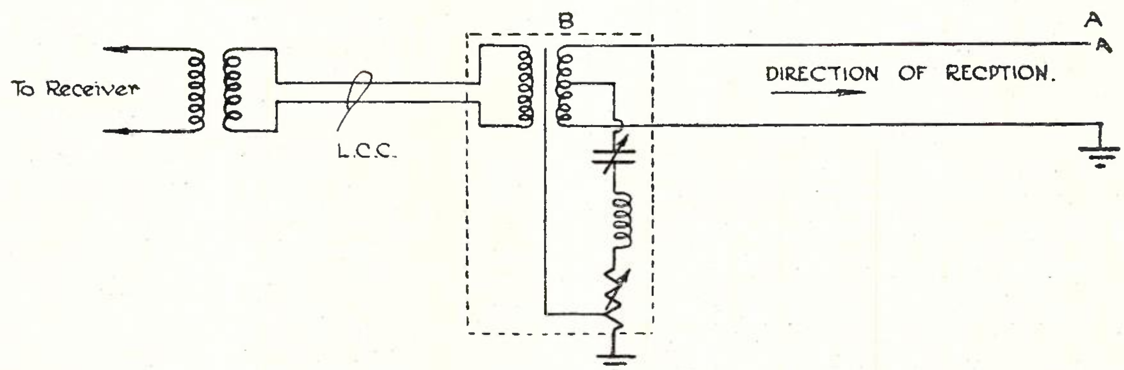


Fig. 2B.—Two Wire Antenna.

General Engineering Features

It is brought out in the discussion of the theory that, so far as collecting signal energy is concerned, there is no objection to placing the wires of a wave antenna higher than is required for security, and to pass obstructions.

A high line will show slightly greater wave velocity and less attenuation than a low line, and be less affected by changes in ground conditions or proximity of trees, which sometimes cause sufficient changes in the line constants to give rise to slight reflections. The differences in favour of the higher line, however, are so small that they would rarely warrant the expense of taller poles.

Apart from the importance of a straight line and avoiding proximity of other conductors, the specification for wave antenna construction or material might be taken bodily from those written for an open wire copper telephone circuit. Any change in construction or material which will appreciably alter the line impedance and give rise to reflections should be avoided. Special care should be given to joints, connections, etc., since we are dealing with voltages which on the average are very small.

Except for temporary or experimental purposes, two wire antennae are practically always desirable since they permit at the receiver end, the balancing out of "back end" disturbances.

It should be remembered that, as the antenna is an aerial construction, it is subject to electrical storms and, therefore, should be protected. The best type of protection is a vacuum type lightning arrester, one being fitted at each end of the antenna. For amateur and experimental use where ample space is available without the necessity for crossing roads, etc., quite satisfactory results may be obtained by running insulated wire directly on the ground.

Construction

In the construction of a Beverage wave antenna the following principles should be followed:—

(i) Decide upon the direction from which it is desired to receive the maximum signal.

To achieve this directivity, the antenna wire should be run in a direct line from the point B to A, Figure 1, in the direction required. Any bends or deviations in this length B-A will tend to spoil the directivity response of the antenna, and should be avoided.

(ii) The frequency of operation should be chosen and the antenna should be a multiple of one half wave-length long. If space is available, it should be remembered that better results are obtained with an antenna of length one wave-length than one half wave-length. If the antenna is to be used at a number of frequencies, the lowest frequency should be selected—thus for a band 550-1500 kC an antenna one wave-length long at 550 kC would have two output peaks—one at one wave-length long, 550 kC, and the other at two wave-lengths long, 1100 kC. As the output peaks are rather broad, this antenna would give a good response over the band 550-1500 kC.

As it is essential in this type of antenna that the R.F. pick-up be confined to the horizontal portion and not to any of the vertical sections, any vertical sections, including earth leads should be well shielded. The method adopted has been:—

(a) **Far End Termination Pole.**—In the single wire antenna the termination consists of a network to equal $\sqrt{L/C}$. This network is placed in a weatherproof shielded box on top of the pole. The earth lead is run in heavy insulated wire through an earthed pipe to the earth system at the base of the pole. The earthed pipe is connected to the shielding of the box but not to any portion of the antenna except at the earth connection at the base. The shielding of the earth lead would appear at first glance to be futile, but examination will show that if this lead were not shielded it would be possible for a strong field to induce a voltage in this lead between the terminating network and earth, thus spoiling the directivity of the antenna.

(b) **Receiver End Termination Pole.**—To prevent mismatch between the antenna and the transmission line to the receiver, an R.F. transformer is used—in the case of a single wire antenna 500 ohms to 70 ohms and two-wire antenna 500 ohms centre-tapped to 70 ohms, the 70 ohms side being connected to a lead-covered transmission line which runs underground to a receiver. At the receiver end an R.F. transformer, 70 ohms to whatever value input of receiver, is installed. In some installations where a powerful local station causes interference a wave trap is incorporated in this unit.

Similar precautions should be taken with the shielding and earth lead at this pole as at the far end pole.

A good earth system at both end poles is essential for the correct operation of this antenna. A suitable earth system consists of a number of star-shape section galvanized rods 5 ft. in length, driven their full length into the ground and spaced a distance equal to their length, and then bonded together by attaching several turns of wire round each rod and soldering.

The final earth resistance should not be more than 10 ohms, and it should be remembered that the lower this value the more effective the shielding and, what is more important, the more directive the antenna.

Results.—The results obtained in field investigations of a Beverage antenna one wave-length long indicate that the directive properties of the antenna from the direction of reception to reception from 70 degrees to 290 degrees is in order of 32 db, and the gain over a vertical aerial 70 ft. high, 8 db.

Tests to date indicate also that the fading experienced using a Beverage antenna is not as severe as when using a vertical antenna 70 ft. high.

It will be concluded, therefore, that when space is available the Beverage wave antenna has many desirable features for the reception of medium to low frequency signals, particularly when it is remembered that the cost of construction is low compared with more elaborate types of directional arrays.

Identifying Working Cable Pairs with a Modulated Carrier Frequency *

C. M. Hall

It has been apparent that for any scheme to successfully speed up the identification of working cable pairs, wherever possible its basis should be one whereby the searching is conducted at the exchange terminal strips, instead of in a joint in the cable.

The conditions that any such scheme should fulfil are as follows:—

(1) To save waiting time, identification must be carried out on pairs upon which conversations are actually in progress, without disturbing the talking subscribers.

(2) Bells must not be tinkled on idle subscribers' lines.

(3) The identification of cable pairs must be definite, irrespective of the fact that on all idle subscribers' lines the A wires are connected to a common earth in C.B. and Automatic areas.

(4) No special skill should be needed by the operator.

(5) The apparatus be compact and inexpensive.

To meet these conditions, a modulated carrier frequency set has been constructed, and is in use in Queensland. It utilizes a push pull 15 KC oscillator, grid modulated with about 400 cycles so that the modulating frequency cancels out in the output transformer. (See Figure 1.)

This apparatus is located at the exchange. For detecting the application of the modulated carrier to a pair a dry metal rectifier, a key, a retard coil and a dial (mounted in a separate box) are associated with the set, and attached is a pair of head receivers. This detector unit is used by the mechanic for searching in the exchange terminal strips. (See inset Figure 1.)

Operation in Automatic Exchange Areas

Obtaining a Spare Pair as Pilot.—The cable jointer calls the exchange on a working pair, selected at random, by means of a portable telephone, and where possible intimates to the answering mechanic approximately the position the pair he is calling on occupies in the cable, and then holds the line.

The mechanic at the exchange connects the modulated 15 KC metallically to the "called" line, hence it is thus fed out along the calling line to the jointer. (See Figure 2.) The mechanic then

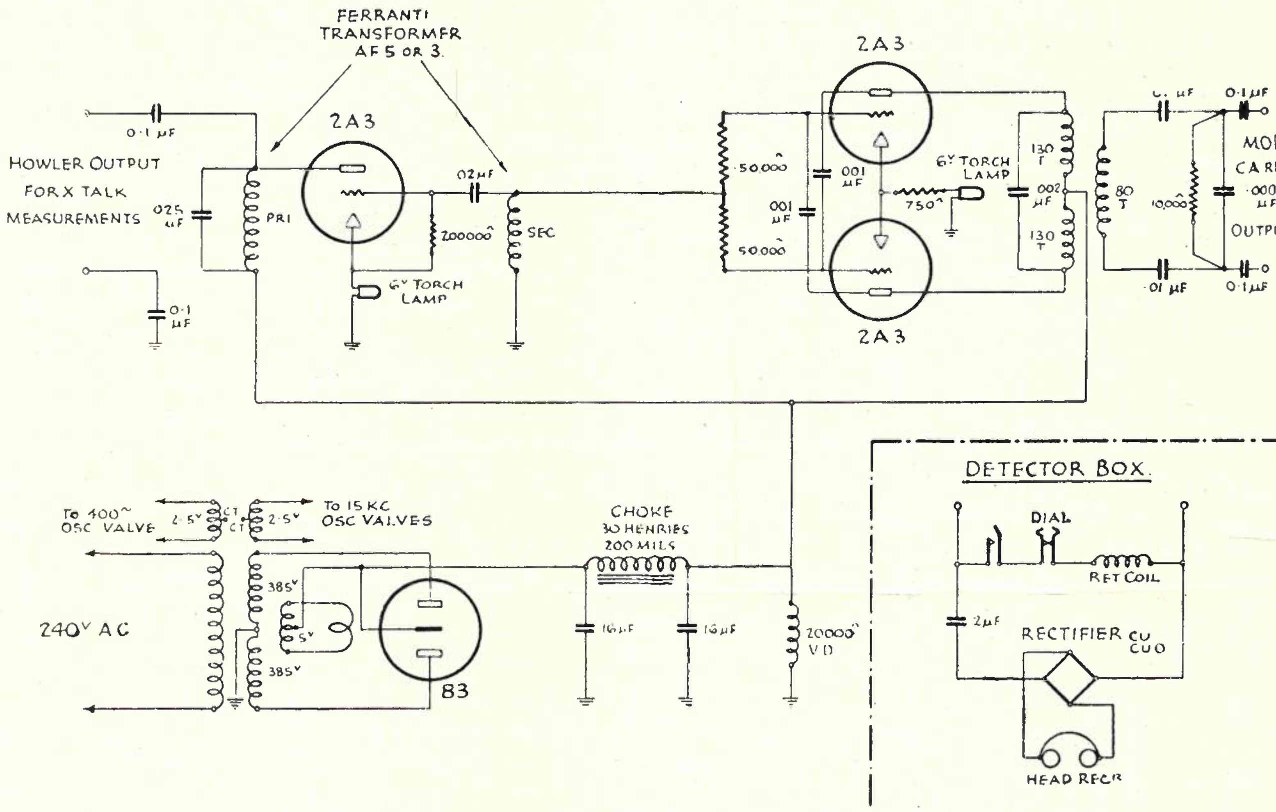


Fig. 1.

* See "Cable Jointing," by G. O. Newton, Vol. 2, No. 2, page 198.

with the detector box and head receiver searches the terminal strips associated with the particular cable until a loud tone is heard in the receiver; this indicates the pair upon which the jointer is calling. (See Figure 2.)

The jointer is informed of the strip number, and still holding the line he feeds the 15 KC receiver. This intimates that he is on the correct B wire, but as all idle lines have their A wires connected to a common earth, he presses the key on the detector box, so placing a loop on the line and extending it through to a selector, thus inserting a relay's impedance between the A wire and earth. If the tone does

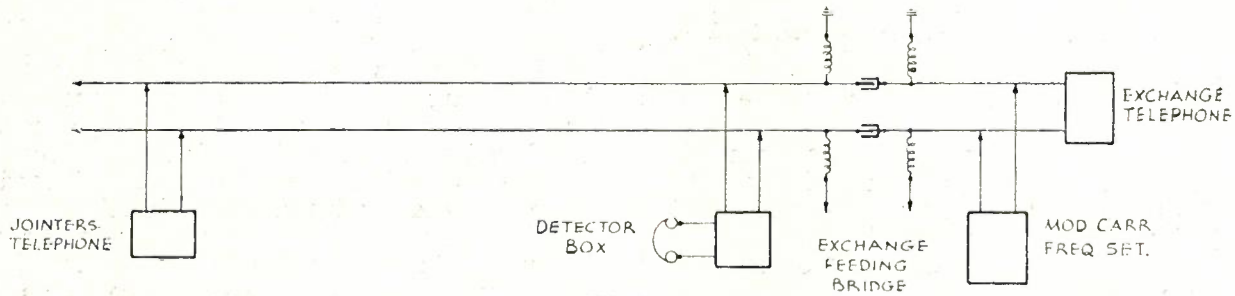


Fig. 2.

back to the exchange through a double clip ended pair of leads, each having a condenser in series, on a cable pair which he thinks is a good spare pair. (See Figure 3.) The mechanic at the exchange again searches, locates and informs the cable jointer of the cable pair number he has connected to, and after one or more trial tests of this nature a spare pair is located, which is used as a pilot pair. (See Figure 3.)

In actual practice on 200 pair working cables, irrespective of the fact that five and six trials may be made by the jointer before he locates the

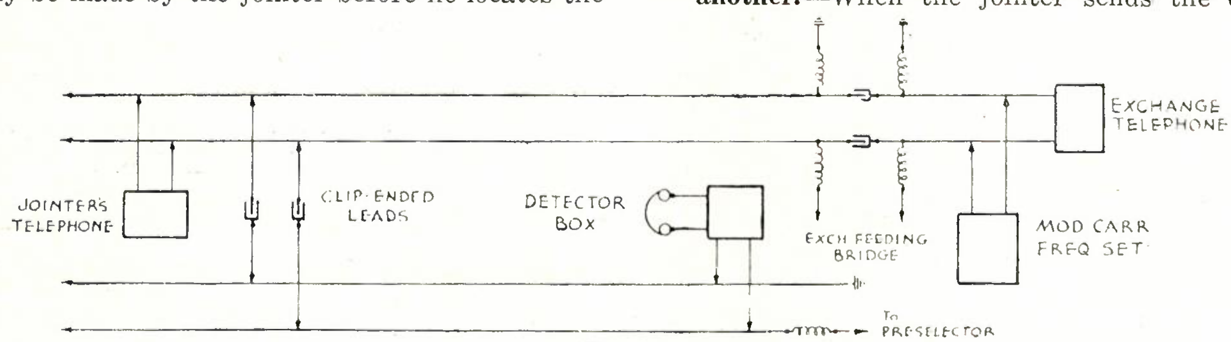


Fig. 3.

spare pair, the average time taken to locate a spare pair is four minutes from the time the mechanic answers the cable jointer's first call; hence only one subscriber's line is interrupted in any way and that for a period of only four minutes. For identification of any remaining required number of pairs, there is no further interruption to any subscriber's line.

General Identification

The modulated 15 KC is fed out to the cable jointer metallically upon the selected spare pair and he in turn feeds it back to the exchange on any other pair. The mechanic at the exchange searches metallically down the strips until he hears the rectified tone at a good level in the receiver.

not diminish when the key is pressed, then he is also on the correct A wire.

If the identification is being conducted over three miles out from an exchange, the dial tone which is heard when the key is pressed may tend to drown the 400 cycle tone; hence under these conditions, one figure is dialled whilst the key is pressed in order to remove the dial tone.

Split Pairs

(1) **When the split pair is composed of the A wire of one exchange pair and the B wire of another.**—When the jointer sends the carrier back to the exchange on a pair split as above, this is indicated at the exchange by a greatly reduced tone level when the key is pressed; no endeavour, however, is made to locate the correct A wire, as another similarly split pair will be met nearby to compensate for the first one.

(2) **When the split pair consists of two B wires.**—Under these conditions the required tone will be heard on both pairs but will be considerably reduced on each when key is pressed.

(3) **When the split pair consists of two A wires.**—A greatly reduced tone will be heard on the two pairs, but this should be simply noted and the next pair proceeded with until

another split pair as in (2) above is found, when, in all probability, the split A's and B's will coincide.

Pairs That Cannot Be Identified Easily

Power leads, pairs with a short circuit upon them, and some types of low impedance fire alarms, etc., cannot readily be metallically identified, but may be identified, each wire singly, by the earth circuit method; but under these conditions an operator needs to have had some experience with the use of the set, as it is necessary to distinguish between various tone levels and select the maximum. It may be noted that the above pairs present similar difficulties under existing methods.

Speed of Identification.—The explanation of the set's operation seems involved, but in actual practice in Brisbane, staff selected at random have succeeded in identifying up to 80 pairs per hour and the average rate is over 40 per hour, which very favourably compares with the average of existing methods. It is interesting to note that during the peak traffic hours identification is accelerated, due to the fact that the common A earth has been removed from a large number of pairs upon which conversations are being held.

General Purpose Use.—The set may be used to quickly indicate the extent of crosstalk present in any cable, and where new work is completed, by its use, a quick means of checking jointers' work is available.

Details of Set.—With the exception of the push pull output transformer and the 750 ohm resistor, all the components of the set are standard radio receiver parts.

As an alternative to Ferranti Transformers, 4012A transformers may be used. The power transformer secondary and choke should be capable of carrying 150 milliamperes. The condenser output is to reduce any modulation component which may arise from tube unbalance. An old output V.F. Transformer was rewound and used as the push pull output transformer. The 750 ohm resistor in the cathode circuit of push pull 2A3 valves is to ensure deep modulation. The respective plate currents are as follows:—

Push Pull Oscillator (when modulated), 60 milliamperes.

400 cycle Oscillator, 40 milliamperes.

Figure 4 shows the assembly of the Testing Set.

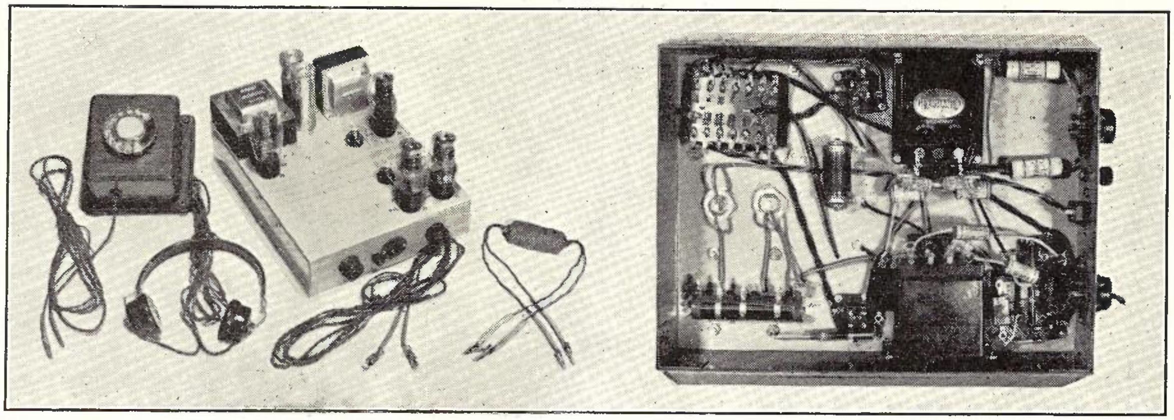


Fig. 4.—Left: Mod. Carrier Identification Set and associated apparatus. Right: Layout and wiring of sub-chassis.

SOFT SOLDERS, SOLDERING AND WIPING

G. O. Newton

PART I.

Introduction.—The methods of joining metals by a fusion process may be divided into two main groups, the first of which is divisible into two sub-groups:—

(i) Soldering—(a) Soft Soldering.
(b) Hard Soldering.

(ii) Welding.

Soft soldering involves the use of solders made of mixtures of the softer metals consisting chiefly of lead and tin, and these are applied by simple processes at comparatively low temperatures which do not involve any melting of the metals to be joined.

Hard soldering covers such similar processes as brazing and silver soldering, requiring higher temperatures.

Welding covers such processes as forging, oxy-acetylene and electric welding and lead-burning, in which the metal surfaces to be joined are brought to a state of fusion by a heating process and united in this condition without the aid of a separate alloy or solder.

These articles will deal solely with the process of soft soldering, which plays an important part in ensuring the satisfactory operation of a large amount of Departmental plant and apparatus. Whilst it is normally looked upon as a simple process requiring only minor consideration, there is a good deal to be learnt from a study of the subject.

History

The art of soldering was known to the late Romans, who used two types:—

(i) Consisting of one part tin to two of lead and used for soldering lead work;

(ii) Consisting of equal parts of lead and tin and used for most other operations.

The compositions of these two solders are similar to those of the two main types of solder in common use at the present day, but, as will be noted later, their use is different. The art of wiping was not known to the Romans, who adopted a system of moulded joints made of pure lead. The inside of the ends of the pipes to be joined was packed with sand and a sand mould prepared in situ around the outside. When the lead was poured into the mould it melted the ends of the pipes so that a homogeneous joint was obtained on solidification.

The wiped joint appears to have been first introduced in England about the 15th Century, but the moulded joint persisted there for some time after, before it was discarded.

Actually the art of soldering and wiping developed into the present-day high standard with very little aid from the scientist and research man, and, although a considerable amount of research work has been done in more recent times, to a large extent it has only served to throw some light on the processes which take place, and to confirm or only slightly modify the practices adopted by early craftsmen who were guided solely by usage and experience. Even now literature on the subject is very limited and reference to articles in periodicals would appear to indicate that there is still a good deal of conflict of opinion, especially in regard to the action of fluxes.

Soft Solder

Solder can be defined generally as a metallic alloy for uniting metal surfaces, and having a melting point lower than that of the metals to be joined. Soft solder is mostly an alloy of tin and lead, the composition varying in proportion according to the purpose for which it is to be used. Soft solders may also contain quantities of such metals as antimony, bismuth, cadmium, etc., together with very minor quantities of impurities such as zinc, copper, iron and aluminium. Many of these metals are soluble in the other components of the alloy (both in the liquid and solid state), in a similar manner to salt in water and ice, whilst residues not in solution are readily held in suspension like fine dust in water. One of the effects of the addition of sufficient salt to water to form a saturated solution is to lower the freezing point about 38° F. (i.e., to —6° F.). In a similar manner a combination of two or more metals may have a lower freezing or solidification point than either pure metal. As the composition of an alloy is varied it will be found that there is a definite proportion of each where the melting point of the solid is lowest. This composition is called the eutectic. The eutectic alloy of tin and lead has a composition of 63 per cent. tin and 37 per cent. lead and melts at about 358° F. The soft solders in common use are mixtures of eutectic and metals in solution and/or in suspension.

If lead and tin and lead-tin alloys of various composition are heated and a note taken of the temperatures at which changes take place, and these plotted on a diagram, the results shown in Fig. 1 will be obtained. Much information about tin-lead solders can be deduced from this diagram, which assists to decide which solder composition is likely to be the most suitable for a particular purpose. The outstanding features which the diagram indicates are:—

(i) All compositions have a lower melting point than lead, and a large proportion of them a lower melting point than tin. This property enables the alloys to be used for soldering the constituent metals without melting them.

(ii) The eutectic alloy of lead and tin melts at about 358° F., and between this temperature and their melting-point, alloys other than the eutectic, containing 16 per cent. or more of tin (see area ABCED) are in a plastic state, due to the fact that the alloy consists of molten eutectic with solid particles of lead or tin in suspension. This property enables use to be made of lead-tin alloys for wiping.

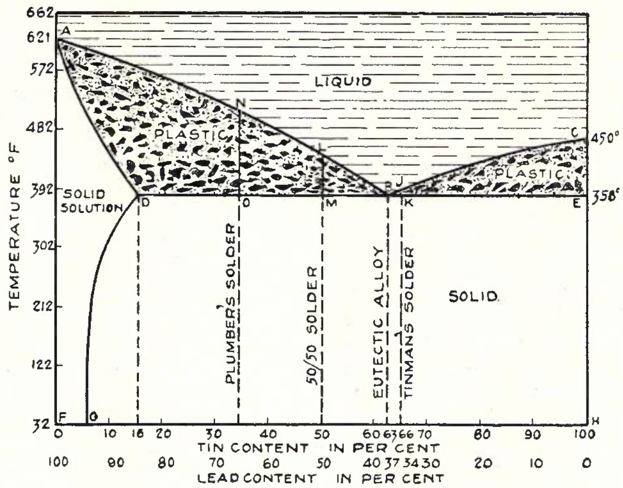


Fig. 1.—Temperature ranges within which various alloys of lead and tin are liquid, semi-liquid and solid.

(iii) Where the tin content is below 16 per cent. (area ADGF) the solder is of a different nature from other compositions, due to the fact that the whole of the tin is in solid solution in the lead. Since lead is only slightly soluble in tin, there is no corresponding area on the opposite side of the diagram.

Item (iii) is of little concern since solders in general use, all contain more than 16 per cent.

Fig. 2.—Photomicrograph showing structure of eutectic Tin-Lead Solder.

tin. If a special solder were required for uniting metals which were normally kept at temperatures within the plastic range of the common solders, an alloy might be used containing about 4 per cent. tin. For ordinary soldering work the diagram indicates that the ideal solder should be the eutectic alloy (63 per cent. tin, 37 per cent. lead), which has the lowest melting point, and not having any plastic

Fig. 3.—Photomicrograph showing structure of 50-50 Tin-Lead Solder.

stage, sets quickly. It will be noted that this is almost the same composition as what is known as "two and one" or "Tinman's" solder (66 per cent. tin, 34 per cent. lead), which is one of the solder compositions handed down by the old craftsmen. A greater percentage of lead assists the spreading of the solder under many condi-

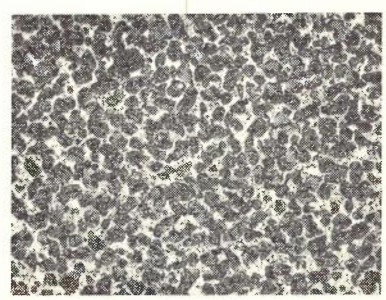


Fig. 4.—Photomicrograph showing structure of 30-70 Tin-Lead Solder.

tions. Since tin is considerably more expensive than lead there is also the economic consideration. For these reasons it is usual to use 50/50 solder for general purposes. This has a melting point of about 414° F. and a plastic temperature range of about 56° F. This melting point is sufficiently low, and the plastic temperature range is small enough to provide for reasonably quick setting of soldered joints. For bit soldering a minimum of 50 per cent. tin appears to be the practical limit, but for dip or stick soldering, where the temperature can be kept reasonably constant and close to the optimum, it is practicable to go to a lower limit of about 40 per cent. tin.

For the wiping of joints a solder with a large plastic temperature range is desirable, but as this increases the melting point gets too close to that of lead, and the solder tends to become porous (or to use a plumber's term, "too coarse"), so that the practical mixture approximates to the old craftsmen's alloy known as "Plumbers' Metal" and containing two parts of lead to one of tin.

The structure of some of these tin-lead alloys can be seen from the photomicrographs, Figs. 2, 3 and 4. Fig. 2 indicates the nature of the eutectic alloy and reveals that it is of an homogeneous character, whilst Figs. 3 and 4 indicate that, with lower tin content, the solder consists of eutectic with particles of lead mixed in it. In Fig. 3 (50/50 solder), there is a small amount of free lead in a considerable mass of eutectic, whilst in Fig. 4 (30/70 solder) the mass consists largely of free lead, the particles of which are in close contact with only a small proportion of eutectic filling the interstices.

Standard Soft Solders: Their Properties and Uses

Table 1 indicates the composition of Australian Standard Soft Solders and their purposes as set out in Australian Standard Specification H1. This Specification is almost identical with the British Standard Specification, the minor differences being indicated at the foot of the table.

It will be noted that nearly all the solders contain a small percentage of antimony, which at one time was regarded as an impurity to be avoided. It has been found that antimony rather improves than degrades many of the properties of solder so long as the percentage does not exceed the limit of its solubility in the tin content, which is 7 per cent. antimony to tin, i.e., in a solder containing equal parts of lead and tin, up to 3 per cent. of antimony can safely be added for many purposes. If the limit of solubility is exceeded, the character of the solder changes and it becomes brittle, weak and difficult to melt, and is sluggish and gritty to use. In the case of several solders, viz., Grades E to J, the maximum amount of antimony allowed is only minor, and usually the actual content present is no more than occurs as an impurity in the constituents tin and lead.

Although antimony has a comparatively high melting point, viz., 1166° F., the addition of antimony up to the limit of its solubility in tin does not alter the melting point diagram (see Fig. 1) to any extent, as will be seen by the solid diagram (Fig. 5), which shows the soluble antimony content as a third dimension. There is a small economic advantage to be gained by the addition of antimony since it can be used to displace tin in the solder composition.

It is of interest to note at this juncture that American Government Specifications do not permit antimony percentages as high as those in the British and Australian Standard Specification. The maximum allowed in the Government

TABLE 1
COMPOSITION OF AUSTRALIAN STANDARD SOFT SOLDERS

GRADE A.S.	Use for which the solder is primarily intended	Tin Per cent.		Antimony Per cent.		Lead	Impurities (Max.) Per cent.			
		Min.	Max.	Min.	Max.		Aluminium or Zinc	Copper	Iron	Total other Impurities
A.	Work requiring low Melting-point; Steel Tube Joints	64.0	66.0		1.0	THE REMAINDER	0.005	0.08	0.02	0.15
B.	Tinsmiths' and Coppersmiths' fine work and bit soldering generally	49.0	51.0	2.5	3.0		0.005	0.12	0.02	0.20
C.	General Work	39.0	41.0	2.0	2.4		0.005	0.12	0.02	0.20
D.	Plumbers' Wiped Joints (a)	33.0	35.0		1.7		0.005	0.05	0.02	0.15
E.	Special Electrical Purposes	94.5	95.5		0.5		0.005	0.08	0.03	0.14
F.	General Electrical Purposes; Zinc and Galvanized Iron Work	49.0	51.0		0.5		0.005	0.08	0.02	0.15
G.	Dipping Baths Zinc and Galvanized Iron Work; Tinned Electrical Joints (b)	40.0	42.0		0.4		0.005	0.06	0.02	0.15
H.	Lead Cable Wiped Joints	34.0	36.0		0.3		0.005	0.05	0.02	0.15
J.	Dipping Baths	29.0	31.0		0.3		0.005	0.05	0.02	0.15

(a) Corresponding B.E.S.A. Specification (No. 219 of 1932) gives tin content 29 to 31 per cent. with a minimum of 1 per cent. antimony.
(b) Corresponding B.E.S.A. Specification (No. 219 of 1932) gives tin content 41 to 43 per cent.
Other variations of the B.E.S.A. Specification are:—Total impurities allowed all Grades, .25 per cent.
No percentage of copper is specified, but .05 per cent. of arsenic is allowed in all grades except E.
The amount of aluminium or zinc must be less than measurable by normal methods.
The B.E.S.A. Specification includes a further grade, K, for special machine soldering, containing 59-61 per cent. tin and .5 per cent. Max. antimony.

Standard Specification issued by the Bureau of Standards for any grade is 1.5 per cent., whilst

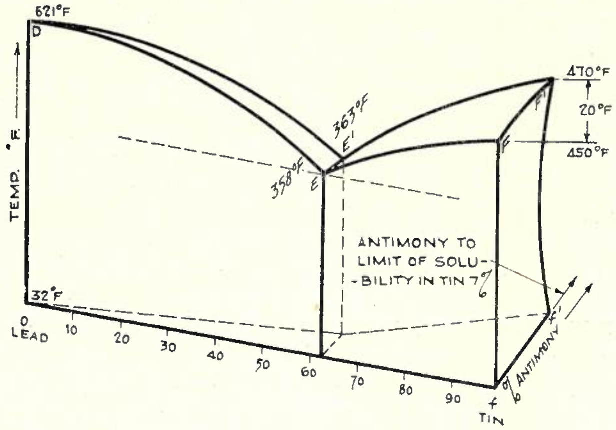


Fig. 5.—Equilibrium Diagram of the Solder Alloys of the Ternary System Lead, Tin and Antimony.

.12 per cent. only is allowed in most grades. Fig. 6a, which is a photomicrograph of tin-lead antimony eutectic, indicates that it is of a simi-

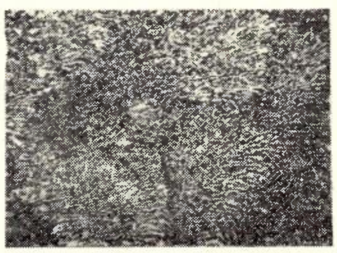


Fig. 6 (a).—Photomicrograph showing structure of Tin-Lead-Antimony eutectic.

lar nature to the tin-lead eutectic. The effect of excess antimony which forms comparatively large crystals, is seen in the photomicrograph of Fig. 6b.

Table 2 indicates the general physical properties of the standard solders and the constituent metals. It will be noted that both tin and lead have tensile and shear strengths of a low order (about 1 ton per square inch), but alloys of these two have strengths twice to four times that of either constituent. Impact strength remains fairly constant as the tin content is reduced from 100 per cent. down to 40 per cent., after which it falls off rapidly to the figure for lead. Usually the shear and impact strengths are the most important. The addition of antimony (see Grades B and F), so long as the limit of solubility in tin is not exceeded, increases tensile and shear strengths, but reduces impact strength except in the case of the special alloy consisting of tin 94.4 per cent., antimony 5.6 per cent. At this point it may be as well to mention that the strength of the solder must not be confused with the strength of the soldered joint, since the latter depends on other factors besides the former.

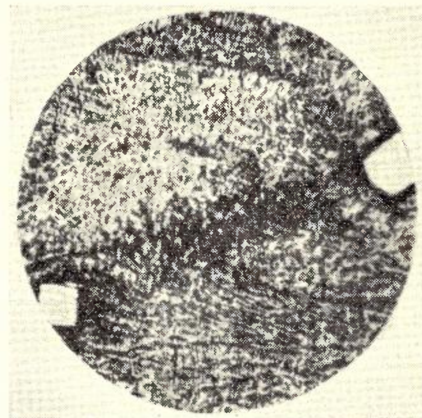


Fig. 6 (b).—Photomicrograph showing structure of Solder containing excess Antimony.

The ductility of the solders as measured by the elongation percentage, decreases as the strength increases, and is low where the tin content is low or the antimony high. The ductility of the solder is important since the stress in a soldered joint due to contraction on cooling is least with the solder having the highest ductility. Conductivity graduates through the alloys from the higher figure for tin to the lower one for lead.

Briefly, the use and properties of the solders listed in Tables 1 and 2 are:—

Grade A Solder is almost identical with the eutectic alloy. Having no plastic range, it sets almost instantaneously. It has a high degree of fluidity and mechanical strength which makes it suitable for fine work or where close strong joints are required, or where the minimum soldering temperature is necessary. To ensure the retention of a high degree of fluidity, the antimony content is limited to a maximum of 1 per cent.

Grade B Solder is a general purpose solder where a bit is required. It is a little slower to work than the similar Grade F, and consequently the latter is preferred for repetition soldering. Apart from this, it has a lower melting point than Grade F, and the lower lead content gives it greater strength except under impact. The ductility is not as good, although it is still of a useful value.

Grade C Solder is also a general purpose solder, but is more sluggish than B, if used with a bit. It is preferably used for blowlamp soldering where there is better control over heat. It has high ductility combined with good strength, and consequently makes strong joints.

Grades D and H Solders are wiping solders and will be discussed when dealing with the subject of wiping.

Grade E Solder is a special purpose solder which will be discussed under that heading.

Grade F Solder is the composition mostly used for soldering operations. It is also the grade used in the manufacture of resin and acid cored solders. It is a good solder for bit work, especially on repetition work, where time is a factor. On account of its low antimony content it is preferred for zinc and galvanized iron work. This is due to the tendency of the antimony to form viscous and gritty alloys of high melting point in such cases, resulting in brittle joints and rendering the soldering operation slow and unsatisfactory. This solder is also preferred for "pot" soldering owing to the tendency for segregation of antimony in the pot if solders with high antimony content are used. Although the shear strength of this solder is low compared with other grades, other things being equal, the resulting joints have a strength of high order.

Grade G Solder is a dip solder. On account of the low tin content it is not entirely suitable for bit soldering. Owing to the tendency for antimony to segregate in the pot, and to trouble arising from the presence of zinc, a low antimony content is essential. In practice, Grade F solder is also used for dip work.

Grade J Solder is a plumbers' type and is used for dipping baths for tinning brass, copper or iron pipes which have to be wiped to lead pipes. Being a dipping solder, a low antimony content is essential.

B.E.S.A. Grade K Solder is largely used for machine soldering in the tin-can industry in Great Britain, although Grade F is also extensively used for this purpose. The soldering in such cases is performed at a high rate (in some cases the rate is of the order of 300 cans per minute), and this necessitates a quick setting solder of good fluidity and giving a uniform and

TABLE 2
SUMMARY OF PHYSICAL PROPERTIES OF STANDARD SOFT SOLDERS

Grade	Composition			Physical Properties					
	Tin	Antimony	Lead	Ultimate Tensile Strength Tons/Sq. In.	Shear Strength Tons/Sq. In.	Impact Strength Ft. Lbs.	Elongation on 4 ins. % (Ductility)	Conductivity Copper = 100	Approximate Plastic Range ° F.
—	100	—	0	.94	1.12	14	55	13.9	—
—	94.4	5.6	0	2.81	2.44	21	42	10.7	455-451
A.S.S. —A	65	1	THE REMAINDER	3.89	2.86	15	20	11.4	370-362
,, —B	50	3		3.75	3.06	11	29	9.8	397-363
,, —C	40	2.4		3.55	2.64	—	34	9.2	444-362
,, —D	34	1.7		3.30	2.2	—	22	9.0	480-362
,, —E	95	.5		2.00	2.0	—	47	13.6	432-360
,, —F	50	.5		3.00	2.0	15	40	10.7	417-360
,, —G	41	.4		2.80	2.0	—	38	10.2	453-360
,, —H	35	.3		2.90	2.13	—	25	9.7	477-360
,, —J	30	.3		3.00	2.2	11	22	9.3	486-360
B.E.S.A.—K	60	.5		3.40	2.2	—	30	11.6	370-360
—	0	0	100	.89	.89	5.6	39	7.91	—

TABLE 3
COMPOSITION OF SPECIAL SOFT SOLDERS WITH LOW MELTING POINTS

No.	Composition (Parts)					Approx. Melting Temperature Fahrenheit
	Lead	Tin	Bismuth	Cadmium	Mercury	
1.	1	—	1	—	3	68°
2.	1	1	2	—	10	113°
3.	8	4	15	3	—	149°
4.	2	1	4	1	—	158°
5.	6	—	7	1	—	180°
6.	1	1	2	—	—	209°
7.	3	2	5	—	—	212°
8.	3	2	2	—	—	270°
Approx. Melting Point of Constituent (Fahrenheit)	621°	450°	520°	610°	−39°	—

regular flow. The solder should, therefore, approximate to the eutectic mixture and have a very low antimony content.

Solders for Special Purposes. Apart from what may be described as the normal grades of solders which have just been discussed, it is necessary on occasions to use a solder of some special composition to meet some abnormal requirement. Grade E solder, which has a very high tin content, is such a type. It has high electrical conductivity and, although relatively weak, retains its strength to a high point in the temperature scale due to the low proportion of eutectic in its composition. For these reasons it can be used where good conductivity is desirable or where the normal temperature of the members to be soldered approaches the melting point of the eutectic. The possibility of using a solder with a low tin content (about 4 per cent.) when the normal temperature of the members is a little above the melting point of the eutectic, was previously referred to. Other special solders for use where the members are subject to high temperatures are:—

(1) Tin 94.4 per cent., Antimony 5.6 per cent. (see Table 2), Plastic Range 455°-451° F. This solder has good impact strength, compares with other solders for shear and tensile strength, and has good ductility.

(2) Tin 15 per cent., Zinc 65 per cent., Cadmium 20 per cent. This solder is stated to be suitable for temperatures up to 660° F., and where the soldered parts require to be enamelled.

Another special case is the solder used on heat coils. This requires the use of a solder with a low melting point of the order of 150°-160° F. Such solders are obtainable by adding bismuth and cadmium to tin and lead. By adding mercury, still lower melting temperatures are obtainable. Table 3 sets out the composition of some of these solders. A recent analysis of the solder used on some heat coils showed that the composition was approximately equal to No. 4.

Fluxes

The satisfactory uniting of metals by soldering requires that their surfaces come into intimate contact with the solder and this necessitates clean surfaces and the use of an agent known as a flux. The term "wetting" is applied to this action of obtaining the intimate contact between the solder and the surfaces to ensure the proper adhesion of the metal surfaces for a satisfactory joint. This wetting of the surface of the metals with solders is hindered by the presence of dirt, grease, oxide, or sometimes carbonate or sulphide films, etc., and by what is known as the surface tension of the molten and solid metals. The property of surface tension is recognisable in such things as raindrops on windows and windscreens, where the spreading of the water on the glass and so the wetting of the surface with a thin film of water, does not take place until some special action is taken to make it do so.

The functions of fluxes are:—

(i) Cleansing surfaces of base metals to be joined or keeping clean, surfaces which have already been cleaned, including the removal of oxides produced by the heat of soldering.

(ii) Removal of solder oxides formed during soldering.

(iii) Aiding the wetting power and improving the flowing qualities of the molten solder.

The actual processes which take place during these functions are somewhat obscure, and since published explanations are far from unanimous it would appear that a satisfactory theory to cover all the known facts has still to be advanced.

Fluxes in common use can be divided into two broad classes—the chemically active and the non-corrosive. The first class may be divided into strong and weak types. The strong type includes such fluxes as Hydrochloric Acid (Spirits of Salts), Chloride of Zinc (Killed Spirits), Ammonium Chloride, and various combinations of these, and the weak type, Tallow, Stearine, etc. Resin is, at present, the only flux of the non-corrosive type.

The chemically active flux of the strong type is the one mostly used for general purposes. In addition to acting as cleansers, they are more stable than the weak type and do not char or volatilise when subjected to prolonged heating. They are, therefore, very suitable for use with metals where there is a tendency to rapid oxidisation, and where prolonged heating and high temperatures are necessary, but their highly corrosive nature limits their use to those cases where the residue after soldering can be completely removed by washing or other process, or where some corrosion is not of great importance. Another objection to their use is their electrical conductivity, which is augmented by the tendency of their residues to absorb moisture and flow and spread to adjacent parts of the equipment and materials on which the soldering operation has taken place. Such fluxes within Departmental activities are, therefore, limited to use on open wires where residues are normally removed by rain, and to workshop and other operations where any residues can be removed by washing and special processes. For soldering galvanized iron or zinc, Hydrochloric Acid is the most suitable, but for general purposes, including open wire work, a combination of Zinc Chloride and Ammonium Chloride is usually the best.

The usual action of these fluxes when heat is applied for soldering, is first to vaporise the water content, leaving a film of flux of a solid or viscous nature, which later melts, clears a path for the solder and finally vaporises or runs clear as the soldering action is completed. For this reason a good flux should melt just below the melting point of the solder and remain liquid until the soldering process is just complete.

Zinc Chloride on its own has the objection that it has a high melting point (522° F.), and since soldering can be performed at and below this temperature there is a danger of solid particles of flux being left in the join, which weakens it and later sets up corrosive action. Ammonium Chloride, on the other hand, does not melt at all, but commences to sublime at a temperature of about 400° F. It has the disadvantage that the action is somewhat dirty, that it requires a rather high temperature to start action, and the heat must be controlled to prevent complete sublimation before soldering is complete. Due apparently to good cleansing properties, it is a suitable flux in cases where little or no preliminary cleaning is desirable.

The eutectic mixture of these two (71 per cent. Zinc Chloride + 29 per cent. Ammonium Chloride) has a melting point just below that of eutectic tin-lead solder, and for this reason is often regarded as the most suitable flux of its kind. In practice, however, a smaller proportion of Ammonium Chloride seems to give greater ability to flow ahead of the solder and prepare a path for it, especially where the spacing between members to be jointed is very fine. It is usual to add a fairly high percentage of water to guard against the use of an excessive amount of flux, and to help to obtain an even spread of the flux over the parts to be soldered.

The Departmental Specification provides for a fluid consisting of not less than 25 per cent. by weight of Zinc Chloride, and of Ammonium Chloride not less than 2 per cent. by weight, nor more than one-third of the Zinc Chloride content and the balance water. The decision to use these figures was based on soldering trials on copper wire since outside these compositions the action was not clean, and in most cases undue heat was necessary to obtain a good wetting effect.

The weakening effect on soldered joints due to the use of Zinc Chloride alone at low soldering temperatures is shown by the results recorded in the diagram of Fig. 7.

The most common fluxes of the weak corrosive type are tallow and stearine, which are used for lead work. It is a common belief that these fluxes only provide a protective coating and are inactive and non-corrosive. The flux action of the former is due to the presence of stearic and palmitic acid (which form a large portion of the substance) and oleic acid, all of which acids can be used separately as fluxes. Stearine, which is a derivative of tallow, owes its flux action to the presence of a high stearic acid content. The weak nature of these acids compared with the former class has apparently given rise to the idea that they are inactive, but action does take place, although the final result may often be delayed for long periods. The residues of these acids are also electrically conductive to a small

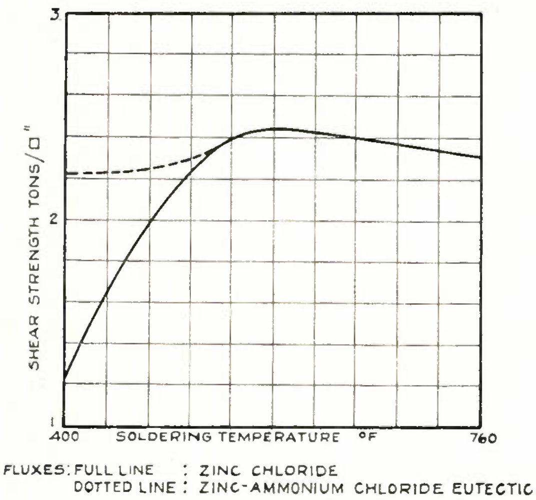


Fig. 7.—Comparison of the effect of two fluxes on the shear strength of soldered joints.

extent. These facts are supported by the troubles which arise if molten tallow or stearine is dropped amongst the conductors of a cable. In time, minor insulation loss will develop, and an examination usually discloses the presence of verdigris on the copper wire.

The effective temperature range of these fluxes is short since they char or volatilise under long and continued heating. Their use is usually confined to lead, tin and soft alloys which do not readily oxidise at the soldering temperature, which is limited by their low melting points. The ease with which they spread over lead surfaces which require tinning together with the facts that they are only mildly active and the residue is usually burnt away, renders them very suitable for use on lead work, stearine usually being regarded as the better flux of the two. Since their cleansing action is too mild and slow, it is necessary in all cases first to clean the parts to be soldered before the flux is applied. Tallow varies very considerably in composition, but has the advantage that a complete film of flux can be more readily applied to the cleaned part by hand, whereas stearine requires heating to ensure a continuous film in all cases.

The last and only flux of its class—Resin—is very important. The term "non-corrosive type" is not strictly correct since resin is only inert in the solid state. In the liquid state it is mildly cleansing under most conditions, particularly when applied to copper, the cleansing being more marked with certain types of metal coatings than others. On account of its mild and variable cleansing effect, the parts to be soldered should always be cleaned mechanically and preferably tinned beforehand. As well as being non-corrosive when cold, it is non-conductive and does not absorb moisture, and is therefore most suitable for use on electrical equipment.

For fine soldering, where resin is used as a flux, a combined flux and solder in the shape of the well-known resin-cored solder is mostly used. This solder, as previously stated, is of 50/50 composition (Grade F) with a minimum of 3 per cent. and a maximum of 5 per cent. resin. This lines up with British and Australian Standard Specifications, but the British Post Office now specifies 2.5 per cent. to 3.5 per cent. resin, and this seems quite sufficient since 2 per cent. of flux will normally ensure effective soldering. At one time most of the Specifications provided for 4 per cent. to 6 per cent. of flux, but it was found in practice that this resulted in too much solder running on to the bit, and the forming of clumsy soldered connections with a large amount of resin thereon. It was also a not infrequent occurrence to find a dry joint under this surplus flux.

A substitute for resin-cored solder favoured by some for certain classes of work is the use of wire solder with a separate flux consisting of resin dissolved in alcohol. The surfaces to be soldered can be painted with the flux, the alcohol content of which evaporates, leaving it coated with a thin film resin. It is then only necessary to apply the soldering bit and wire solder to complete the operation.

NORTH AUSTRALIA TELEGRAPH SERVICES

H. Hawke

The advance in the art of telegraph communication in Australia during the last decade has in most instances been in conformity with similar advances in the more populated countries overseas. The changes are indicated by the gradual replacement of the single wire telegraph by the physical telephone pair, and the consequent derived telegraph channels by means of the composite legs, also the various carrier systems used to convey the telegraph signals between defined terminals. The carrier systems, in particular, have not only permitted increased speeds of working on the individual channels, but have provided extra channels for use by the various machine telegraph systems in vogue.

Fast speed Wheatstone and Creed circuits previously worked on single wires as a duplex channel can be still used on the carrier circuits, but these cumbersome printing systems with the many manipulative operations necessary to obtain the printed message have gradually been replaced by the direct page printing systems such as the teletype, multiplex, and teleprinter services. Although the actual speed in "words per minute" that can be effected with a Wheatstone system is greater than with, say, a teleprinter or one arm of a multiplex, the benefits derived by the reduction in operative effort at the transmitting end, and the resultant page printed reception of these systems, together with the extra "arms" procurable in the case of the multiplex far outweigh the advantages of the earlier method. Working over telephone lines has been particularly evident in the use made of circuits between the capital cities of Australia, also between capitals and major towns where physical telephone pairs were comparatively easy to obtain and telegraph channels could be derived, the actual lines being converted for dual purpose requirements.

Possibly the one route in the whole of the Commonwealth where this dual purpose requirement has not been economically procurable is that important link, the "Overland Telegraph" between Adelaide and Darwin. Much has been written regarding the early pioneering of Central and North Australia, together with the romantic and historical erection of the first iron wire on this route, erected under the guidance of the late Sir Charles Todd, and opened for traffic in 1872. This iron wire, unlike practically all of its contemporaries, has not been discarded in favour of better routes or dismantled to make way for a copper line, but together with the single 265 lb. copper erected in 1899, is still giving valuable service.

A huge capital cost would be involved in replacing that iron wire with a copper to form a physical pair with the existing copper line.

It is proposed to describe some of the methods that have been adopted to keep abreast with development in telegraph practice without the aid of the carrier channel. In order to provide carrier channels, one of which would be sufficient for some years to come, the following work would be necessary, unless some satisfactory high gain single channel system can be evolved which would be suitable for use on a single wire circuit.

1. Erection of 1,745 miles of 265 lb. copper line, of which 1,100 miles is through uninhabited country where road transport is more or less difficult.

2. Erection of a crossarm for 1,124 miles, together with additional staying, and the fitting of transpositions for the whole 1,745 miles.

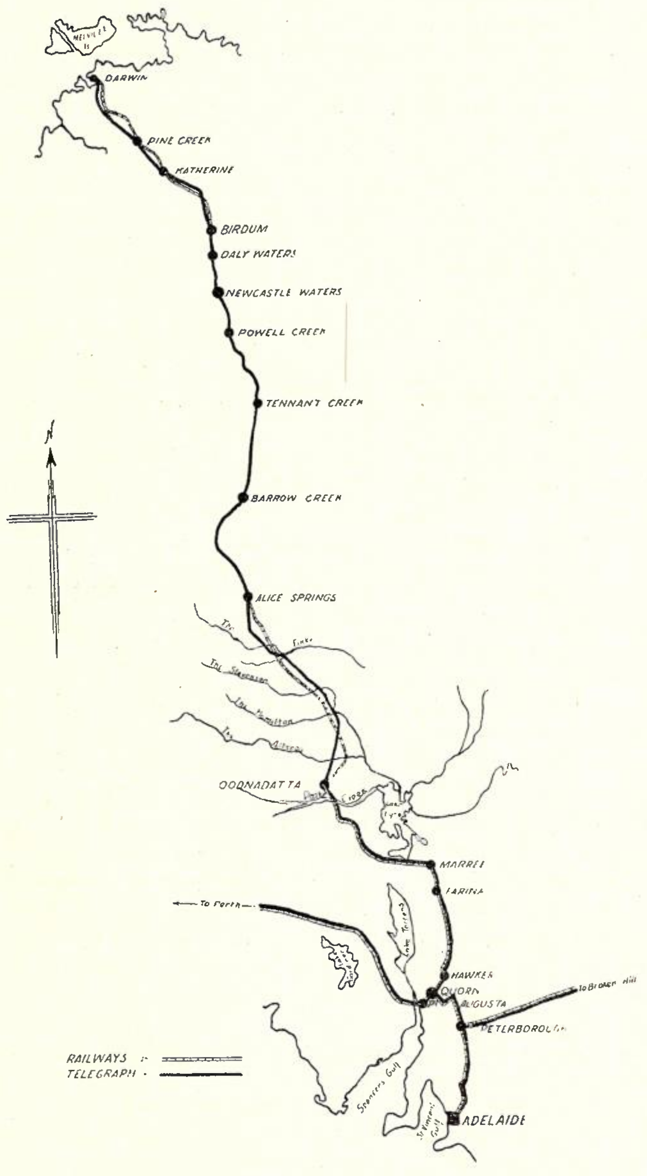
3. Provision of carrier terminal equipment at Darwin and Adelaide.

4. Provision of carrier repeater equipment at possibly five stations.

5. Erection of several suitable buildings to house repeater and power plant equipment.

6. Additional mechanical staff at three stations for maintenance purposes.

7. Erection of housing accommodation for the staff mentioned in 6.



8. Fuel and other costly maintenance charges at three additional stations to provide power.

9. Minor and unforeseen charges such as District Allowance, frequent transport costs for officers, due to remote localities being "three year" stations.

In addition, the existing iron circuit, which still has many years of useful life as a hand speed telegraph, would probably be dismantled.

The location of relay repeater stations and offices at which morse telegraph facilities are installed is shown in Figure 1. There are many intermediate telegraph offices on the route, mainly at cattle station homesteads, police stations, etc., where business is despatched to the nearest morse office by means of phonopores superimposed on the iron line. In fact, the whole of the interior north of Marree is dependent upon the two lines which are providing a grade of service comparable with that given to other parts of the Commonwealth. Apart from Darwin there is Tennant Creek with its gold mining industry, and Alice Springs, the terminal of the southern railway, which is the Canberra of North and Central Australia, with its various administrative offices. More recently the Empire Air Mail link which branches from Darwin, has brought Katherine, Daly Waters, Tennant Creek, and Oodnadatta, more prominently into the communication network. Aviation services have necessitated a twenty-four hour day weather observation, and all of these offices are important in this regard, each one being an all-night service.

All of the services are catered for on either the iron or copper line, traffic disposal arrangements being carried out in the following manner:—

Adelaide-Darwin.—Machine duplex on the copper line.

Adelaide-Maree-Oodnadatta-Alice Springs-Tennant Creek.—Hand speed duplex and simplex on the iron line.

Darwin - Pine Creek - Katherine - Daly Waters-Powell Creek.—Hand speed duplex and simplex to Darwin.

When traffic normally despatched on the iron line overloads the channel, Alice Springs has access to the copper line and intersperses his business with that to and from Darwin.

In order to keep the lag within required limits, equipment arrangements at Darwin are as shown in Figure 2. This is in addition to the Wheatstone apparatus available, as required between Alice Springs and Adelaide to relieve congestion on the iron line. Particular attention has been necessary to handle the business effectively when one circuit becomes faulty, leaving only one duplex channel available to meet all requirements. These arrangements are briefly as follows:—

Adelaide. — Duplex teleprinter interchangeable with Wheatstone in one or both directions simultaneously.

Darwin.—Ditto.

Alice Springs. — Hand duplex on north and south sides of the iron line by dividing the repeater. Access to the copper line in a similar manner plus Wheatstone on the Adelaide side.

Full use of all available facilities can therefore be made, and although duplex teleprinter traffic is normally worked between Adelaide and

Darwin, should either station receive heavy lodgements, teleprinter working continues while a batch of traffic is prepared on a perforator for Wheatstone transmission. When ready, this is disposed of in the Wheatstone transmitter in the direction concerned, without interrupting teleprinter working in the other direction. This method quickly restores the business awaiting transmission at either end to normal proportions. Similar facilities for Wheatstone being available at Alice Springs enables any overload on the iron line to be disposed of without undue delay.

The Teleprinter Wheatstone combination is, therefore, a very effective means of handling traffic and keeping lag, particularly at the transmitting end, within reasonable limits. It is also effective in other directions, since the Eastern Extension & China Telegraph Coy.'s cable to Banjowangie, which terminates at Darwin, also uses the copper line to Adelaide as a continuation link. Traffic received by the Company at Darwin and Adelaide is prepared on the Wheatstone tape at the respective Company's office, and handed to the Post Offices ready for transmission. Throughout the daily routine, therefore, the despatch of Wheatstone tapes is continuously interspersed with teleprinter traffic,

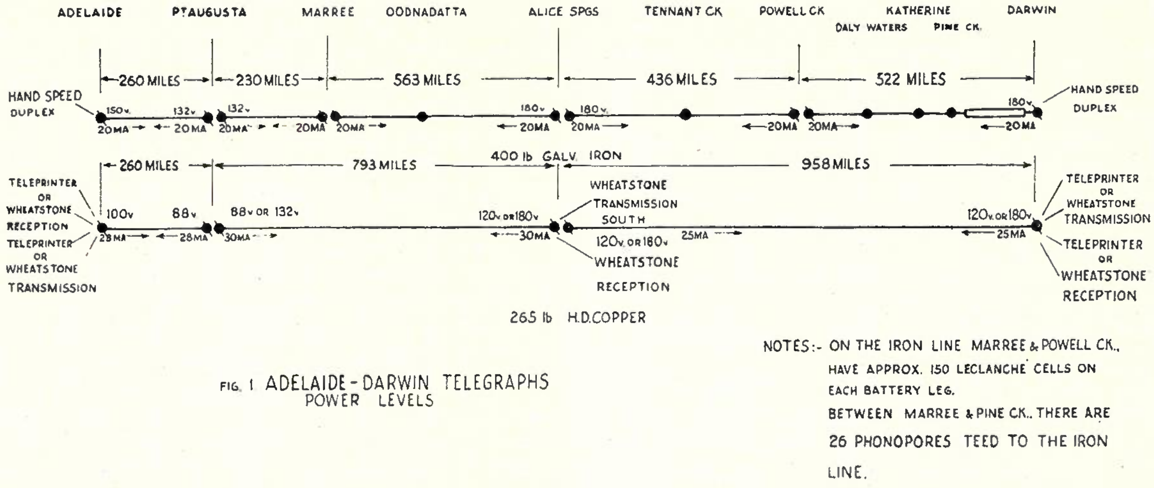


FIG. 1 ADELAIDE-DARWIN TELEGRAPHS POWER LEVELS

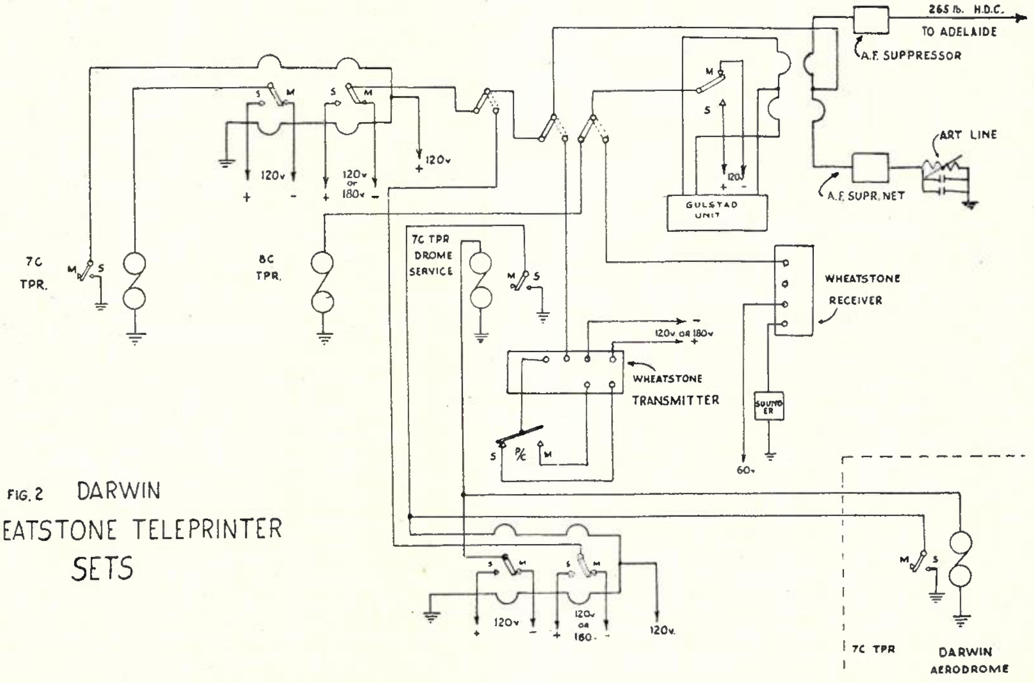


FIG. 2 DARWIN WHEATSTONE TELEPRINTER SETS

and the operators have become expert at quick change-over in one direction only.

When line troubles occur on this 2,000 mile route, traffic is delayed, as unfortunately there are no alternative routes to obtain a quick patch, and it is only by alternative equipment arrangements that service can be maintained. In these cases the longest length of copper line available is procured and those stations which perhaps lose a circuit must re-transmit to another station. The loss of one line south of Alice Springs necessitates Tennant Creek sending his traffic to Alice Springs, who prepares it, together with his own for Wheatstone transmission, and as opportunity offers intersperses it with Darwin on the copper line. Similarly, the loss of one line between Alice Springs and Tennant Creek would necessitate the latter's business being transacted via Darwin. By resorting to Wheatstone working under these contingencies, in one or both directions, full benefit is derived of all available line time.

It will be noticed that both the copper and iron lines are worked as physical duplex systems, but that between respective repeater stations there are several morse offices inserted on the iron line. These are worked on the orthodox back stop method with reversed battery in the duplex section. All morse station sets, however, can be patched into the copper line, and as all batteries at repeater or terminal stations on this line are fitted with battery reversing switches, an intermediate morse station can establish quick communication on the copper line should an occasion demand. A further emergency facility is provision at repeater stations for disconnecting the spacing leg of the line battery so that a morse station can work a repeater station when a line fault prevents double current working, e.g., a faulty line between Tennant Creek and Powell Creek does not prevent communication between Alice Springs and Tennant Creek.

Having given a resume of the equipment and line arrangements, some theoretical deductions compared with practical results obtained might be of interest.

Figure 1 shows distances between repeater stations, and it will be noticed that Port Augusta is not in the electrical centre although both lines are diverted through repeaters in this office. This enables low power levels to be used over the Adelaide-Port Augusta section, and reduces crossfire difficulties into the many telephone and carrier circuits on the main pole route feeding the northern and western parts of South Australia, as well as the Western Australian circuits. North of Port Augusta, the problem of crossfire is not so important, except between the two telegraph lines themselves, more of which will be discussed later. Port Augusta repeaters are bridged out of the copper line after 9 p.m., when Adelaide - Darwin is worked in approximately 1,000 mile sections, with only Alice Springs repeating.

For the purposes of calculation consider the Alice Springs-Darwin section where the copper line is approximately 1,000 miles in length, and the longer portion of the iron approximately 500 miles, viz., Powell Creek-Darwin. At first sight the idea of working fast speed machine telegraph traffic as a duplex system does not appear feasible without some additional aid, such as a regenerative repeater or reduction in length of repeater sections. An analysis of the position reveals that under normal line conditions duplex Wheatstone working at over 100 words per minute can be accomplished, whilst duplex teleprinter working is also well within the limits of the circuit.

From the well-known KR law:—

Speed of working $= A/KR$ or A/L^2KR

where A = Constant for class of wire
K = Capacity in farads per mile
R = Resistance in ohms per mile
L = Length of line in miles.

265 lb. copper	**400 lb. iron**
A = 12	A = 10
R = 3.32 ohms	R = 13.32 ohms
K = .0151 uf.	K = .0157 uf.
L = 1000	L = 500
Speed = 234 words per minute.	Speed = 191 words per minute.

These figures, taken from line constants, are somewhat misleading and apply to simplex working. In addition, it assumes that the orthodox shunted condenser is used at the receiving end. The respective values for duplex working are 2/3rds those for a simplex, which reduces the speeds to the following values:—

1,000 miles, 265 lb. copper, 156 words per minute.

500 miles, 400 lb. iron, 127 words per minute.

In actual practice it has been possible on the copper line to work duplex Wheatstone traffic between Adelaide and Darwin at speeds in the vicinity of 120 words per minute, but in the case of the iron line, Wheatstone working is seldom possible at speeds of more than 50 words per minute.

This is no doubt due to several factors, viz.:—

(1) The cumulative distortion of four repeater sets.
(2) The "skin effect" of the iron wire.
(3) The inability to obtain duplex balances of sufficient accuracy to simulate the impedance of the line at the signalling frequencies.
(4) The number of phonopores (condenser telephones) teed to the line.

The insertion of a 200 mile patch of iron wire into the copper line is often sufficient to reduce duplex working to 50 words per minute but this feature will be dealt with at a later stage, when proposals now in progress to overcome the difficulty will be discussed. Referring to the recent innovation of teleprinter working on the copper line, we find that a teleprinter running at normal speed (400 r.p.m.) equals 46.6 Bauds, also that the duration of a current element is .02 seconds.

For Wheatstone: Speed in Bauds = number of direction holes per second × 2.

Also: One foot of Wheatstone tape = 120 direction holes = 5 words.

Therefore: 46.6 Bauds = (120 × 2 × F)/60 (where F represents feet of tape per minute) = 11.65 feet of tape = 58.25 words per minute.

Again from Kelvin's Law and Arrival Curve, maximum current value is attained at the receiving end after a period of 10 times the "silent interval" has elapsed. The silent interval "t" is approximately .023 KR seconds, so that for the two cases under discussion:—

1,000 miles, 265 lb. copper.—"t" = 11.76 milliseconds.

500 miles, 400 lb. iron.—"t" = 12.02 milliseconds.

Both of these values are well below the element signal time of 20 milliseconds for a teleprinter and therefore provide ample margin for operation of the printing mechanism. It shows that both lines should be capable of machine working, but as previously mentioned other practical factors place serious limitations on the working speed of the iron line.

Having shown that the lines, the copper in particular, are capable of the requisite speed, the next considerations are those applying to the equipment. The operating staffs are called upon to maintain the working at all repeater stations and the Darwin terminal. Standard equipment has been used throughout, viz., artificial line units in use are the usual standard box with two timers. Signalling and reading condensers are not used, and although Gulstad control units are available their use is not encouraged nor is it necessary. The line relays have proved to be an important adjunct to increase of speed on the copper line. The W.E. 209FA type relays have been in use at Port Augusta for some years, but those at Alice Springs and Darwin were B.P.O. type prior to the installation of teleprinters. The B.P.O. type have been replaced with Creed model 27C during the recent installation of teleprinters, resulting in a marked improvement by eliminating signal distortion. The use of the Gulstad vibrating winding has also been found unnecessary for general teleprinter working. Other factors which it is found govern good high speed working, in addition to the use of the modern type of relay, are:—

(1) The "duplex balance" must be exceedingly accurate and is generally checked by duplex reversals.
(2) Line currents must be accurately adjusted on both marking and spacing sides.
(3) Line loss and foreign current must not be excessive.
(4) Inductive interference from neighbouring circuits must be a minimum.
(5) Line batteries (primary) should have low internal resistance.

With regard to item (1), this is checked at each morning line-up and again whenever necessary during the day. Item (2) is fixed for each battery voltage used and cannot be varied by the operating staff. Item (3) is a variable quantity, but fortunately line leakage north of Port Augusta is not often severe, and in the Alice Springs-Darwin section is almost unknown. Occasionally loss occurs in the winter months through light rains in the Flinders Ranges immediately north of Port Augusta, and also through heavy winter dew in the dry sandy stretches between Farina and Oodnadatta as well as in the Depot Sandhills between Finke River and Alice Springs. Foreign current is at times a factor to be reckoned with, and is severe in the northern section during the tropical wet season when monsoonal storms not only prevent even hand speed working, but often cause considerable damage to equipment through lightning discharges. Cross fire (item 4) is a governing factor which must be carefully watched throughout this route, in order to maintain service on both circuits.

From a glance at Figure 1 the reader will realize the long distances on which these two wires comprise the only conductors on the poles, the iron on a top pin, and the copper approximately 18 inches below on a bracket. One line is working high speed duplex and the other hand speed either from a double current source at a repeater or terminal, or perhaps single current from one of the intermediate morse stations. Power levels must be carefully arranged, those in the iron must not affect the copper or vice versa. The voltage applied to the iron wire must be high enough to provide suitable line current in this high resistance line over the shorter repeater sections, and at the same time must not cause interference in the copper line whose repeater sections are double the length. On the other hand it is just as important that power levels in the longer sections of the copper circuit shall also not cause induction in the iron line. This has been accomplished by the choice of 180 volts with 20 milliamps in the iron line and 120 volts with 30 milliamps on the copper. When leakage is excessive, 180 volts is also used on the copper line, but the increase in line current often renders the iron line unworkable. This is due no doubt to the leakage being mutual to both lines, thus reducing effective currents in the iron line rendering it more susceptible to inductive interference. The question of battery supply is gradually being improved; originally all repeater stations as well as Darwin used primary cells, but at Port Augusta, Alice Springs and Darwin secondary batteries have now been in use for some years. At Powell Creek primary batteries are shortly to be replaced with accumulators using 120 and 180 volt line voltages. It is the use of existing primary batteries at Marree and Powell Creek, together with the fact that relays have not yet been replaced with the more efficient modern type, that full use of the iron line's workable capacity has not been attained.

It is not anticipated that the theoretical speed of working value will ever be approached throughout the whole of this line as a through circuit, particularly as it is understood that there are still sections of the old time steel stranded wire in portions of the route. The use of this line in sections up to 200 miles or more, is desired as a patch for the copper, and the present aim is to maintain teleprinter working when perhaps 200 or 300 miles of iron wire has to be inserted into the Alice Springs-Darwin section of the copper circuit. Secondary batteries and modern high speed duplex repeaters at Powell Creek should have the desired effect in this regard since KR values will be considerably reduced. The cost of providing power at Powell Creek would be particularly high owing to its inaccessibility with consequent higher transport charges for material delivered, and a new departure in the secondary battery plant will be the provision of a wind-driven generator.

Some further interesting problems which add to the complexity of equipment on these lines are:—

(1) Coupling of a leased printergram service at Darwin to the main Adelaide Teleprinter Service at certain periods.
(2) A system of calling-in devices used when terminal and repeater stations are not staffed.
(3) Suppression of radio interference emitted from the telegraph equipment.
(4) Reduction of audio frequency interference into adjacent circuits.

Figure 2 shows the circuit arrangements on the copper line at Darwin and it will be seen that when required, the printergram service to the local aerodrome weather office can be coupled to the Adelaide channel. Whilst this coupling is effected the Adelaide channel is reduced to simplex working but simultaneous transmission from Darwin to Adelaide and the Darwin aerodrome is available. Both receiving stations, viz., Adelaide and Darwin aerodrome can query any portion of their reception or "break" the transmitting station. This facility permits the simultaneous transmission of lengthy five-figure weather messages received at Darwin from Batavia several times daily. The arrangement considerably reduces lag and operative effort, etc., in the Darwin office. At this office the printergram machine is used for transmitting these messages, and as this is mounted adjacent to the 8c receiving machine on the Adelaide line the operator can see any query raised by either receiving terminal. The query from Adelaide is received on the 8c machine, whilst any query transmitted by the machine at the aerodrome will mutilate the home record copy in the Darwin office and also the received copy at Adelaide.

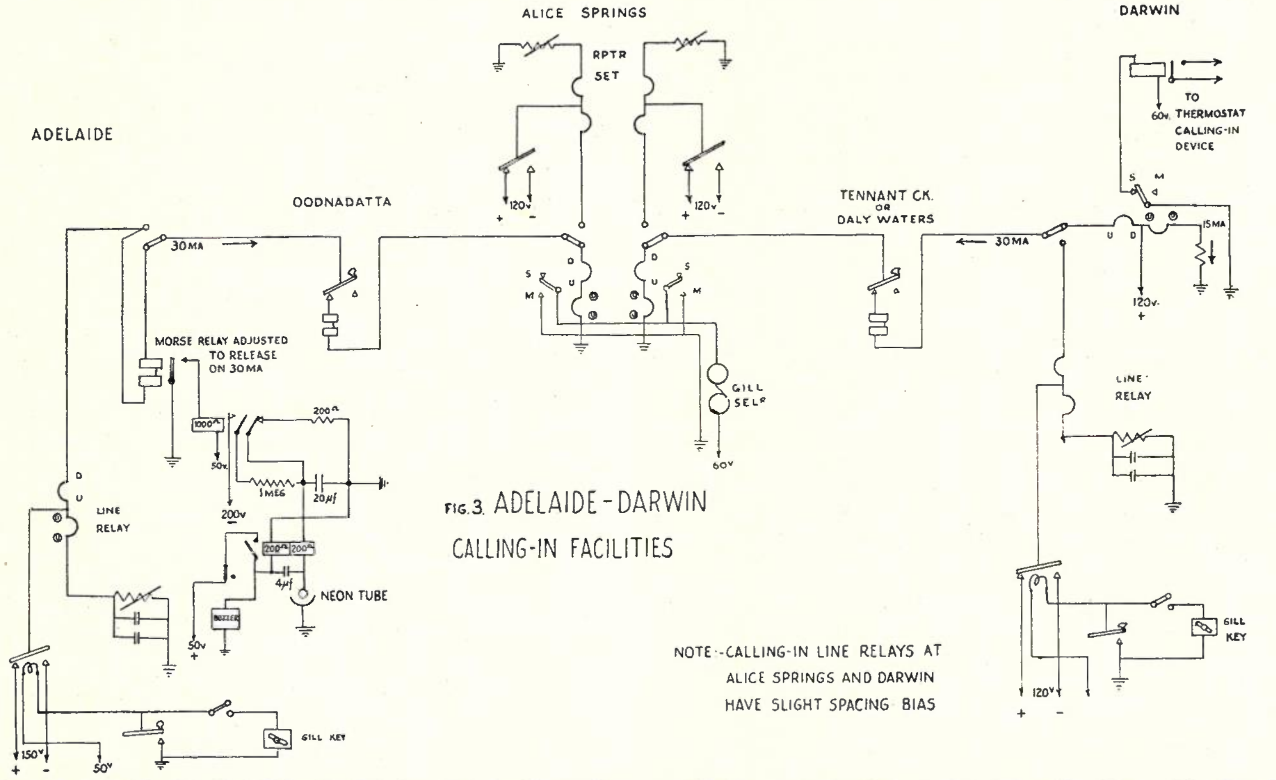


FIG. 3. ADELAIDE-DARWIN CALLING-IN FACILITIES

Calling-in devices at Alice Springs and Darwin are an essential part of the service, as during the night the line is closed and staff released after about 9 p.m. Urgent aviation weather messages are despatched at intervals throughout the night, and these, in addition to emergency calls, necessitate a reliable calling-in device system so that Adelaide, Alice Springs and Darwin can call each other at will. Extension of this service is anticipated when aviation weather services are extended at Oodnadatta, Tennant Creek and Daly Waters. For this reason the system has been arranged so that it will permit intermediate morse stations to raise one of the terminal offices. The circuit shown in Figure 3 indicates the line and circuit conditions throughout the whole route when all offices have been closed for the night. At Alice Springs a code calling Gill selector is used with transmitting keys at Darwin and Adelaide, both having the same code combination. At Darwin a thermostat "Blinker" device is used; this gives the alarm after a delayed interval of spacing current or no current is applied to the incoming line. At Adelaide, where staff is always on duty, the set is left intact, but as an added precaution a Neon tube alarm is fitted to call the operator's attention. The alarm at Alice Springs can only be operated by the transmission of an uninterrupted combination of impulses, but those at the terminal offices are actuated by the application of a continuous "spacing" ("marking" in the case of an intermediate morse office) of approximately 30 seconds' duration.

Special features in regard to this service were the prevention of false calls, damage to equipment by lightning storms, wastage of battery power at Alice Springs, etc. The Gill Selector Code Calling Device, which operates only on the reception of a complete sequence of marking and spacing impulses, has proved very reliable. It minimizes the likelihood of false alarms being received at Alice Springs where the telegraphists' residences are some distance from the Post Office. At the terminal stations, the delayed signal device is quite sufficient to meet requirements, and both the thermostat and Neon tube circuits have proved satisfactory. The possibility of damage to equipment by lightning is a real difficulty notwithstanding the various protective measures which are installed. For this reason the normal equipment at both Alice Springs and Darwin is removed from the line, and only calling-in apparatus is allowed to remain in circuit overnight. Polar relays of the B.P.O. pattern take the place of the more expensive Creed type. The circuit has also been arranged so that the centre of the entire section is earthed, and further it permits the removal of battery from the line at Alice Springs, reducing wastage at a point where charging costs are expensive. Any intermediate morse station is able to call one of the terminals by patching in a "back stop" morse set and opening the line by giving a marking signal on his key. A failure of the line through an open circuit will also call the attention of a terminal station.

Elimination of radio interference into broadcast receivers has necessitated the fitting of exceedingly effective suppressors to all contact points of telegraph equipment in the Northern Territory. Most of the broadcast receivers in these parts are high gain sets, and daylight reception of even the nearest station is very indifferent with the set operating at full gain. For this reason interference from nearby local sources is very apparent and the slightest amount of radiated energy is easily discernible. The problem resolves itself into the complete suppression of interference from the telegraph equipment without altering the wave shape or otherwise interfering with the efficiency of machine speed telegraph signals on a line where working margins are already limited.

Various types of radio frequency chokes and filtering circuits have been tried, but many of them either distorted the telegraph signal or, due to added inductance, caused excessive sparking at contacts. By the use of a "Tobe" noise measuring set and an oscillograph, first in the laboratory, and later on the equipment at Alice Springs and Darwin a compromise has been arrived at between good telegraph signal shape without undue radio frequency radiation. The main sources of interference were line battery contacts on relays and pole-changers, in addition to somewhat lesser trouble from local circuit contacts. The local circuit suppression was effected by inserting one-half of the winding of a Type 3 Suppressor (Drawing C965) in series with the battery lead, together with a .25 to .5 MF condenser and 40 ohm non-inductive resistance across the contact. In the case of the line battery contacts the difficulty was not so easily overcome as radiation from the line itself was often severe. Small honeycomb wound radio frequency chokes of 8 millihenries inductance have been placed in series with the line battery feeds at the contacts of polechangers and line relays. A further improvement was effected by placing a .005 MF condenser in series with a 100 ohm resistance across the contacts. This condenser and resistance unit is made up from the usual small component parts used in radio set construction so that together with the choke coil the whole unit takes up very little space and is easily mounted very near to the contact points.

It is essential that the radio frequency chokes should be electrically as close as possible to the contact itself, as even a short lead from the contact to the choke is sufficient to cause radiation and interfere with broadcast reception. In the case of the 209FA relays the lug on the choke coil has been soldered direct to the lug on the relay socket. With the Creed type relays the base has been mounted on a wooden ring $1\frac{1}{4}$ inches thick, with a hole in its centre having a diameter of $2\frac{1}{2}$ inches. The suppressor components are placed in the centre of this ring and connect with very short wires to the relay base. This permits relays to be changed while suppressor equipment remains in the permanent circuit and is always electrically close to the contact points. On polechangers the equipment is mounted beneath the polechanger base in association with the shunt resistance on the local coil windings.

It has also been necessary to eliminate audio frequency interference from the two telegraph circuits south of Port Augusta to prevent disturbance into the many carrier and broadcast channels (including the Adelaide-Perth system), and north of Port Augusta so as to permit phonopore (condenser telephone) working on the iron line. A low pass filter with a cut-off frequency of 300 c.p.s. has been effective in this regard, details of which are shown in Figure 4. This filter, which is placed in the "line" and "artificial" circuits, does not materially distort the signal shape, but does increase the difficulties of obtaining an accurate "duplex balance."

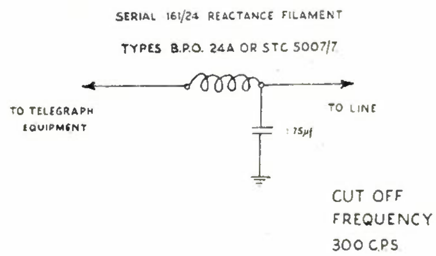
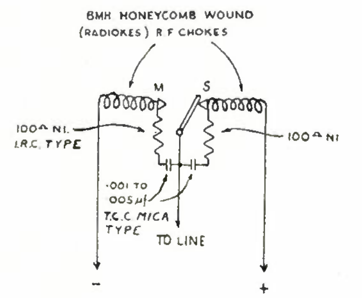


FIG. 4. LOW PASS FILTER TO SUPPRESS TELEGRAPH SIGNALS FROM AUDIO-FREQUENCY CHANNELS.



LINE RELAY & POLECHANGER. RADIO FREQUENCY SUPPRESSION UNIT.

Many other interesting features beyond the scope of this article are associated with the "Overland Telegraph," not the least important of which is the organization and methods adopted for the expeditious clearing of line faults. Many stories can be told of the heroic efforts of men engaged on this work, especially in some of the more isolated sections, where at times the lineman's own existence depends upon his initiative and resource.

In the last list of Birthday Honours the name of one of these officers appeared in recognition of his fine efforts in restoring service during heavy floods early this year. On this occasion nearly 100 poles were washed away at one of the most inaccessible and uninhabited portions of the route. Suffice it to say that the grade of service on this route is equal to that elsewhere in the continent. The Darwin teleprinter service has been extended to Melbourne, for trial purposes, using a repeater at Adelaide and a carrier between Adelaide and Melbourne so that the day may come when if necessary a leased service at Darwin could be extended to a similar service in Melbourne.

ANSWERS TO EXAMINATION PAPERS

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

EXAMINATION No. 2190.—MECHANIC, GRADE 2, BROADCASTING

R. M. BADENACH, B.Sc., A.M.I.E. (Aust.)

Q. 1.—A vertical broadcasting radiator, when measured at a frequency of 800 kilocycles per second, is found to have a resistance of 50 ohms and a capacity to ground of 1,500 micro-micro-farads. Calculate the value of the inductance that will need to be inserted between the base of the radiator and ground in order that the maximum current will flow in the radiator. If, in the above circumstances, the unmodulated carrier power in the radiator is 5,000 watts, what is the value of the current in it?

(Assume the inductance to be of negligible resistance.)

A.—Maximum current will flow in the radiator when it is in electrical resonance, that is, when the capacitative and inductive reactances are equal—

i.e., When $1/2\pi fC = 2\pi fL/1$ . . . (1).
Where $f = 800{,}000$ cycles per second.
$C = 1500\ \mu\mu F$.
$L =$ required inductance.

From equation (1), $L = 1/(2\pi f)^2C$ henries . . . (2).

Substituting in equation (2), and remembering to convert the 1500 $\mu\mu F$ to farads, the required inductance is 26.3 microhenries.

In resonant conditions, and assuming no loss in the added inductance, the power is absorbed in the resistance of the radiator—

i.e., $I^2R = 5000$ watts.
$\therefore I^2 = 5000/50 = 100$ amps.
$\therefore$ the current (I) will be 10 amperes.

Q. 2.—Explain with the aid of a simple diagram how it is possible to obtain "self" or "automatic" grid bias for an amplifying stage in an audio-frequency amplifier by utilising a voltage drop obtained from the plate current. How are variations in the plate current, due to the audio-frequency component, prevented from varying the bias?

A.—The method of obtaining self-bias for an amplifying stage is shown in Fig. 1.

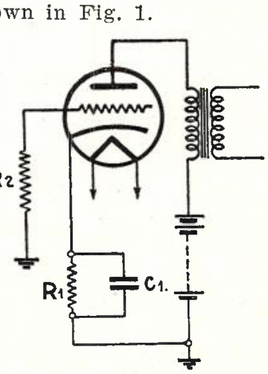


Fig. 1.

In the above circuit the electron flow is from cathode to plate, thence through the plate battery and the bias resistance R1 to the cathode. There is, therefore, a voltage drop across the resistance with the result that the cathode end of resistance R1 is at a higher potential than the earthed end. Since under normal conditions of operation there is no current flowing through the grid resistance R2, the grid is at earth potential. It follows that the cathode is at a higher potential than the grid of a value equivalent to the voltage drop through the bias resistance R1.

The value of the bias resistance is calculated directly from Ohm's Law. If I_p equals the normal plate current and E_g is the required grid bias, then the value of the resistance required would be E_g/I_p.

Since the bias resistance R1 is in series with the plate of the tube, the audio-frequency component of the plate current would pass through this resistance. If this were so, the instantaneous value of the bias would alter depending upon the value of the audio-frequency component of the plate current. To prevent this difficulty, the bias resistance is shunted by the condenser C1. This condenser must have a sufficiently high value so that its reactance at the lowest audio-frequency which it is desired to transmit will be small compared with the value of the bias resistance R1.

Q. 3.—In a transformer coupled audio-frequency amplifier why is it:—

(a) Necessary to have a large primary inductance in the coupling transformers?

(b) Desirable to use transformer cores of high permeability material such as nickel iron?

(c) Necessary to adopt a method of parallel feed in supplying plate volts to the amplifying tubes when high permeability transformer cores are used?

A.—(a) A coupled stage in an audio-frequency amplifier is a voltage amplifying device. It is necessary that the load into which a tube works should be high compared with its plate impedance. Furthermore, the variation of the impedance of the load over the frequency range of the amplifier should be small compared with the plate tube impedance. In other words, the voltage generated across the load at the lowest frequency it is desired to pass should not differ materially from that generated at the highest frequency.

The impedance of the load is directly proportional to the inductance of the primary winding of the transformer and inversely proportional to the frequency being amplified. Therefore, if this impedance is to be kept high the inductance must be high, particularly at low frequencies, otherwise the amplifier will attenuate them.

(b) By using a high permeability core material, the necessary primary inductance may be obtained with a minimum number of turns. Therefore fewer turns are required on the secondary winding in order to obtain the necessary turns ratio for the voltage step-up. The fewer the turns on the transformer the less liability there is of trouble due to the distributed capacity of the windings, with the consequent result of an improved high-frequency response in the amplifier.

(c) High permeability core material becomes magnetically saturated by the passage of small direct currents through the windings. Such saturation, apart from possibly permanently damaging the transformer, results in poor performance of the amplifier. To overcome this possibility of trouble, the plate volt supply must be fed through a choke or high resistance connected in parallel with the primary winding of the transformer.

Q. 4.—Why must harmonic radiation of the carrier frequency of a broadcast station be kept to a minimum? Describe one method of reducing harmonic radiation.

A.—Harmonic radiation must be kept to a minimum in order to prevent interference to other radio services that may have the harmonic frequencies as their working waves. Furthermore, a broadcast station should make the utmost use of its fundamental frequency. If it emits harmonics, there is a certain loss of efficiency on its fundamental frequency because the harmonic frequencies may be regarded as a certain waste of energy.

Harmonic radiation is a function of transmitter design and maintenance but, notwithstanding all care in this direction, it is usual for a station to be equipped with some form of harmonic absorbing device connected between its output circuit and the aerial. Such a device is shown in Figure 1.

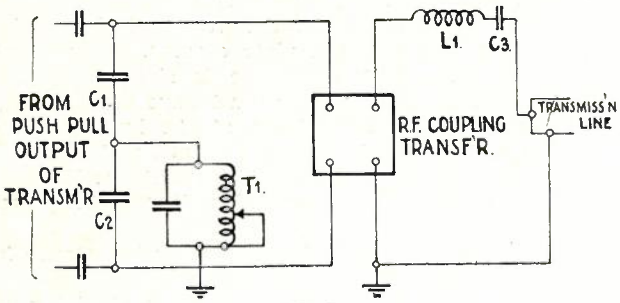


Fig. 1.

In this circuit there are two harmonic absorbing devices, the first consisting of condensers C1, C2 and the tuned circuit T1 and the second of inductance L1 and condenser C3. The first device is intended to absorb the second harmonic, and in its operation the two push-pull tubes of the transmitter are regarded as being connected in parallel. The tuned circuit T1 is then tuned so that, in conjunction with condensers C1 and C2, it forms a series resonance circuit for the second harmonic, which is thereby shunted direct to ground. The second harmonic device is tuned to series resonance with the fundamental frequency of the transmitter so that it thereby attenuates all frequencies except the fundamental.

Q. 5.—Explain briefly the purpose of each of the five elements in a pentode type receiving tube.

A.—The purposes of each of the five elements in the pentode type receiving tube are as follow:—

(i) **The Cathode.**—On heating, the cathode liberates electrons which are attracted to the anode, thus resulting in a current flow through the tube.

(ii) **The Anode.**—The anode is at a positive potential in relation to the cathode, and thereby attracts the freed electrons from the cathode, with a resultant current flow.

(iii) **The Control Grid.**—The input signal is applied to the control grid and, depending upon its instantaneous voltage, the current flow through the tube is regulated, thus giving the required output signal.

(iv) **The Screen Grid.**—The screen grid is connected between the control grid and the anode, and is given a positive potential of less value than that connected to the plate. Its main function is to reduce the inter-electrode capacity between the control grid and the anode, thus obviating feed-back difficulties and ensuring greater stability at radio-frequencies. Since it is at a positive potential in relation to the cathode, it also tends to neutralize the negative field near the anode, thus further reducing the space charge with a consequent increase in the amplification factor of the tube.

(v) **The Suppressor Grid.**—The suppressor grid is placed close to the anode, and is connected to the cathode, and is at a much lower potential than the anode and the screen grid. Its function is to suppress or repel those electrons which are freed from the plate as the result of electronic bombardment, thus reducing the space charge in the tube with a consequent increase in the amplification factor. Its effect is particularly marked when, as the result of the signal applied to the control grid, the instantaneous anode voltage falls below that of the screen. In these circumstances, if it were not for the presence of the suppressor, the electron flow would pass to the positively charged screen grid with the result that the output of the tube would fall right away and severe distortion would be experienced.

Q. 6.—What safety precautions must be taken in regard to the order in which the filament and plate circuits of a hot cathode mercury vapour tube are closed? Why are the precautions necessary? Describe briefly a device that will automatically provide the required safeguard.

A.—During normal operation, the filament circuit of a hot cathode mercury vapour tube must be closed approximately 30 seconds before the plate circuit. The reason for this precaution is that it is necessary to allow sufficient time for the space charge to build up around the filament in order to prevent the positively charged mercury vapour ions released as the result of the ionization of the mercury vapour from bombarding the filament, and so eventually causing it to disintegrate. A device that will automatically provide the desired safeguard is shown schematically in Figure 1.

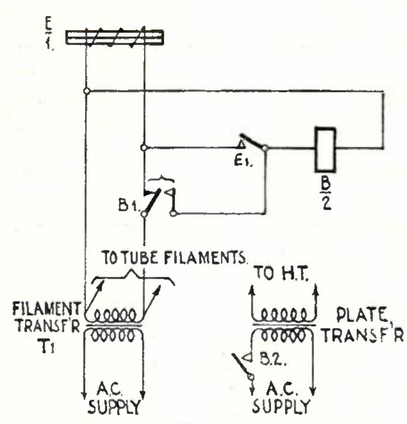


Fig. 1.

When the filament supply to the tubes is closed through transformer T1, power is also applied to a heating element surrounding a bi-metallic strip E. This strip is composed of two dissimilar metals of different temperature coefficients so that as the result of the heating effect it bends. The time that it takes to bend may be controlled mechanically or by the heating effect. After the necessary time has elapsed, it bends sufficiently to close a contact, E1, which applies power to relay B. Contact B2 of relay B closes the primary circuit of the H.T. transformer, thus applying the plate voltage. A further make before break contact, B1, opens the circuit of the heating element, and locks relay B until power is removed from the filament transformer.

Q. 7.—What is a thermocouple unit, and how is it adapted to measure low value radio-frequency currents?

A.—If the junction of two dissimilar metals such as iron and constantan or platinum and platinum iridium be heated, a small E.M.F. is generated at the junction, this E.M.F. being proportional to the heating effect. A junction of two dissimilar metals so arranged is called a thermocouple.

For measuring small radio-frequency currents, the junction is so arranged as to be heated by a fine wire carrying the current to be measured (see Figure 1).

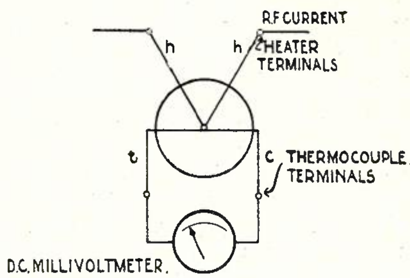


Fig. 1.

The current heats the junction and an E.M.F. is developed. This E.M.F. is read from a D.C. millivoltmeter connected to the two free terminals of the two elements of the thermocouple. As the E.M.F. is proportional to the heating of the thermocouple, and as the heat developed is proportional to the square of the current, then the reading on the millivoltmeter is proportional to the square of the current being measured, i.e., the meter is a current squared meter.

As the sensitivity of the thermocouple is increased by reducing the air pressure surrounding it, for low value currents the thermocouple is enclosed in a vacuum glass bulb.

Q. 8.—The output stage of an audio-frequency amplifier consists of a single triode. The audio-frequency signal fed to the grid of this triode is 20 Volts (R.M.S.), its plate impedance is 1,000 ohms and its mutual conductance is 5 milliamps per volt. Assuming the tube is matched to the load on the basis of maximum undistorted output being obtained when the load impedance is equal to twice the tube impedance, calculate the power output. What is the maximum power that can be obtained from the tube with the above signal voltage applied to the grid?

A.—Representing the Power output by P then—

$$P = I^2 \times \text{Load Impedance}$$

where I = Signal current.

$$I = \frac{\text{Total voltage generated in tube}}{\text{Tube impedance} + \text{load impedance}}$$

$$= \frac{\mu E_g}{1000 + 2000} \text{ amps. . . . (1)}$$

μ is the Amplification factor and

$$\mu = \text{Mutual conductance} \times \text{plate impedance}$$
$$= 5/1000 \times 1000/1 = 5.$$

Substituting in (1)—

$$I = (5 \times 20)/(1000 + 2000) = 1/30 \text{ amp.}$$
$$\therefore P = 1/30 \times 1/30 \times 2000/1$$
$$= 2.22 \text{ watts.}$$

Maximum power is obtained when the load impedance is equal to the tube impedance.

In these circumstances—

$$I = (5 \times 20)/(1000 + 1000) = 1/20 \text{ amp.}$$
$$\therefore P = 1/20 \times 1/20 \times 1000/1$$
$$= 2.5 \text{ watts.}$$

Q. 9.—What safety and alarm devices are usually associated with the water-cooling system of a broadcast transmitter utilizing water-cooled tubes? Why are they necessary? Why is the cooling water fed to a water-cooled transmitting tube through an insulated hose such as rubber or porcelain?

A.—The safety and alarm devices usually associated with the water-cooling system are as follow:—

(a) A water flow alarm inserted in the water circulating system and so connected to the electrical control circuits that only when the water is flowing at a correct rate is it possible to connect any power to the filament or plate of the tube it is desired to protect. Furthermore, should the flow of water fall below a safe value or cease, the device so operates as to disconnect immediately all power.

(b) A water temperature alarm which functions from a contact making thermometer or thermostat, which is inserted in the water flow at the output of the tube. Should the water reach temperatures above those for which the alarm is set, an alarm is rung, drawing the attention of the operator to the dangerous condition.

Both alarms are necessary to ensure that the cooling system of costly transmitting tubes is working satisfactorily. Should the water not be flowing or cease to flow with power connected, the heat generated within the tube would be such that it would be quickly ruined. Similarly, if the temperature of the cooling water goes beyond safe limits, the tube would be damaged.

In a water-cooling system, the cooling water is in direct contact with the anode of the tube and its associated water jacket. The anode is at a high D.C. potential. There is sufficient resistance in the water column used, particularly if distilled water is used, not to cause undue leakage from this high D.C. potential. This condition holds only if the water column is held in an insulating material such as rubber or porcelain. Otherwise, the column would be to all intents and purposes short-circuited and its high resistance properties destroyed.

Q. 10.—Describe with the aid of a simple diagram the modified Heising system of modulating a carrier wave by utilizing transformer coupling.

If in the unmodulated condition the D.C. voltage on the plate of the modulated amplifier is 1,000, within what voltage limits will the plate voltage swing when the carrier is fully modulated?

A.—The modified Heising system of modulation is shown in Figure 1. V1 is a radio-frequency amplifying tube. Radio-frequency energy is fed to its grid and the anode, which is tuned, supplies modulated R.F. to the next stage or the aerial. V2 is an audio-frequency amplifier, the output of which is connected through the primary winding of an audio-frequency modulating transformer T. The secondary of this transformer is connected in series with the anode supply to V1. It will be seen, therefore, that when an audio-frequency signal is applied to V2 the anode volts on V1 will be increased or decreased depending upon the polarity of the audio-frequency signal, i.e., for the positive half of an audio wave the voltage on V1 will be increased and for the negative half it will be decreased. Thus, the amplitude of the radio-frequency peak currents delivered by V1 to the next stage vary in accordance with the audio wave; that is, they are amplitude modulated.

If a carrier is fully modulated, then on the positive peaks of modulation the voltage on the modulated amplifier will rise to twice that in the unmodulated condition, and on negative peaks the voltage from the modulator will just annul that normally on the modu-

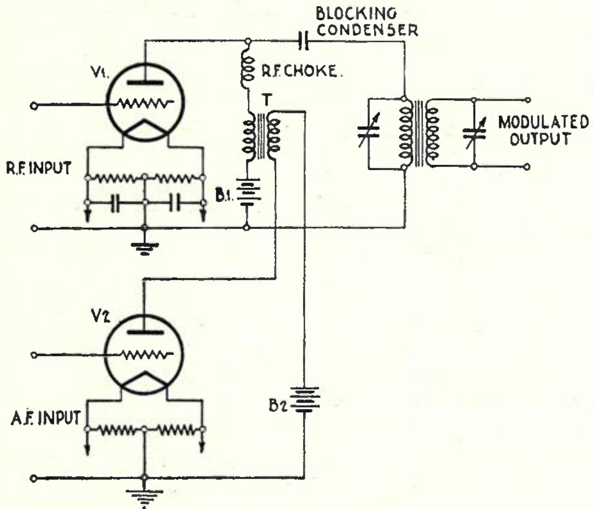


Fig. 1.

lated tube. If the voltage is 1,000 unmodulated, it will swing between 2,000 and zero under fully modulated conditions.

Q. 11.—How is the capacity of a fixed condenser affected by:—

(a) The size of the metal plates?

(b) The thickness of the dielectric between the plates?

(c) The dielectric constant of the insulating material?

How is the construction of a fixed radio-frequency condenser arranged to ensure that it is of minimum inductance and resistance?

A.—The capacity of a condenser is:—

(a) Directly proportional to the area of the plates.

(b) Inversely proportional to the distance between the plates (i.e., the thickness of the dielectric between them).

(c) Directly proportional to the dielectric constant of the insulating material.

The practical method of manufacturing condensers by winding thin strips of metallic foil and thin paper dielectric in the form of a roll and connecting terminals to the foil at one spot results in the condenser having

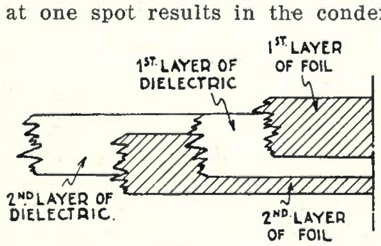


Fig. 1.

appreciable inductance and resistance at radio frequencies. This is because the radio currents, in passing through the condenser, travel round and round as if traversing a coil of wire, thus introducing an inductive effect at the frequencies concerned. Furthermore, in traversing a sheet of foil from the one terminal, the currents take a path which obviously has appreciable resistance. These effects are greatly reduced by adopting a form of construction as shown in Figure 1.

With this arrangement the metallic foil and the paper dielectric are made the same width, and the alternate foils are allowed to project over the edge of the paper on opposite sides. When the assembly is rolled up there is a bunch of foil projecting on each side of the roll. By squeezing these projecting ends together and connecting the terminals thereto, all parts of each condenser plate are connected in parallel so that the current reaches the heart of the condenser without having to traverse a spiral path, thus avoiding inductive and resistance effects.

High voltage transmitting condensers are usually constructed with flat plates of metal connected in parallel; that is, there is no spiral effect. Resistance is kept low by sweating the alternate layers of plates to heavy busbars which are connected in turn to the terminals.

Q. 12.—Describe with the aid of a simple sketch how sound energy is converted into electrical energy in a velocity (or ribbon) type microphone. To what extent is the output of a velocity microphone dependent upon the direction of the sound source?

A.—The velocity microphone consists essentially of a very light corrugated aluminium ribbon hung loosely between the pole pieces of a powerful permanent magnet in such a way that the lines of force cut the edge of the ribbon (see Figure 1 (a).). When the

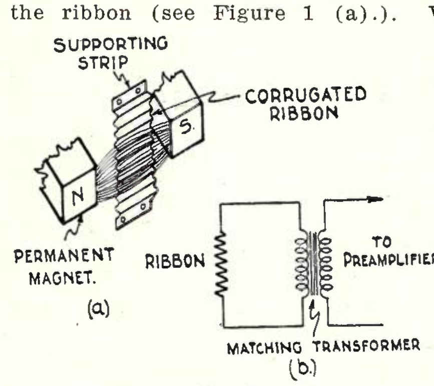


Fig. 1.

ribbon is placed suitably in a sound field, it moves in proportional response to the velocity component of the sound wave, thus cutting the field of the permanent magnet. There is, therefore, induced in the ribbon an E.M.F. which is an exact reproduction of the ribbon movement in both amplitude and frequency. This E.M.F. induces currents in the ribbon which are led away to the preamplifier. Hence, the sound energy is converted into electrical energy.

As the resistance of the ribbon is only a fraction of an ohm, its output is transferred immediately to the primary of a matching transformer forming part of the microphone assembly. The secondary of the transformer is usually tapped in order to permit of the choice of a suitable impedance to match that of the succeeding equipment.

As the ribbon is actuated by air particle velocity and not by sound pressure, and as, because of the shape of the ribbon and its location in regard to the pole pieces of the magnet, it is acoustically shielded on the two sides, the microphone transmits sound equally well from either its front or back, but as the angle of sound incidence departs at either the front or back from an angle of 90 degrees with the face of the ribbon, the total response at all frequencies falls off. The polar diagram is therefore approximately of the form of a figure "8" with minimum response in the direction of the plane of the ribbon.

EXAMINATION NO. 2199.—MECHANIC, GRADE 2—TELEPHONE INSTALLATION AND MAINTENANCE

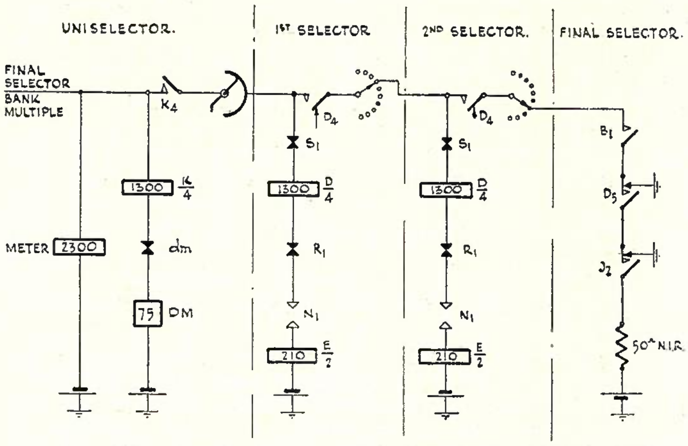
W. H. WESTWOOD

Q. 1.—(a) Draw the metering circuit for a local call in a four figure automatic exchange.

(b) Describe the operation of this circuit.

(c) To ensure correct operation, what tests should be made on a subscriber's meter?

A.—(a)



(b) The circuit shows the arrangement for booster battery metering.

When a call is originated and the required number has been dialled, the ringing condition of the final selector having been set up, the circuit conditions with regard to metering are as follows:—

Uniselector.—Relay K is operated to the circuit holding earth via contact B1 in final selector (D.M. does not operate in series with K.)

1st and 2nd Selectors.—N1 is closed, relay D is operated to circuit holding earth and contact D4 is operated. (Relay E does not operate in series with Relay D.)

Final Selector.—Relays B and J and contacts B1 and J2 are operated.

In this condition current flows in the meter to the circuit holding earth, but this current is not sufficient to operate the meter.

When the called subscriber answers, relay D of the final selector operates and de-energizes relay J which is slow to release. During the slow release of J the circuit holding earth condition is changed at contact D5 to a positive potential of approximately 48 V. and in series with the normal negative battery impresses approximately 96 volts on the circuit, double the normal current flows in the circuit and the meter operates.

On the release of J the circuit holding earth is restored again at contact J2.

(c) The following tests are applied with the Standard test set:—

(i) A test for crossed meter trunks.

(ii) The meter is operated eight times with a test current of 30 MA.

(iii) A current of 43MA is applied to the meter to provide a saturation test.

(iv) A non-operate test is next applied with a current value of 25MA.

(v) A final operation test as in (ii) is then applied, and the meter should now have operated 10 times. The meter reading should be checked to ensure correct operation.

Q. 2.—(a) List the facilities provided on intercommunication telephones, Types A5 and A10.

(b) Draw a block schematic diagram showing a typical layout of an A5 system with one exchange line, four internal extensions and one external extension.

A.—(a) **Local Intercommunication Calls:—**

(i) Direct calling between all internal extension stations on the system.

(ii) No secrecy is provided on local intercommunication calls.

(iii) An engaged test is given if a called extension is engaged on an exchange call.

(iv) Direct calling of an external extension from all internal extensions.

(v) An external extension obtains a connection to an internal extension via the main station. The main station requests the desired internal extension to call the external extension.

(vi) Conference facilities for speaking from any station to all or any number of stations on the system simultaneously are provided.

Exchange Calls:—

(i) Direct connection from any internal extension to the exchange over any exchange line connected to the installation.

(ii) Direct outgoing exchange calls may be barred to chosen extensions. These extensions may originate exchange calls via the main station at the discretion of the main station operator.

(iii) Connection (via the main station) of an external extension to the exchange over any exchange line connected to the installation.

(iv) Incoming exchange calls may be answered at any pre-determined station. This extension is known as the main station.

Any one of the internal extension stations may be equipped as a second choice main station and the functions of the first choice main station transferred to it when desired (by the operation of a key or keys at the first choice main station). Alternatively, any internal extension station with full facilities may be equipped with extension bells, to enable incoming exchange and external extension calls to be answered at this point.

(v) Internal extension stations with full facilities may transfer incoming or originated exchange calls to any other station connected to the installation without breaking down the exchange connection. The transfer of exchange calls to extensions stations with barred exchange facilities or to an external extension must be carried out via the main station.

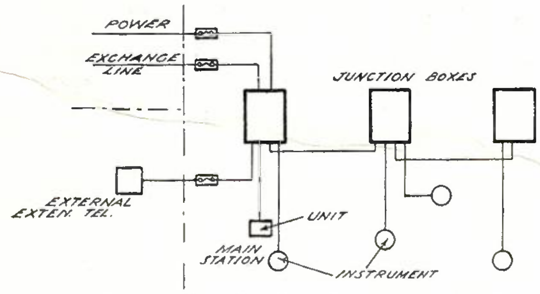
(vi) Any internal extension may hold an exchange call whilst making a call with any other station on the system and the waiting caller on the exchange line is unable to overhear the conversation. On installations with two exchange lines, stations with full facilities may hold one exchange line whilst making a call on the second line.

(vii) On engaged exchange lines an audible test is given on pressing the exchange line button.

(viii) Secrecy is given on exchange connections. Monitoring facilities may be allowed at the main station or any of the internal extensions stations if desired.

(ix) If required, any extension may be completely barred exchange access.

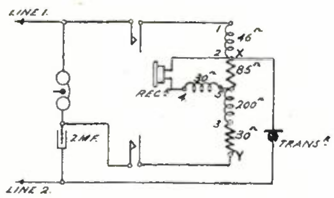
(b)



Q.3.—(a) Draw the circuit of a handset table telephone in which an anti-sidetone induction coil is used.

(b) Briefly describe the operation of the telephone.

A.—(a)



(b) (i) **Ringing.**—The ringing circuit is from Line 1 through magneto bell and 2mF condenser to Line 2.

(ii) **Transmission Circuit.**—The operation of the transmitter sets up a varying current which divides, part going via winding 1-2, Line 1 and back through Line 2 to the transmitter and the major part through the local circuit consisting of X-Y, 2mF condenser and transmitter.

The current through winding 5-3 produces a greater magnetic flux than that through winding 1-2 and a step up transformer action takes place from winding 5-3 to winding 1-2 resulting in an increased line current which is sometimes referred to as the booster effect.

(iii) **Receiving Circuit.**—The major part of the incoming voice frequency current passes from Line 1, winding 1-2, transmitter to Line 2. Transformer action between windings 1-2 and 4-5 causes a current to flow in the local circuit consisting of windings 2-5, 4-5 and the receiver. Any line current passing through winding 5-3 tends to assist the current passing through winding 1-2.

(iv) **Side Tone Control.** — The flux produced by transmitter current in the core of the induction coil, by windings 1-2 and 3-5 will induce an E.M.F. in winding 4-5, and this will produce sidetone current in the receiver. To retain the booster effect previously referred to, and at the same time reduce side tone, the non-inductive winding 2-5 is included, as under normal line conditions the potential across this winding opposes the E.M.F. induced in winding 4-5. Winding 2-5 is therefore designed to give minimum side tone under average line conditions.

Q. 4.—After installing a C.B. floor type P.B.X., what tests should be made before placing the board in service?

A.—Tests with Exchange Test Desk:—

(i) Speak from the switchboard and test the insulation and loop resistance of each exchange line and receive a ring.

(ii) On exchange Line No. 1 operate the extension test key and using a switchboard cord circuit connect each extension in turn to this line. Speak from each extension telephone and test the insulation and loop resistance of each extension line and receive a ring.

(iii) Operate any Night Switching keys provided and test from the extension telephones connected for night switching purposes.

Local Tests:—

(i) Call the switchboard from each extension telephone and receive a ring from the switchboard.

(ii) Test the operation of all switchboard cord circuits on the test jacks provided on the switchboard.

(iii) Test the power leads at the P.B.X. busbars for the minimum permissible voltage of 21 Volts, with the maximum number of simultaneous connections likely under average working conditions.

(iv) Test the operation of the night alarm circuit and buzzer.

(v) Test the operation of the power switch on and off positions.

(vi) If ringing leads are provided operate the change over key and test the operation of the hand generator.

(vii) Test the exchange lines for correct polarity to ensure that negative battery is on the "B" side of the line.

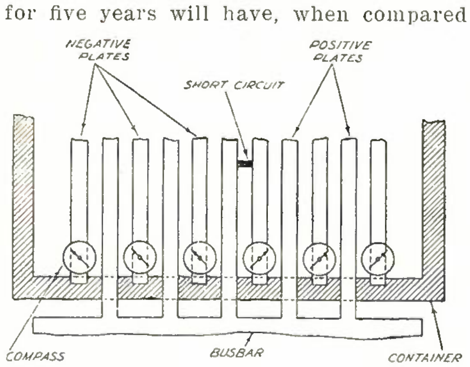
(viii) The transmission and reception of the operators telephone circuit should be observed during the foregoing tests.

Q. 5.—(a) What variations are likely to be experienced in the operation of a new secondary battery and one which has been in service for five years?

(b) What are the symptoms of a short circuit in a secondary battery cell?

(c) How would a short circuit between two plates in a secondary battery cell be located?

A.—(a) A secondary battery which has been in service for five years will have, when compared with a new battery, a lower voltage per cell at the end of a regular charge; and will not be capable of giving its full rated capacity as would be the case with a new battery.



USE OF COMPASS IN LOCATING SHORT CIRCUIT

Fig. 1.

(b) The symptoms are:—

(i) When on charge, lack of gassing in line with the remainder of the cells on charge.

(ii) High temperature.

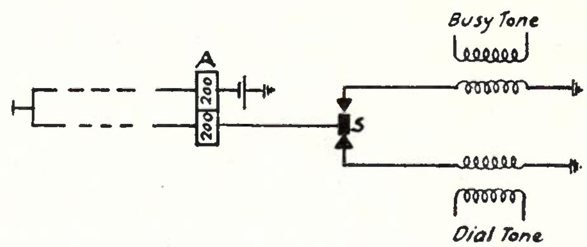
(iii) Low specific gravity if the short circuit has been on for some time.

(c) A small compass approximately 1 inch in diameter mounted on a piece of insulating strip should be placed between the connecting lugs of the plates one after another, so that it rests on the suspending lugs of the opposite plates as shown in Figure 1. As the compass is moved from lug to lug, the needle shows little or no variation until the plate where the short circuit exists is reached, when the deflection changes and remains in this new position up to the other end of the cell. Mark the plate where the change of deflection occurred and test in a similar manner the suspending lugs on the opposite side of the cell. The compass needle will change its deflection at a plate adjacent to the one already marked on the opposite side of the cell. The short circuit will be found to exist between the pair of plates on which the changes of deflection took place.

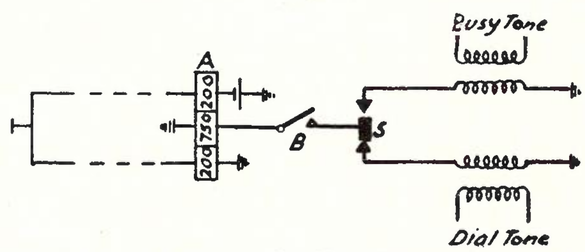
Q. 6.—(a) By means of schematic diagrams show the methods of providing dialling and busy tones on the type 2,000 and earlier types of automatic equipment.

(b) State the advantages of the methods used with the type 2,000 equipment.

A.—(a)



EARLIER METHOD



TYPE 2000 METHOD

Fig. 1.

(b) The advantages are:—

(i) The purity of the tone under all conditions when provided by induction from a third winding which is independent of the line windings on the A relay.

(ii) The balanced condition to earth which this arrangement provides for both line wires thereby reducing the mutual interference between adjacent lines and circuits.

Q. 7.—(a) Draw a schematic circuit of any uniselector with which you are familiar.

(b) Briefly describe the method of operation.

A.—(a) For figure see page 217, Fig. b.

(b) The circuit is of a non-homing uniselector and as such the wipers are left standing on the contacts they were previously using. Contact L1X of the line relay is arranged to operate before contact L2.

Originating Calls.—When the subscriber lifts his receiver, relay L operates via contact K2, subscribers loop, contact K3 to earth. The drive magnet DM is now connected to the private wiper over contacts L1 and K1.

Should the wipers be standing on an engaged outlet, the private bank contact will be earthed, relay K is short circuited at contact L2 and the circuit of D.M. is completed. D.M. operates and causes the switch to step to the next outlet.

If this outlet should also be engaged D.M. will again operate and step the switch on. This action will continue until a free outlet is encountered when an earth condition is not found on the private bank contact; the short circuit is removed from relay K which operates to contact L2 in series with D.M. which will not operate.

Relay K in operating, switches the negative, positive and private wires through to the first selector and disconnects the drive magnet D.M. Relay K also opens the circuit of relay L which releases after a short interval, but by that time the earth on the private wire from the selector holds K operated.

When the call is completed the earth is removed from the private wire and K releases. The switch remains standing on the contacts just used, in readiness for the next call.

Incoming Calls.—On a call incoming to the subscriber an earth is connected to the private wire at the final selector and this completes a circuit for K of the uniselector. As the switch wipers are standing on the outlet previously used for an originating call, a mechanical latch is introduced to limit the armature stroke of K, so that the break contacts are operated, but the make contacts are not completed, thereby disconnecting the circuits of L and the drive magnet but preventing the switch from cutting through to a 1st selector.

Q. 8.—(a) Describe the construction of an impulsing relay of the 3,000 type.

(b) What adjustments would you apply for satisfactory operation on a subscriber's line?

A.—(a) The chief features of an impulsing relay of the 3,000 type are:—

(i) Sandwich winding of the relay coils to give equal resistance, turns, and impedance to each winding and this is achieved by having half the turns of the first winding wound on the core, followed by the whole of the second winding and then the second half of the first winding.

(ii) As an impulsing relay is bridged across transmission circuits, three thin nickel iron sleeves are fitted over the standard iron core to produce a coil which has a high impedance to speech currents without affecting, to any marked extent, its sensitivity on direct current.

(iii) The armature is of the isthmus type where the cross-sectional area of the centre portion of the armature is reduced to produce a relay in which the lags are independent of battery voltage, and ensure a more accurate repetition of impulses over a wide range of line resistance.

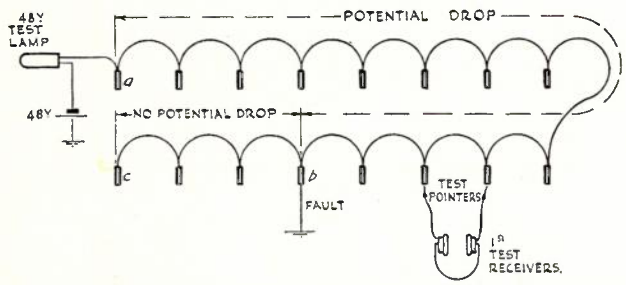
(iv) Adjustable residual screws are provided for the armature and platinum points for the impulsing spring contacts.

(b) Firstly, set the residual and armature travel within the specified limits, measurements being made by means of a feeler gauge; all buffered springs are then tensioned against the buffer block to a certain figure and each lever spring is tensioned until its associated back spring is just moved away from the buffer block. All lever springs are tensioned to limits (which are subject to the relay functioning on the operate and non-operate current tests specified) against the lever spring below or the armature itself, thus ensuring a uniform load on the relay and avoiding clearance between the stud and pin. A test current is then applied to ensure correct operation.

Q. 9.—In a group of 16 final selector banks, the negative contact on line 89 is grounded in the banks. How would you locate the particular bank contact which is grounded? Illustrate your answer with a diagram.

A.—The negative and private wires of the final selector multiple should be opened at the terminal assembly and the private wire of the final selector multiple should be earthed. This will enable the subscriber to originate calls and make the line busy to incoming calls.

A test lamp is used to connect battery to the negative bank wire of the final selector multiple to allow a reasonable amount of current to flow and enable the drop of potential over the bank wiring to be utilized to locate the fault. (See figure.)



A potential drop takes place from (a) to (b), and as the test pointers are progressively bridged over the bank contacts from (a) to (b), a low click is heard in the test receivers. From (b) to (c) no potential exists in the circuit and a click is not heard in the receivers when the test pointers are bridged across the adjacent bank contacts in this portion of the circuit.

The point at which the drop of potential is lost when making the above tests is the point at which the fault exists and in the above case this is found to be at the point (b).

Q. 10 (a) A group selector will step vertically but will not cut in on any level. What are the likely causes of the trouble?

(b) What adjustments should be applied to a selector rotary magnet armature to ensure correct rotary operation?

A.—(a) The causes of the trouble may be mechanical or electrical or both. Some likely causes are:—

(i) Stationary dog out of adjustment.
(ii) Wipers out of alignment.
(iii) Faulty rotary armature restoring spring.
(iv) Faulty rotary magnet or interrupter springs.
(v) Failure of relay E or its contacts.
(vi) Failure of the off normal contacts in the circuit of relay E.

(b) The rotary armature bearing pin must be adjusted so that the armature swings freely, but with not more than 2 mils vertical play. The position of the armature must be such that, when normal, the rotary armature pawl rests squarely on the rotary armature back stop, and the pawl rides centrally on the pawl guide. The rotary pawl guide must be adjusted so that the rotary pawl strikes cleanly in the bottom of the rotary notch relative to the second and subsequent rotary steps. The rotary pawl should leave the guide just as the shaft begins to rotate.

The normal pin must be adjusted so that the rotary pawl strikes cleanly into the bottom of the notch relative to the first rotary step.

The rotary armature back stop must be adjusted so that, when the armature is normal the hub can rotate on release without risk of striking the pawl. The tip of the pawl should clear the tip of the rotary teeth by not more than 10 mils.

The rotary magnets must be adjusted so that with the rotary armature operated electrically there is a space of 6 mils, plus or minus 4 mils, between the front face of the rotary dog and the short face of each rotary notch. The rotary armature in operating must strike both magnet cores simultaneously.

The adjustment of the rotary pawl front stop must be such that, when the rotary armature is fully operated, the rotary pawl is lightly wedged between the hub and the front stop.

The tension of the rotary pawl spring, measured at the pawl tip, must not be less than 20 grammes when the armature is normal.

The rotary armature restoring spring should be tensioned to give the best rotary operation, and should fully restore the armature to normal. To ensure this the tension should not be reduced below 200 grammes.

EXAMINATION NO. 2194.—ENGINEER—NATURAL SCIENCE

R. W. BOSWELL, M.Sc.

Q. 1.—(a) A vector quantity is represented by the symbol $A\varepsilon^{j\phi}$

Write down two other symbolic forms in which the same vector quantity can be represented.

(b) Operate on the quantity—

$$\frac{a + jb}{c - jd}$$

so as to put it into the form A + jB.

A.—(a) $A\varepsilon^{j\phi} = A\angle\phi$

$= A(\cos\phi + j\sin\phi).$

(b) $\dfrac{a + jb}{c - jd}.$

Multiplying the numerator and denominator by c + jd, we get—

$$\frac{a + jb}{c - jd} \times \frac{c + jd}{c + jd} = \frac{ac - bd + j(bc + ad)}{c^2 + d^2}$$

$$= \frac{ac - bd}{c^2 + d^2} + j\frac{bc + ad}{c^2 + d^2}$$

Q. 2.—Calculate the volume of a solution of Sulphuric Acid, density 1.8, and containing 90 per cent. of pure acid that would be required to make 200 grams of Hydrogen Chloride by acting on Sodium Chloride.

Use the following values for Atomic Weights:—

H = 1, S = 32, O = 16, Na = 23, C1 = 35.

A.—As we are dealing with concentrated acid, the reaction will be—

$H_2 So_4 + 2\ NaC1 \longrightarrow 2\ HC1 + Na_2 So_4$

∴ (2 + 32 + 64) grms. of sulphuric acid gives 2(1 + 35) grms. of hydrochloric acid.

98 grms. give 72 grms.

x ,, ,, 200 ,,

x = 98 × 200/72 grms.

= 272 grms. of sulphuric acid.

Mass of solution = 272 × 10/9 grms.

= 303 grms.

∴ Volume of solution = Mass/density = 303/1.8 ccs.

= 168 ccs.

Q. 3.—The walls of a cottage are 12 cms. thick and are built of a material of thermal conductivity 0.0035. The temperature inside the cottage is kept at 15° C. whilst the outside temperature is 5° C. The area of the walls is 1,000 square metres. Assuming that all the heat generated is used to warm the room, what amount of coal of calorific value 8,400 calories per gram must be burnt per hour to maintain the interior temperature

constant?

A.—The heat generated must equal that conducted through the walls. Using the formula—

$$Q = \frac{K\,A\,T\,\theta}{d}$$

Where Q = quantity of heat conducted through the walls in calories
K = coefficient of thermal conductivity
A = area of walls in square cms.
T = time in seconds
θ = temperature difference in degrees Centigrade
d = thickness in cms.

$$Q = \frac{.0035 \times 10^3 \times 10^4 \times 3600 \times 10}{12} = 1.05 \times 10^8 \text{ cals.}$$

Amount of coal needed per hour—

$$= \frac{1.05 \times 10^8}{8400} \text{ grms.}$$

$$= 1.25 \times 10^4 \text{ grms.}$$

Q. 4.—Two oscillatory circuits, each of which separately, would be resonant at a frequency of 600 kilocycles per second, are coupled by mutual inductance. The inductance of the one coil is 1,210 microhenrys, of the other 1,190 microhenrys and the mutual inductance between the two coils is 120 microhenrys. Calculate to a first degree of approximation:—

(a) The coefficient of coupling.

(b) The two resonant frequencies that result from the coupling of the circuits.

A.—

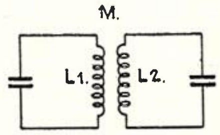


Fig. 1.

The coefficient of coupling is defined as—

$$K = \frac{M}{\sqrt{L_1 L_2}}$$

where M = mutual inductance between the circuits
L_1 = inductance of primary circuit
L_2 = inductance of secondary circuit.

$$K = \frac{120}{\sqrt{1210 \times 1190}} = .100$$

The resonant frequencies are given by—

$$f = \frac{F}{\sqrt{1 \pm K}}$$

where f = resonant frequency
F = resonant frequency of either circuit alone

$$\therefore f_1 = \frac{600}{\sqrt{1.10}} = 571 \text{ kC/s}$$

$$f_2 = \frac{600}{\sqrt{0.90}} = 632 \text{ kC/s.}$$

Q. 5.—A point-source of light of 100 candle-power is at the centre of a sphere of 12 cm. radius. The inside of the sphere is blackened and has a circular hole 1 cm. in diameter cut in it. Calculate:—

(a) The light flux in lumens passing through the hole in the sphere.

(b) The intensity in metre-candles of the illumination on a screen placed 48 cm. from the point-source.

A.—F = luminous flux (lumens)
= $I\omega$.
Where I = luminous intensity (candles)
ω = solid angle (steradians).
Here I = 100 candles

$$\text{and } \omega = \frac{\pi/4 \times 1^2}{4\pi \times 12^2} \times 4\pi$$

.00546 steradians

$\therefore$ F = 0.546 lumens.

E = intensity of illumination in meter candles

$$= \frac{I}{d^2}.$$

Where I = luminous intensity of source in candles
d = distance between source and screen

$$\therefore E = \frac{100}{(.48)^2} = 434 \text{ meter candles.}$$

Q. 6.—Taking the shearing strength of mild steel to be 20 tons per square inch, calculate the force necessary to punch a ¾ in. circular hole in a ⅝ in. plate. Find also the stress in the punch.

A.—Area of shear = circumference × depth

$$= \frac{\pi \times 3 \times 5}{4 \times 8}$$

$$\therefore \text{Force} = \frac{20 \times \pi 3 \times 5}{4 \times 8}$$

= 29.4 tons weight.

Stress = force/unit area

$$= \frac{29.4}{\pi/4 \times (3/4)^2}$$

= 66.6 tons/sq. inch.

Q. 7.—State and illustrate, in each case by a diagram and an equation, Kirchhoff's two laws relating to currents and voltages in networks. In the case of the second law both cases of mesh should be illustrated, namely—

(i) without E.M.F.;

(ii) with E.M.F.

Explanation of the application of these laws to practical problems is not required.

A.—Kirchhoff's first law states that the algebraic sum of the currents which meet at any point is zero.

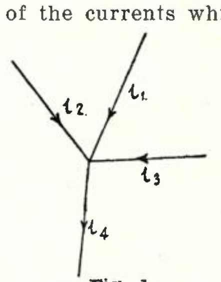


Fig. 1.

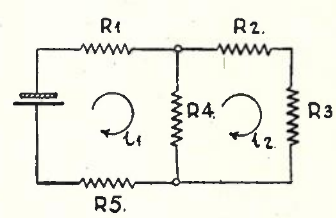


Fig. 2.

Thus from Figure (1):

$$i_1 + i_2 + i_3 - i_4 = 0.$$

Kirchhoff's second law states that in any closed circuit the algebraic sum of the products of the current and resistance of each part of the circuit is equal to the electromotive force in the circuit.

In Figure (2):

$$R_2\,i_2 + R_3\,i_2 + R_4\,(i_2 - i_1) = 0 \ldots (1).$$

$$R_1\,i_1 + R_4\,(i_1 - i_2) + R_5\,i_1 = e \ldots (2).$$

Q. 8.—An iron ring of mean radius 10 cm. and area

of cross section 12 cm.² is wound uniformly with 1,200 turns of insulated wire. A current of 1 amp. is sent through the wire. For a permeability of 700 for the iron, calculate the flux in the ring before and after a gap of 1 mm. is cut in it.

A.—The flux is equal to the magneto-motive force divided by the sum of the reluctances.

$$\phi = \frac{4\pi I N/10}{l/\mu A}$$

Where I = current in amperes
N = number of turns
l = mean length of magnetic circuit
μ = permeability
A = cross-sectional area of specimen

$$\phi = \frac{4\pi \times 1 \times 1200 \times 700 \times 12}{10 \times 2\pi \times 10}$$

$= 2.02 \times 10^5$ lines without air gap.

Total reluctance with the air gap

$$= \frac{l_1}{\mu_1 A_1} + \frac{l_2}{\mu_2 A_2}$$

$$= \frac{62.7}{700 \times 12} + \frac{.1}{1 \times 12}$$

$$= \frac{132.7}{700 \times 12}$$

$$\therefore \phi = \frac{4\pi \times 1200 \times 700 \times 12}{132.7 \times 10}$$

9.60×10^4 lines.

Q. 9.—(a) State in words and show by symbols the rule for integration of powers, for example, of x^n.

(b) Write down the indefinite integrals of the following functions of "x":—

(i) $px^2 + qx + r$
(ii) cos x
(iii) 1/x.

A.—(a) To integrate a power of x, say, x^n, increase the index by unity and divide by the index so increased.

$$\int x^n \, dx = \frac{x^{n+1}}{n+1}$$

(b) (i) $\frac{1}{3} px^3 + \frac{1}{2} qx^2 + rx + c$
(ii) $\text{Sin } x + c$
(iii) $\text{Log}_e \, x + c$.

Q. 10.—Two stretched wires, A and B, each of the same metal and under the same tension, emit the same note when plucked. The length of A is 100 cm. and its diameter is half that of B. (a) What is the length of B? (b) If the tension of B is doubled, to what length must it be adjusted to again give the same note as A?

A.—Using the formula

$$f = \frac{1}{2l}\sqrt{\frac{T}{m}}$$

f = frequency in cycles/sec.
l = length of string in cms.
T = stretching force in dynes
m = mass per unit length in grams

If "f" and "T" are constant

$$\frac{l_1}{l_2} = \frac{\sqrt{m_2}}{\sqrt{m_1}}$$

l_1 = 100 cms.
l_2 = unknown

$$\frac{m_1}{m_2} = \frac{1}{4}$$

$$\therefore l_2 = \frac{100 \times 1}{2}$$

= 50 cms.

If "f" and "m" are constant

$$\frac{\sqrt{T_1}}{l_1} = \frac{\sqrt{T_2}}{l_2}$$

l_1 = 100 cms.
l_2 = unknown

$$\frac{T_1}{T_2} = \frac{1}{2}$$

$$\therefore l_2 = \frac{100}{\sqrt{2}}$$

= 70.7 cms.

Q. 11.—Draw schematic diagrams of the following A.C. bridges set up for the audio-frequency measurements indicated:—

BRIDGE	**UNKNOWN**
Wien's	A paper condenser.
Resonance	An inductor as used for voice-frequency loading.
Hybrid coil	A non-loaded cable pair open at the far end.

At a frequency such that ω = 10,000 radians per second, the variables of the Resonance bridge for balance are found to be 0.1 microfarad and 20 ohms for equal ratio arms. Calculate the electrical dimensions of the unknown.

A.—

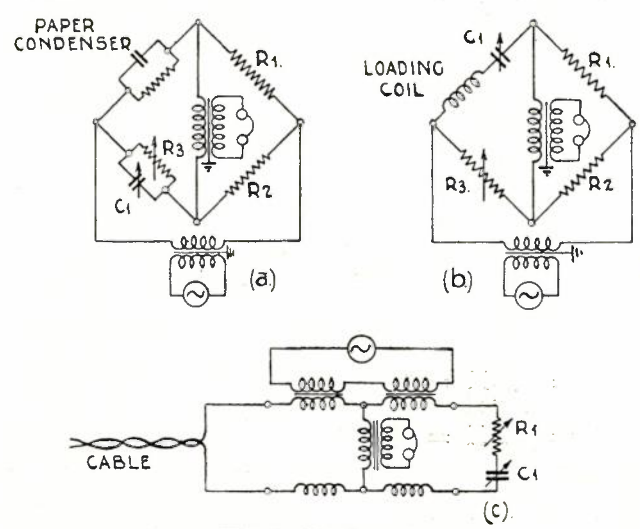


Fig. 1 (a) (b) (c)

Assuming we have a series bridge

$$\omega^2 LC = 1$$

where $\omega = 2\pi$ frequency

L = inductance in henries
C = capacity in farads

$$\therefore L = \frac{1}{\omega^2 C}$$

$$= \frac{1}{10^8 \times 1 \times 10^{-7}}$$

L = 0.10 henries.

Resistance of the coil = 20 ohms.

Q. 12.—(a) State, but do not explain, Newton's three laws of motion.

(b) A force of 100 dynes acts on a body of which the mass is 50 grams. What will be the velocity and momentum of the body 15 seconds after it starts from rest.

A.—(a) Every body continues in a state of rest or uniform motion in a straight line until caused to change that state by the action of some outside impressed force.

Rate of change of momentum is proportional to the impressed force and takes place in the direction of this force.

Action and reaction are equal and opposite.

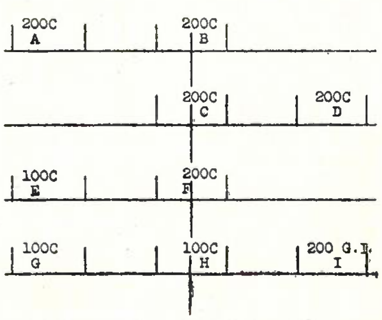
(b) $F = m\alpha$

Where F = force in dynes
m = mass in grams
α = acceleration in cm./sec.^{2}
α = 100/50 = 2.0 cm./sec.^{2}
$V = \alpha T$
V = final velocity
α = acceleration
T = time in seconds
$V = 2 \times 15$
= 30 cms./sec.
Momentum = mass × velocity.
= 30 × 50
= 1500 grm. cm./sec.

EXAMINATION No. 2194.—ENGINEER—LINE CONSTRUCTION

A. N. HOGGART, B.Sc

Q.1A.—On an existing pole route the 6-pin arms are to be changed to 8-pin arms. The existing pole plan is shown in the sketch:—



Circuits A and B and C and D are phantom transposed. The other circuits are not. One additional 200-lb. copper circuit is to be provided and the 200-lb. G.I. circuit is to be replaced by a 100-lb. copper circuit. All circuits on the reconstructed route are to be phantom transposed and the two top arms are to be designed for carrier working.

(a) Prepare the pole plan you would propose for the reconstructed route, showing the spacing between arms and wires and the position of each circuit, using the designation letters shown in the sketch.

(b) Describe the process of carrying out the work, giving the operations in their correct order with particular reference to the handling of the wires when changing their positions. State the precautions to be observed to prevent interruptions.

(c) Describe briefly the best method of tensioning wires and state the principles on which it depends.

A.—(a) The pole plan for reconstructed route is shown in Figure 1, where J is the new 200C circuit. In the new position F uses one wire of C in its old position and vice versa. This is necessary, as it is very difficult to transfer wires, except on the top arm, from one side of the pole to the other. Similarly, the new 100C wires being erected in lieu of the 200 G.I. are paired separately with existing wires of H to form new circuits H and I.

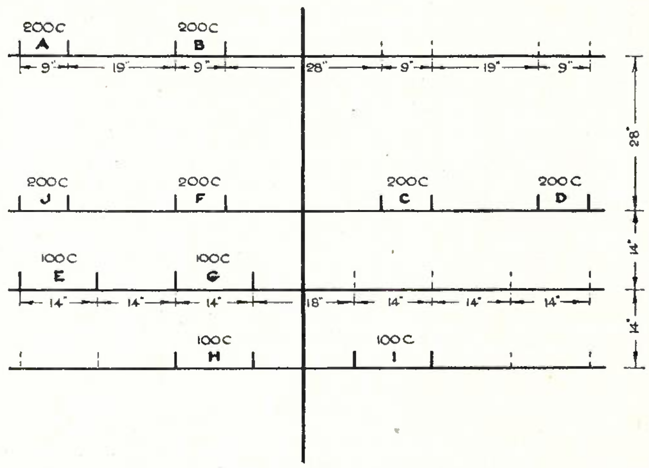


Fig. 1

(b) The work is conveniently treated by taking a suitable section of route, say 1 mile, and carrying out all work on that section before treating the next. The tapes and ties are removed from all wires in the section and wires left in running ties. Starting then from first pole in the section, the re-arming is carried out. The lowest arm is fitted first, then the new third arm fitted in place of existing 4th arm. While doing this, circuits H and I are dropped to new lowest arm, then G and afterwards E are re-arranged to their new positions. The new second arm then replaces the existing third arm, the wires of F being replaced in their old positions. The old second arm is then removed, the wires of C and D being dropped to the new second arm (in third position). The renewal of top arm and re-arrangement of wires A and B is straightforward. During the re-arrangement, precautions are necessary to avoid interruptions. All wires must be re-arranged in the pre-determined order, and the work should be carried out progressively along the route. All wires should be kept in running ties, and only one wire shifted at a time and during the shift adjacent spans closely watched for contacts.

As the re-arming and re-arrangement proceeds, any new poles, etc., should be erected, all necessary preliminary fitting, etc., having first been completed. Also, old transpositions should be cut out and new ones cut in. Special precautions are necessary with phantom transposition, either two must be cut in or cut out concurrently, or one cut in and another cut out on the same phantom group. Similar remarks apply to circuits on which composite telegraphs are in use, also to circuits C and F until the pairing of the wires is altered. Whilst cutting and piecing wires temporary bridges of covered wire should be provided to prevent interruptions.

On the completion of the re-arming and re-arranging, the running of new wire can be carried out and following this, the dismantling of the old G.I. wire. On completion of the above in a section, the regulation of all wires should be checked and then the tying in of the wires may proceed; also, any alteration to the pairing of the wires effected by changing over at each end of the section, transposition poles where wires are terminated being a convenient point to make the changes.

(c) The beat method of measuring the tension of wires is based on the principle that the time taken for a wave to travel the full length of a span of wire and return is inversely proportional to the square root of the tension in the wire.

In practice, a wave is set up in the wire by striking it with the hand and the time recorded for the wave to travel to the far end of the span and return 20 times.

The tension can then be calculated from:—

$$\text{Tension (in lbs.)} = 4\,Wl^2/gt^2.$$

where W = weight in lbs. per foot of wire.
l = length of wire in feet.
t = time for wave to go and return in seconds.
g = acceleration of gravity = 32 feet per sec.

Graphs are available from which the tension can be read off without the necessity of making calculations.

Q. 1B.—(a) Describe concisely the present Departmental practice in regard to the inspection of wooden poles. Include in your answer reference to the following:—

(i) Periodicity of inspections and time within which poles marked for renewal should be replaced.

(ii) Method of examination of a wooden pole about ten years old, mentioning any precautions desirable in regard to the handling of the soil or treatment of the pole.

(iii) Markings to be placed on poles by the inspecting officer stating the significance of each.

(iv) Method of recording and following up the results of pole inspections up to the replacement of the condemned poles.

(b) What precautions should be taken before a lineman ascends a pole marked as requiring renewal?

A.—(a) Wooden poles are inspected once every twelve months for the purpose of detecting poles which are approaching the end of their life or are in a dangerous condition. Condemned poles (those marked for renewal) should be attended to as soon as possible after being condemned, preferably within six months, but not later than twelve months. Dangerous poles should be given immediate attention.

In testing the pole, the following procedure is followed:—

First the pole is examined just below the "wind and water line" by prodding the surface with a heavy knife. If there is sign of softness and the pole has not been sapped, the sapwood should be removed and the true wood tested. If there is any doubt as to the condition of the true wood, a small chip should be broken off and broken in the fingers. Sound timber will break irregularly, but if it breaks with a short fracture as would a carrot, there is evidence of decay.

If these tests show no signs of decay and there is no external evidence of termite attack, the pole should be sounded with the back of an axe. If hollowness is indicated a ½ inch auger is bored downwards into the pole from a point close to the ground line to determine the condition of the interior. The amount of sound wood and not the size of the pipe is, however, the determining factor in the condition of the pole.

As a final precaution, the pole should be given a push test by pushing as high as possible, using if possible a pike or a ladder. This may reveal weakness not brought to light by other methods.

If the ground around the pole has been puddled with creosote, precautions are necessary to ensure that treated soil is not removed and replaced with untreated soil, thus rendering the pole more susceptible to attack by termites, etc. One shovelful only of the soil should be removed and retained on the shovel until it is replaced in its old position.

On completion of the examination all cut surfaces should be treated with creosote, and auger holes plugged with creosoted soft wood plugs.

Poles which it is considered will require renewal within the next twelve months should be marked with a single cross thus—X. Poles which are dangerous and require immediate renewal should be marked with a double cross thus—XX.

The results of the examination of the poles are recorded in field books showing each pole on the route. In addition to recording poles condemned, remarks should be included covering the condition of poles, result of auger tests, etc., and need for treatment to prevent decay or termite attack. From the field books estimates are prepared for the work of renewals, when duly authorized. Also card records are kept showing at any time the number of condemned poles on a route, and approximate date of condemnation, and progress regarding renewals. These cards are kept constantly under review in order that any undue delay in attending to defective poles may come under notice.

(b) Before a pole marked for renewal is climbed, it should be made secure from falling by means of ladders, pole pikes, ropes or a tripod.

If all wires are to be removed and the pole is on firm level ground, a tripod or three ladders or pole pikes should be placed around the pole with an angle of 120 degrees between any two of them. The head of each ladder or pike should be secured to the pole by means of rope or wire, in such a manner that there is no possibility of slipping. Also the feet of the pikes or ladders should be provided with an adequate stop. If a tripod is used it is necessary to ensure that the head grips the pole. If the heads and feet of ladders, etc., cannot be secured, as an additional safeguard the pole should be secured with rope or wire stays, not less than three equally spaced around the pole being employed.

If the pole carries two or more wires, and these are not to be removed, two ladders, pikes, or ropes on opposite sides of the pole and at right angles to the wires will be sufficient.

In sloping or bad ground where pikes or ladders cannot be used, the pole should be secured by rope stays, attached to trees or fences, or if no suitable anchor is available, to a bar or picket driven into the ground, and the rope attached near the ground level. The top of the bar should be secured by lashing it to a second bar driven into the ground behind the first one.

Q. 2.—A pole route carries as its ultimate load three arms of wires. At a point where the route makes an angle of 90 degrees the angle pole is stayed with one

stay. The stay is attached to the pole at the same point as the second arm.

The spacing between the top arm and second arm is 28 inches and between the second arm and the third arm is 14 inches. The third arm is 12 ft. 6 ins. above the ground.

The total tension in the span on each side of the angle pole at minimum temperature in the wires on the top arm is 2,000 lbs., on the second arm 1,500 lbs., and on the third arm 720 lbs. Wind pressure may be neglected.

(a) If the stay makes an angle of 45 degrees with the pole—

(i) Find the tension in it when it bisects the angle made by the wires;

(ii) What is the result if the stay is placed so as to make an angle of 60 degrees with one line of wires produced?

(b) If some of the wires terminate on the angle pole referred to so that the total tension in one direction is half of that in the other direction, how would you determine the correct position for a single stay?

A.—(a) (i) The resultant pull on each arm will by parallelogram of forces be at an angle of 45 degrees to wires in each adjacent span and will amount to $\sqrt{t_1^2 + t_2^2}$ where t_1 and t_2 are tensions in each span.

As the tension is equal in each case, the resultant for each arm will be:—

Top Arm $T_1 = 2{,}000 \times \sqrt{2} = 2{,}828$ lbs.
2nd Arm $T_2 = 1{,}500 \times \sqrt{2} = 2{,}122$ lbs.
3rd Arm $T_3 = 720 \times \sqrt{2} = 990$ lbs.

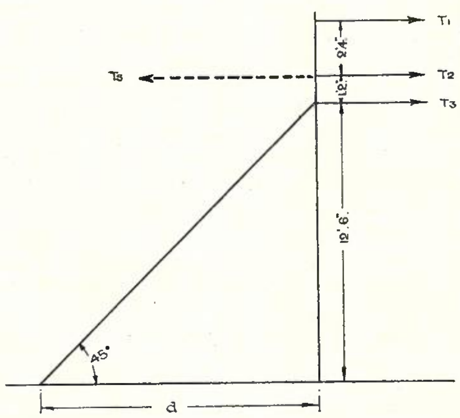


Fig. 1.

Figure 1 shows the forces acting on pole and stay where T_s is horizontal component of tension in stay wire. Then by principle of moments—

$$T_s \times 13'8'' = T_3 \times 12'6'' + T_2 \times 13'8'' + T_1 \times 16'$$
$$(T_s - T_2)\ 13'8'' = 990 \times 12.5 + 2{,}828 \times 16$$
$$= 12{,}490 + 45{,}300$$
$$T_s - T_2 = 57{,}790/13.67 = 4{,}230$$
$$T_s = 2{,}122 + 4{,}230 = 6{,}352 \text{ lbs.}$$

The stress in lbs. exerted by the stay is given by—

$$(w\sqrt{h^2 + d^2})/d = w\sqrt{2} \text{ where } d = h$$
$$= 6{,}352\ \sqrt{2}$$
$$= 9{,}000 \text{ lbs. approximately.}$$

(ii) If the stay is placed so as to make an angle of 60 degrees with one line of wires produced, the stay will not be at the resultant pull of the wires, and therefore will not be effective in holding the pole, which will move in the direction shown approximately by Figure 2.

(b) If the tension in each adjacent span is different, the correct position of the stay can be calculated by

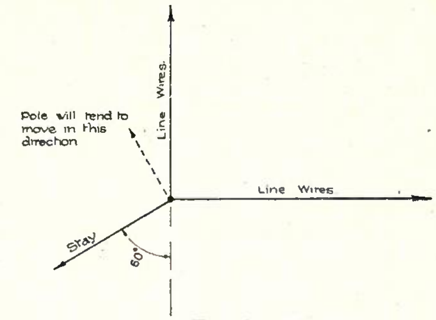


Fig. 2.

applying the parallelogram of forces where the sides are proportional to the total tension in each span and the diagonal gives the direction of the resultant pull. see Fig. 3.

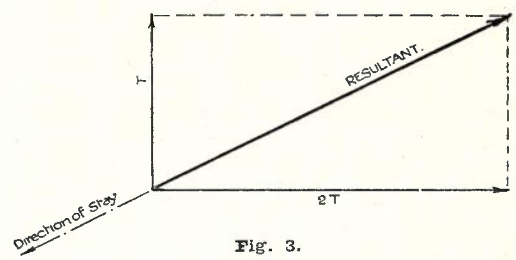


Fig. 3.

On the field this can be carried out by projecting the line of the wires with greater tension back 20 feet from the pole, then measuring 10 feet off at right angles; a line from this point back to the pole then gives the correct direction of the stay.

Q. 3.—(a) Discuss briefly the theoretical basis for determining the spacing between loading coils, including reference to the effect of inductance and coil spacing on cut-off frequency.

(b) State the inductance of loading coils and spacing between them, used on underground trunk cable circuits required to carry:—

(i) 42.5 kilocycle programme channel;

(ii) A three-channel telephone carrier system;

(iii) Voice frequency circuits.

(c) What are the important differences between Grade II. and Grade III. loading coils used by the Department and under what circumstances is each grade used?

(d) What is the attenuation per mile of unloaded 20 lb. star quad cable at 3 kilocycles and 30 kilocycles? To what values are these attenuations reduced by the loading usually employed? State the value of loading for each case on which your answer is based.

A.—(a) A loaded cable line is shown diagrammatically in Figure 1.

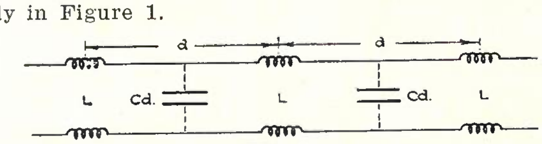


Fig. 1.

In general, inductance of the cable pair can be neglected and the line can be considered as successive series inductance and shunt capacitance elements, i.e., it is of the form of a low pass filter.

If L = total inductance of each loading coil (in Henries)
C = capacitance per mile of cable (in Farads)
d = coil spacing in miles.

The cut off frequency of the cable is the cut off frequency of the equivalent low pass frequency and is given by:—

$$f_c = 1/\sqrt{LCd}$$
$$= 1/\sqrt{L_A Cd^2}$$

where L_A = added inductance per mile.

In practice owing to losses due to resistance and leakance, a sharp cut off frequency is not realized, the attenuation versus frequency curve starting to rise before the theoretical cut off is reached. It is therefore common practice to regard the cut off of a cable as 75 per cent. of its theoretical value.

To calculate the coil spacing, it is necessary to know the capacitance per mile, the inductance required to be added per mile and the cut off frequency, then the above formula can be applied.

From the above formula it is apparent that if the coil spacing is increased without altering the value of the coil, the cut off frequency is reduced.

Also, if the value of the inductance of the coils is increased, the cut off frequency is increased.

(b) Loading particulars for:—

(1) 42.5 kilocycles programme channel:—3.5 mH. coils at 705 ft. spacing (for cable .065 mF. per mile).

(2) Three-channel carrier system: 3.5 mH. coils at 705 ft. spacing are usually employed.

(3) Voice frequency circuits: Heavy loading, 176 mH. coils at 6,000 ft. spacing. Medium loading, 88 mH. coils at 6,000 ft. spacing. Light loading, 44 mH. coils at 6,000 ft. spacing. 8,000 and 9,000 ft. spacings are also used in special cases. Medium loading is most generally used.

(c) Grade II. loading coils are superior in quality to Grade III. coils, particularly in the following respects:—

Their D.C. resistance is lower.

Their inductance must conform to closer limits.

The cross talk between coils is lower.

Grade II. coils are used for loading main U.G. trunk cables not exceeding one repeater length or loading minor trunk or junction cables where phantom loading is required.

Grade III. coils are used for loading junction or minor trunk cables where side circuit only is required.

(d) Attenuation per mile of 20 lb. star quad cable:—

At 3 Kilocycles unloaded: 1.75 db.; loaded 14 mH. at 3,000 ft.: .745 db. (Programme loading).

At 30 Kilocycles unloaded: 3.2 db.; loaded 3.5 mH. at 705 ft.: 1.2 db. (Carrier loading).

Q. 4.—A fault occurs in a submarine cable 100 miles long having a single copper conductor. The preliminary test from each end shows very low insulation.

(a) Describe a suitable Direct Current test to determine the position of the fault. Show how to calculate the distance to the fault from the readings obtained.

(b) Describe an Alternating Current test that could be used in the case of a fault on the same cable with the conductor broken. Show how the distance to the fault is calculated.

(c) What special features are presented by the breakage of a copper conductor in sea water?

A.—(a) A suitable direct current test for determining the position of a fault on a long single core submarine cable is Kennelly's two current test. The test is made with a Wheatstone Bridge with the addition of a milliameter in series with the line. The loop resistance along the line and return to earth through the fault is measured on the bridge, using a false zero. The false zero is ascertained by depressing the galvanometer key with the battery key open and the deflection noted. The bridge is balanced to this false zero which is checked after each balance.

The resistance is measured with a line current I_1 not greater than 30 mA. and again with a smaller current I_2.

The value of the fault resistance is eliminated by using "Kennelly Root Law" and the distance x in nauts. to the fault is given by—

$$x = \frac{R_1\sqrt{I_1} - R_2\sqrt{I_2}}{r\sqrt{I_1} - r\sqrt{I_2}}$$

where R_1 is balance with current I_1,
R_2 is balance with current I_2,
r is resistance of cable conductor per naut.

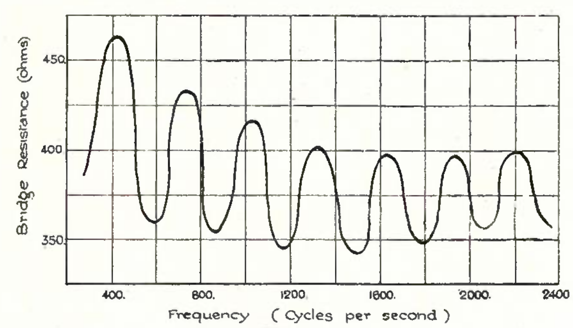


Fig. 1.

(b) An Alternating Current test for a submarine cable with a broken conductor, can be made by measuring the impedance of the cable over a range of frequencies (say from 200 to 3,000 cycles) by means of an impedance bridge. If the impedance is plotted against frequency it will be found that a curve similar to Figure 1 is obtained with regularly occurring maximum and minimum points.

The distance x of the fault is given by—

$$x = K/f$$

where K is a constant dependent on the cable,
f is frequency interval between successive maxima.

K should be determined by obtaining the impedance versus frequency curve for the cable in good condition with the far end open circuit, and calculating from—

$$K = f'l$$

where l = length of cable.

(c) When a copper conductor breaks and comes into contact with sea water the effect known as "polarization" occurs, which results in higher and more varying fault resistance than due to punctured dielectric alone. The "polarization" is set up in the following manner:—

(1) The fault acts as simple cell set up between the copper, iron and salt-water, and the resultant current affects the galvanometer reading.

(2) The testing current itself has an electrolytic action on the cable, coating the copper with chloride of copper or hydrogen, depending on whether the conductor is positive or negative to earth.

(3) Secondary e.m.f.'s are set up by films of hydrogen and copper chloride and will appear and disappear from the circuit with these deposits.

These factors are all apparent as varying fault resistance and render very difficult the location of faults of this nature.

Another factor is the variation of earth potential between testing point and the fault, but this can, if at all steady, be overcome by use of "false zero."

(To be continued.)

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