THE Post Office Electrical Engineers' Journal

SPEED OF SIGNAL TRANSMISSION OVER CARRIER TELEGRAPH CHANNELS.

A SERIES of very interesting tests were carried out on 21-6-31, by the Postmaster-General's Department, over the carrier telegraph systems which have been installed during the last few years in Australia. These tests had for their object the determination of the speed at which telegraph signals are transmitted over carrier telegraph channels.

Three carrier telegraph systems are now in use, *i.e.* :—

(i) Perth to Adelaide—16 uni-directional channels
(ii) Adelaide to Melbourne—12 uni-directional channels, and
(iii) Melbourne to Sydney—12 uni-directional channels.

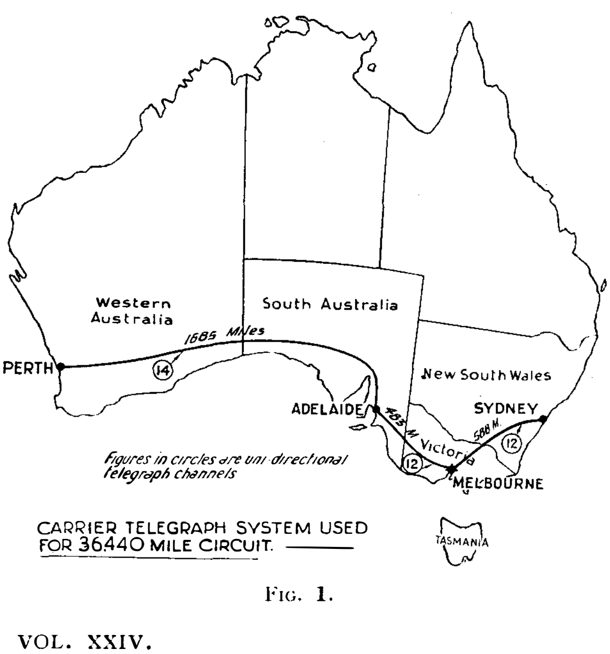


Fig. 1.

All of these channels were linked together for the test, with the exception of two between Perth and Adelaide, which were in use for urgent business. Fig. 1 shows the geographical location of the system, the number of channels used for the test, and the route lengths of each system.

A total of thirty-eight channels were linked together to obtain a telegraph circuit 36,440 miles in length, with both sending and receiving terminals located in the Central Telegraph Office, Melbourne.

The time taken by telegraph signals to traverse the circuit was determined by means of a Westinghouse 3-element oscillograph in the Research Laboratory of the Central Administration of the Department, which is located a short distance away from the Central Telegraph Office. The connections from the sending and receiving apparatus at the Central Telegraph Office to the carrier channels were made through elements of the oscillograph. The arrangement of measuring apparatus, carrier channels, etc., is illustrated in Fig. 2. The third element of the oscillograph was connected to a 100/cycle/sec. timing wave.

The oscillograms obtained from the test gave the

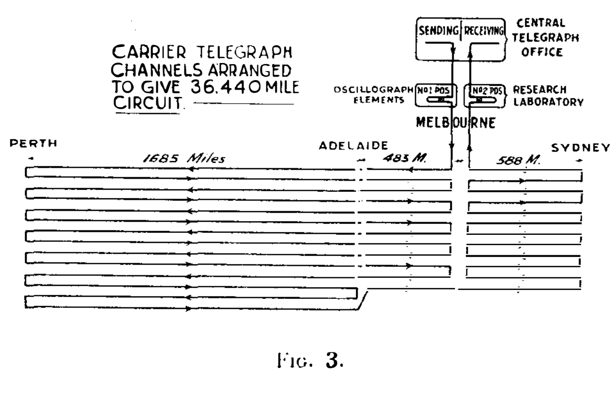


Fig. 3.

time delay, as measured for a number of independent signals, as lying between 0.706 and 0.712 seconds. The average may be taken as 0.71 seconds. This represents the time taken for a signal to traverse the whole 36,440 miles of circuit used, from the time the tongue of the transmitting relay left the spacing contact to the corresponding instant for the receiving relay.

Fig. **3** is a copy of one of the oscillograms obtained from the test. The average time delay of 0.71 seconds, measured from the oscillograms, gives an average speed of transmission over the circuit of

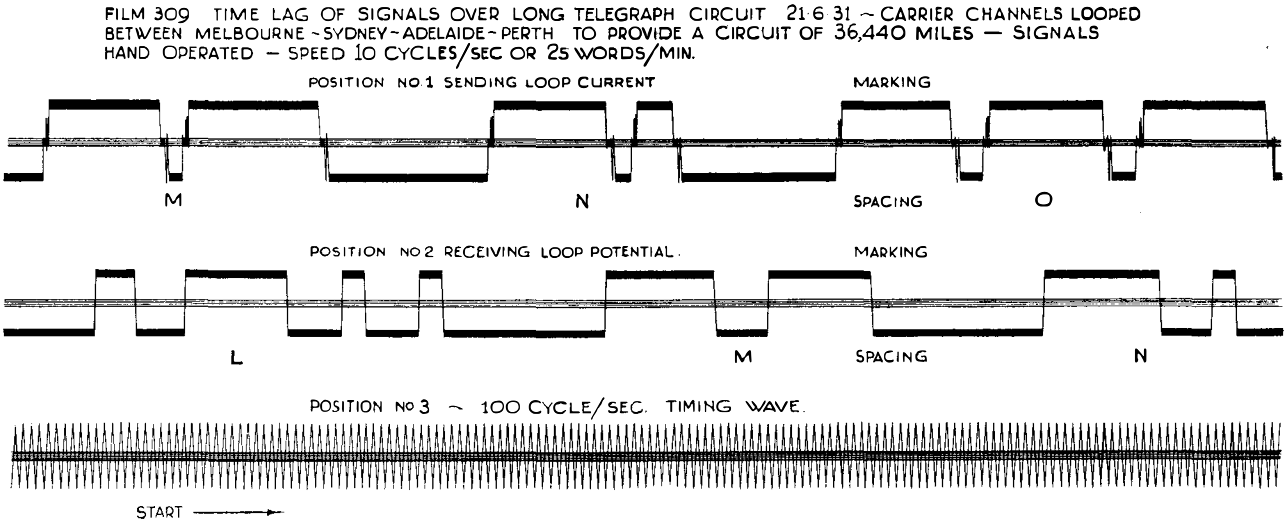


FIG. **2**.

51,300 miles/sec. The delay is due partly to the time taken for the signal to travel over the line, and through the various carrier repeaters, and partly to delay introduced by terminal apparatus associated with each carrier channel. This latter delay is made up principally of—

(i) Lag in sending and receiving relays due to their inductance, and to the travel time of the relay tongues.

(ii) Time taken by the carrier wave to build up to a steady state in the tuned circuits.

As there were, in all, thirty-eight carrier channels linked together with a total of seventy-six sending and receiving relays, and seventy-six sending and receiving tuned circuits, the time delay for apparatus forms an appreciable proportion of the total of 0.71 seconds. Previous measurements had indicated that the delay per channel, due to apparatus, amounted to 0.0082 seconds, giving a total of 0.312 seconds for the thirty-eight channels. The value of 0.0082 seconds was derived from tests on terminal apparatus which gave a delay of 10 to 11 milliseconds at 3,300 cycles/sec. and 5.5 milliseconds at 10,000 cycles/sec. The mean of these two figures, *i.e.*, 8.2 milliseconds, was taken as most nearly representing the actual condition obtaining during the test on the long circuit, as the thirty-eight channels of which it was made up operated at frequencies between 3,300 cycles and 10,000 cycles/sec.

An estimate of 0.358 seconds was also made of the delay due to time of signal travel over the line and through repeaters. This figure was based on a delay of approximately 5.75 milliseconds for the distance from Melbourne to Sydney (588 miles), determined by previous tests.

The estimated delay over the 36,440 mile circuit was, therefore, 0.312 + 0.358 seconds, a total of 0.67 seconds. This estimate of 0.67 seconds compares fairly well with the actual time delay as measured, *i.e.*, 0.71 seconds, especially when allowance is made for the fact that in applying the figure of 5.75 milliseconds to this circuit, a number of general assumptions had to be made.

The tests disclosed that it was possible to transmit messages at up to 30 words per minute either manually or with a Wheatstone transmitter and receiver.

[*A full description of this carrier system, which was manufactured in England by the Standard Telephones and Cables Ltd., will appear in the April issue of this Journal.—Eds. P.O.E.E. Journal.*]

TELEPHONES

WHITEHALL AUTOMATIC EXCHANGE.

THIS Director Exchange was opened on the 3rd October, 1931, and serves, as its name implies, an area which includes not only the Royal Household, but also the Houses of Parliament and the Chief Government Offices of the Empire. The number of working lines transferred from existing Exchanges (Whitehall, Gerrard and Regent Manual) at the date of the opening was 2,288, and this number will be more than doubled in the near future by further transfers.

The equipment consists of :—

7920	Subscribers' Preselectors.
2125	Final Selectors (including Test and Trunk Offering).
1080	First Code Selectors.
4000	Other Selectors.
191	Directors.
50	Coders.
42	Four digit Senders.
1330	Junction Relay Sets.

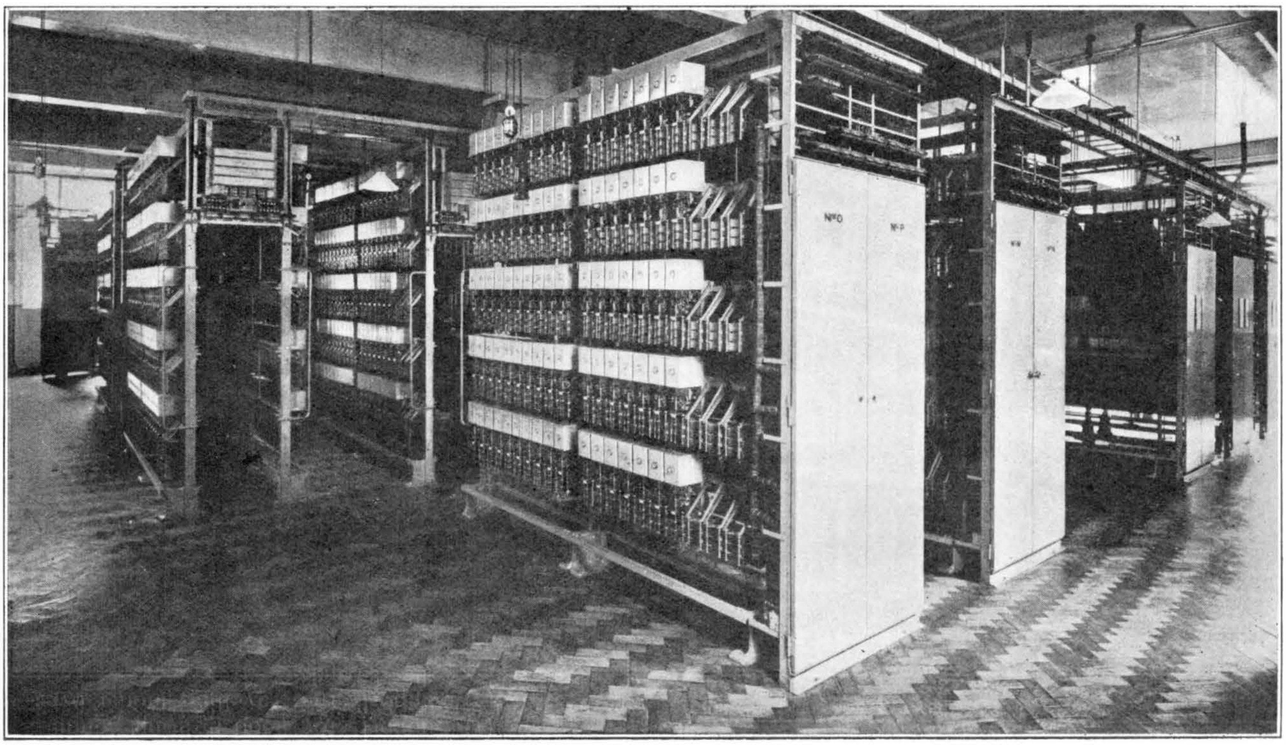


FIG. 1.—WHITEHALL EXCHANGE. NUMERICAL SELECTOR RACKS.

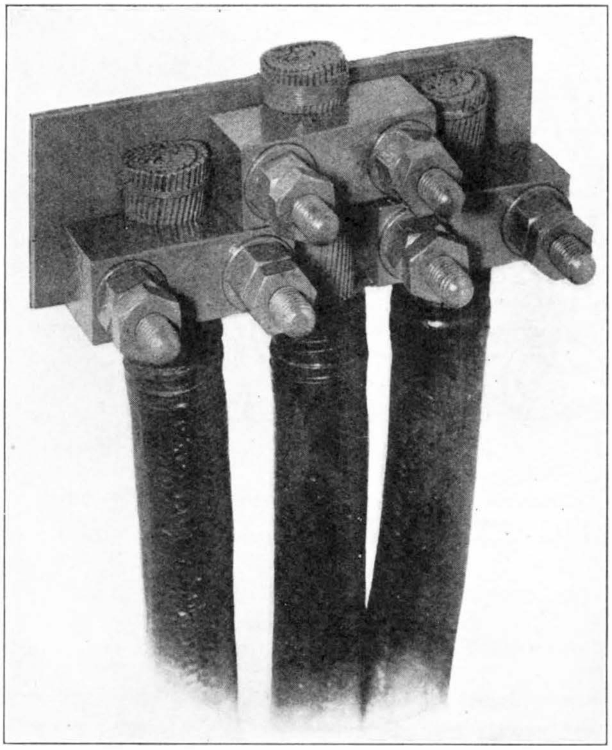


FIG. 2.—POWER CABLE TERMINATIONS.

The special nature of the subscribers in the area is reflected in the details of the Final Selectors, of which there are 559 for Private Branch Exchanges with groups of more than 20 lines, but none of the ordinary or regular type for single subscribers' lines.

All the Code and Numerical Selectors are of the 200 Outlet or 20 Contact per level type and an unusually large proportion of spare banks is fitted to enable additional Selectors to be added rapidly in case of necessity. Fig. 1 depicts a portion of the Numerical Selector Racks.

The equipment was manufactured and installed by Messrs. Siemens Brothers and is of their standard type in accordance with Post Office specification. Numerous deails of such equipment have been given in articles in this Journal describing the nine previous Director Exchanges installed by the same Contractor.

One novel feature of interest is to be found in the method adopted for terminating the cables between the batteries and the power board and the distribution fuse boards. Soldered connections are dispensed with entirely at the cable terminals, the insulation being stripped from the conductors for a length of about six inches and the connections made by clamping the bare copper conductors to the bus bars by bolts and blocks; the extreme ends of the conductors

FIG. 3.—FRONT OF WHITEHALL EXCHANGE.

FIG. 4.—WHITEHALL EXCHANGE. NELL GWYNN'S STAIRCASE.

are bound by tinned copper wire to prevent the splaying of the wires under pressure. The complete connection is painted with red or blue paint. A typical connecting point is illustrated in Fig. **2**.

The building, which occupies two sides of a square known as Craig's Court, is designed to accommodate two 10,000 line Director Exchanges, and the contract for the erection of the second Main Frame has already been placed.

The front of the building, illustrated in Fig. **3**, previously formed part of Harrington House, and this portion, together with the main staircase of the old house, has been scheduled and carefully preserved as a "Historical monument."

Harrington House was probably built shortly before the year 1700 and Mr. Stratton of H.M. Office of Works has given it as his opinion that although Christopher Wren may not have designed it himself some pupil or master mason of his may have done so, and that the stairs also show signs of Wren's influence and were probably the work of one of his joiners.

The house was in the possession of the Earls of Harrington until 1917, when it was purchased by Cox's Bank. It was used by this firm of Army Bankers during the latter part of the war, and was acquired by the Postmaster-General in 1925.

The interesting staircase is illustrated in Fig. **4**, and is often referred to as Nell Gwynn's Staircase. This association is, however, hardly justified by the facts as that lady died in 1687, whilst the most reliable estimate of the date of the building of Harrington House is 1690.

[Figs. **1** and **3** are from photographs supplied by Messrs. Siemens Bros. & Co.]

TELEGRAPH AND TELEPHONE PLANT IN THE UNITED KINGDOM.

TELEPHONES AND WIRE MILEAGES. THE PROPERTY OF AND MAINTAINED BY THE POST OFFICE IN EACH ENGINEERING DISTRICT AS AT 30TH SEPT., 1931.

No. of Telephones owned and maintained by the Post Office.	Overhead Wire Mileages.				Engineering District.	Underground Wire Mileages.			
	Telegraph.	Trunk.	Exchange.	Spare.		Telegraph.	Trunk.	Exchange.	Spare.
723,865	593	3,940	53,199	84	London	25,521	116,089	2,931,185	56,761
98,059	2,225	21,156	72,819	3,208	S. Eastern.	4,000	75,116	334,511	33,861
102,571	4,439	35,299	72,525	3,676	S. Western.	23,620	23,044	234,751	65,979
82,895	6,282	40,920	77,219	6,948	Eastern.	24,784	56,307	184,125	78,950
114,431	8,505	46,166	70,386	4,741	N. Mid.	36,022	82,460	299,593	114,516
102,323	4,783	32,057	85,290	4,574	S. Mid.	15,205	45,501	269,095	93,115
65,200	4,408	30,942	63,872	3,598	S. Wales.	8,011	36,487	156,939	62,514
125,976	7,903	27,582	61,384	4,466	N. Wales.	14,209	44,600	360,518	129,322
176,888	1,331	14,914	46,304	3,723	S. Lancs.	15,544	92,307	574,830	81,533
106,597	6,108	30,845	54,025	3,921	N. Eastern	17,522	62,650	300,021	63,427
72,394	3,772	23,585	43,222	3,207	N. Western.	9,138	40,236	195,003	39,536
55,427	2,402	16,466	29,337	3,227	Northern.	9,951	26,290	165,900	42,109
25,833	4,292	9,824	15,817	748	Ireland N.	141	3,131	60,331	2,686
77,353	4,542	28,923	45,964	1,532	Scotland E.	8,067	22,014	172,352	54,347
99,801	7,247	26,054	48,574	1,245	Scotland W.	12,005	32,333	254,085	32,096
2,029,613	68,832	388,673	839,937	48,898	Total	223,740	758,565	6,493,239	950,743
2,014,539	69,182	387,775	830,367	48,378	Figures as at 30 June, 1931	221,104	731,137	6,346,196	880,182

ACORN EXCHANGE.

PROGRESSIVE INSTALLATION OF THE NEW STANDARD OPEN TYPE RACKS AND SHELVES.

B. Houghton Brown,
Engineering Division, Standard Telephones & Cables, Limited.

THE concluding paragraph of my last article stated that Acorn Exchange was practically completed, and that it was hoped in this issue of the Journal we should be able to report the successful cut-over, and conclude with a few photographs showing this ceremony in progress. The cut-over date, however, has now been settled for January 7th, and will not take place until after the January issue of this Journal has been to print. We will therefore have to content ourselves with a few photographs showing less conventional, though it is hoped none the less interesting views of the equipment.

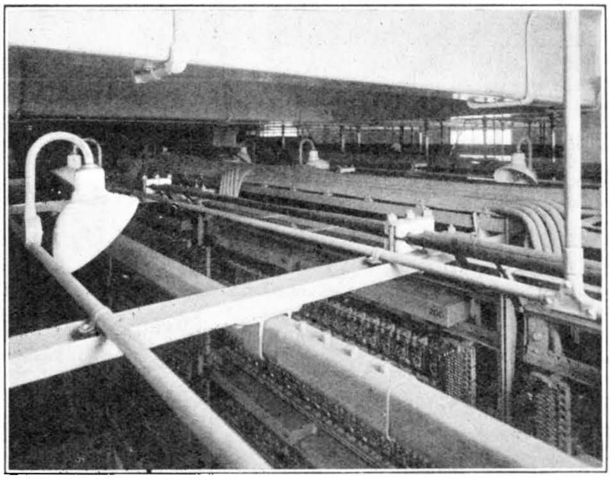


Fig. 21.

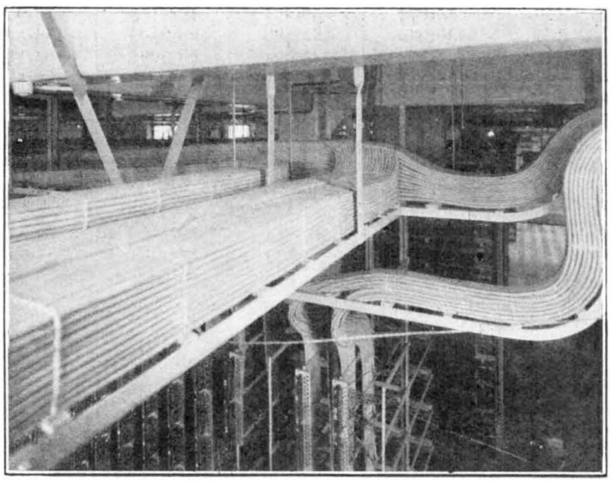


Fig. 22.

Fig. **21** was taken from the top of the cable runways, and is interesting in that it shows :—

(*a*) How the height of the racks has been considered in conjunction with the room height, giving the minimum ceiling clearance necessary for cabling and inspection purposes.

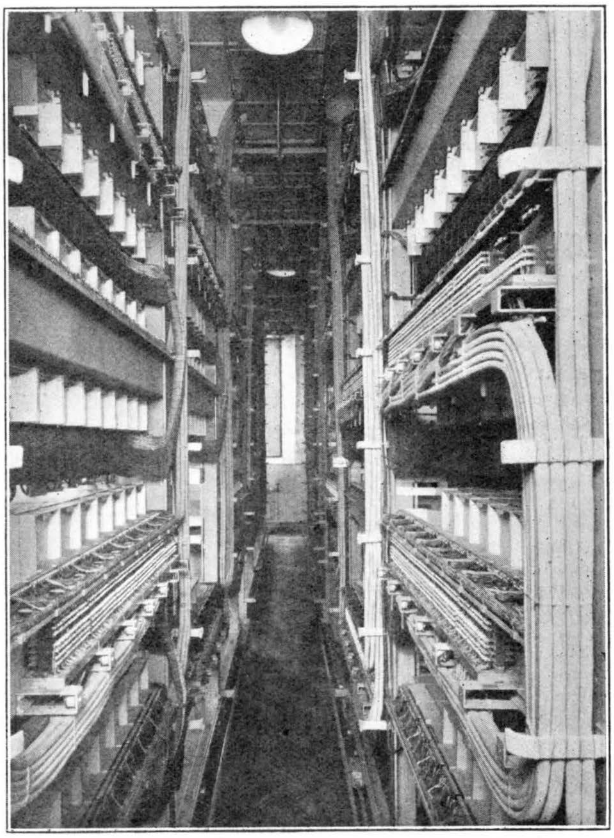


Fig. 23.

(*b*) The self-supporting qualities of the racks, the minimum number of ceiling supports being required.

(*c*) The use to which the intersuite stays are put. From left to right these are :—

(1) Supports the flood lighting conduit.

(2) Supports the travelling ladder overhead track.

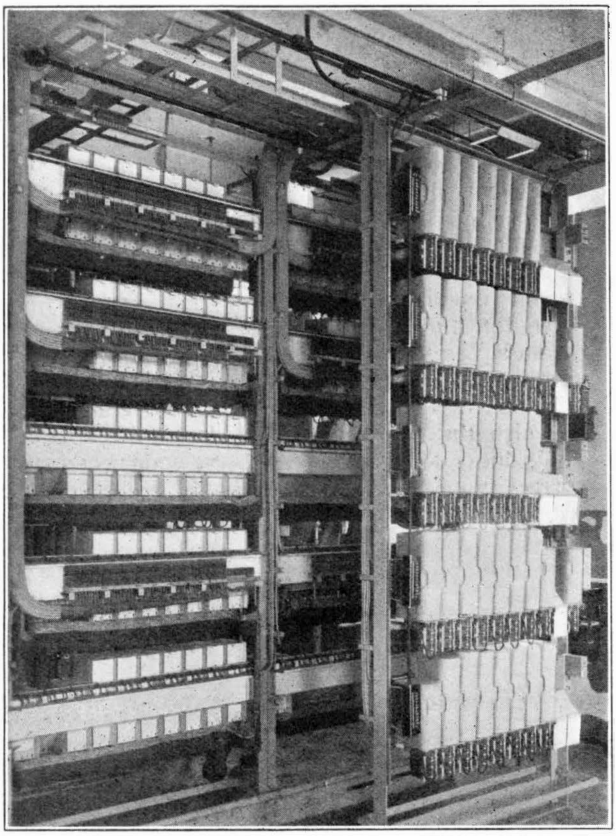


Fig. 24.

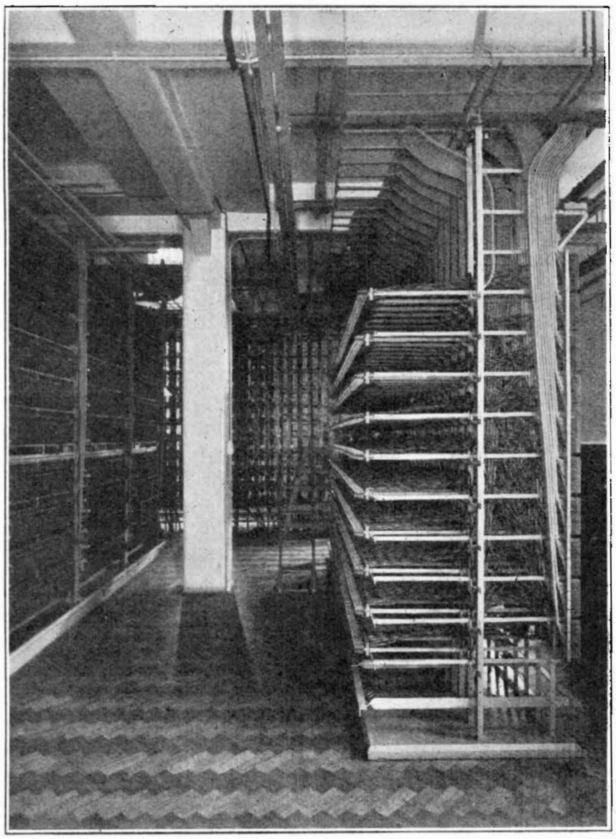


Fig. 25.

(3) Supports the Suite busbars.
(4) Supports the Cable runways.

(*d*) The method of feeding cables from the cable runways to the rack terminal strips.
(*e*) The general scheme of flood lighting.
(*f*) The busbar distribution scheme.

Fig. **22** shows the main cable runways feeding the I.D.F. and gives a good idea of the care and patience which has to be exercised in handling large quantities of cables all feeding from different angles and levels. The standardisation of the height of the racks to 10′ 6″ has done a great deal to simplify the Installer's job from a cabling point of view, but this figure

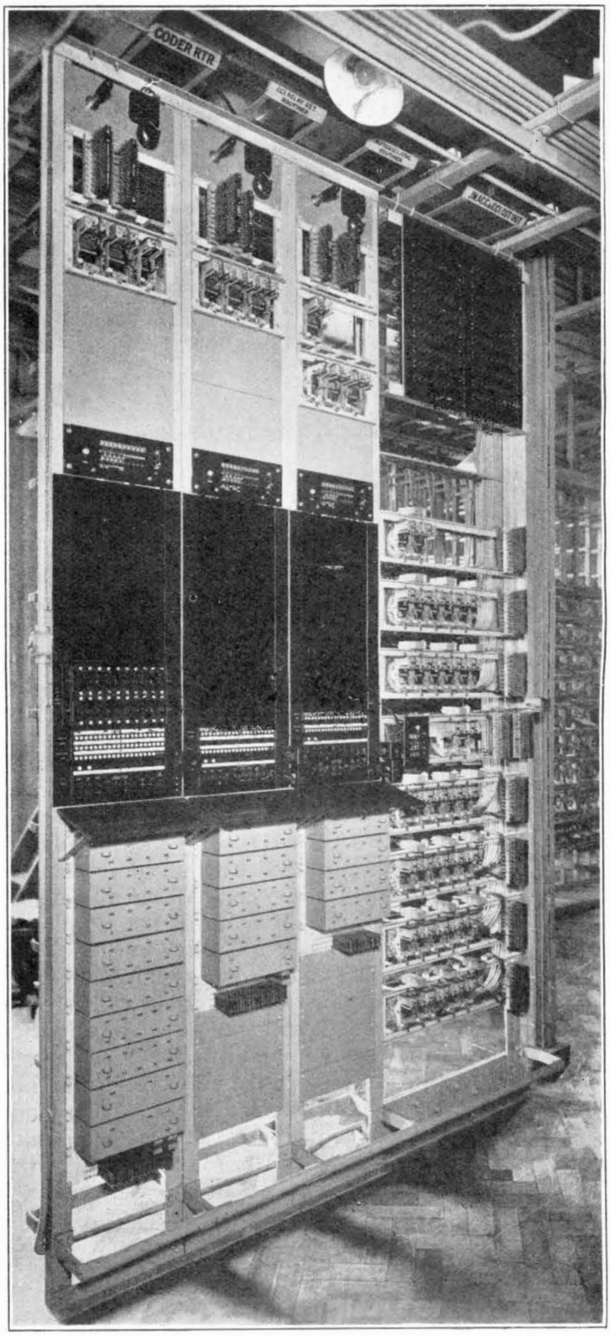


Fig. 26.

impresses on one the enormous importance of arranging the floor plan not only to give the most economical rack lay-out but also to give the best cabling lay-out.

Fig. **23** shows the wiring gangway between two suites of group selectors, and the method of feeding the incoming and tie cables to the shelf terminal strips can be seen and should be compared with that shown in Fig. **24**, which represents the latest method to be adopted, consisting of butting the cables at the end of the shelf and forming out to the terminal strips. In addition to the change in the method of cabling, the shelves for subsequent Exchanges are now fitted with small dust covers protecting the wiring to the selector jacks.

Fig. **25** is included as a matter of general interest, inasmuch as it completes the series of photographs taken at different stages during the erection and cabling of the I.D.F., and shows the frame completely jumpered and ready for service.

Fig. **26** gives an idea of the development that has been made in the art of automatic routine testing and shows the Coder, C.C.I. Relay Set and C.C.I. Junction Routiner, together with the Auto and C.C.I. Access Equipment.

It will be noticed that these racks have not been built up on the open type channel shelf basis, as it is not considered that the circuits are sufficiently standard to warrant their inclusion on the new channel type base.

At the time of writing this article the " call through " tests had been carried out successfully, and the whole equipment was in the hands of the Department's representatives. In these same hands lies also the delicate task of developing the automindedness of 10,000 subscribers, which, next to the correct functioning of the exchange equipment, contributes most to the success of the automatic system.

LINE FINDER DEVELOPMENTS IN THE BRITISH TELEPHONE SYSTEM, USING 2-MOTION SELECTORS.

W. A. Phillips, A.M.I.E.E., and R. Taylor,
Engineering Department, Automatic Telephone Manufacturing Company, Limited.

DURING the last ten years, the technique and application of automatic telephone switching methods have been very greatly extended. Whilst these developments include several important applications, this article deals solely with the recently developed line finder system. It may be said that this system represents an important step in automatic telephone development and is the result of intensive study, research and co-operation between the Department's engineers and those of the manufacturers.

This new line finder system is known as the partial secondary line finder, and differs from previously known finder systems in that fewer first selectors are required than finders. In the rotary switch system each subscriber was provided with an individual uniselector for selecting an idle conversational selector, there being in this system a minimum number of conversational selectors. In the earlier finder system the individual subscriber's uniselector was eliminated and the number of conversational selectors increased, but the nett result gave a saving over the rotary line switch system. With the new partial secondary finder, however, the advantages of both the rotary line switch system and the earlier finder system are retained, with the result that a minimum amount of line equipment is used, combined with a minimum number of conversational selectors. It will be obvious from the following description that this new line finder is equally applicable to both provincial and metropolitan areas.

Briefly, the adoption of the line finder system means that the amount of line equipment provided for each subscriber's line will be very considerably reduced, since the provision of a uniselector per line will be eliminated. Instead, each 200 lines group of subscribers will be served by a common group of from 12 to 30 line finders, of the standard two-motion type, depending upon the amount of traffic originated by each group. Full preselection of the line finders is ensured and two, three or more line finders are arranged to hunt simultaneously in each group, as may be required for the purpose of extending calling lines to the first selectors with a minimum of delay.

Fig. **1** shows the fundamental principle of the line finder system. Certain contacts of the line relays of each 200 lines group are commoned and control the divided starting arrangements. When a call is originated in any group, the operation of the line relay operates one of the start relays, at the same time " marking " the particular private bank contacts of the calling line on the finder multiple. The operation of the start relay immediately causes a preselected finder to hunt vertically and then horizontally until the calling line is found, whereupon the finder extends the calling line through to the 1st selector, and dial tone is then transmitted to the calling party. Simultaneously with the switching through to the selector, the calling subscriber's cut-off relay is actuated, thereby disconnecting the common start circuit. The releasing of the start relay causes the allotter to preselect the next finder in the group in readiness to deal with the next originating call.

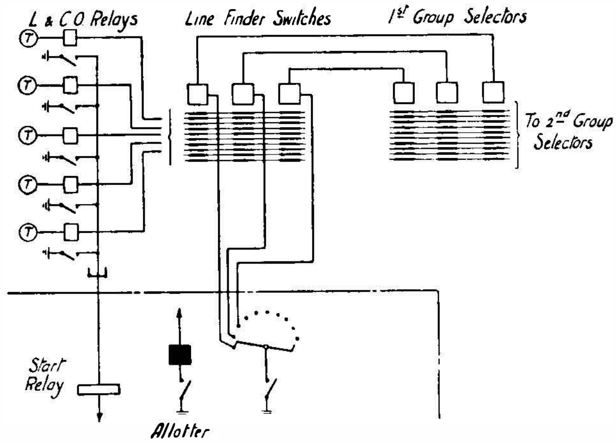


Fig. 1.

The finders are of the 200-point type, as shown in Fig. 2. These finders are of identically the same general construction as group and final selectors, except that they are arranged to hunt both vertically and horizontally. To secure the vertical hunting action a set of vertical interrupter contacts is fitted and arranged to be actuated by the vertical armature. In addition, a small 11-point vertical bank and wiper is fitted to control the vertical hunting action. When seized by a calling subscriber, the line finder hunts vertically to the particular level on which the calling line terminates, the wipers then automatically cut-in on that level and are rotated to the calling line, which is immediately extended to a 1st selector.

The preselection of the line finders is automatically secured by means of allotters and relay sets, two, three or more of which are provided for each group of 200 subscribers' lines. The allotters are of the eight-level, heavy-duty, uniselector type.

In regard therefore to the quantity of subscribers' line equipment, the line finder system secures very considerable economies in comparison with the uniselector system, since, for a group of 200 subscribers, an average of, say, 20 line finders and three uniselectors are required instead of 200 uniselectors. Furthermore, this difference in line equipment is bound to react with beneficial results in regard to maintenance, since generally only one type of mechanism, *i.e.*, the standard two-motion selector, is used.

As is well known, step-by-step line finder equipments are already extensively employed on public exchanges in America, aggregating over three-quarter of a million lines in several hundred exchanges. Attention, however, is drawn to the fact that the Department's new system is fundamentally improved in that the finders per 200 lines are in a common group, the bank multiple is without slip or transposition, chain contact couplings have been eliminated, and allotters determine the order in which the finders shall operate (preventing disruption of service by a faulty finder). Further, the arrangement is self-routining.

An important feature also included in the new system is that of partial secondary trunking, which

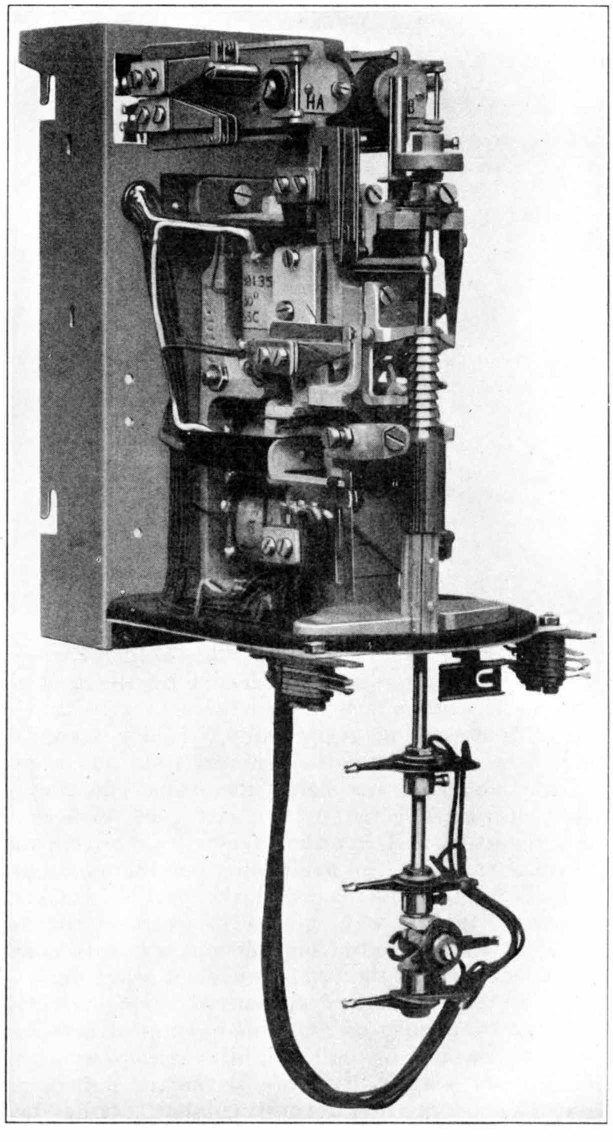


Fig. 2.

secures increased traffic carrying efficiency of the first selectors, with a minimum amount of secondary apparatus. This may be explained as follows :—

The minimum number of 1st selectors occurs when full availability conditions exist and this can only be provided by a system employing full secondary working. Now, as is well known, the traffic carried by selectors selected by earlier choices in a group is very much greater than those selected by later choices and, in a group of say twenty selectors, the actual traffic that may be carried by each selector in successive choices, with a grade of service of 1 in 500, is as given in the following table :—

GROUP OF 20 SELECTORS.

FULL AVAILABILITY.

TRAFFIC OFFERED = 10.07 T.U.

Choice.	*Traffic carried.*
1	0.910 T.U.
2	0.897 T.U.
3	0.876 T.U.
4	0.857 T.U.
5	0.828 T.U.
6	0.796 T.U.
7	0.756 T.U.
8	0.703 T.U.
9	0.652 T.U.
10	0.588 T.U.
11	0.516 T.U.
12	0.441 T.U.
13	0.359 T.U.
14	0.283 T.U.
15	0.210 T.U.
16	0.148 T.U.
17	0.098 T.U.
18	0.063 T.U.
19	0.036 T.U.
20	0.020 T.U.

It may be said that, as the traffic carrying efficiency of the selectors selected by the first ten choices is satisfactory, it is unnecessary to provide access to these from every group. Hence, secondary apparatus for these earlier choices need not be provided. On the other hand, the traffic efficiency of the selectors selected by the last ten choices is unsatisfactory and, in order to increase the occupancy of these switches, full availability conditions are provided for them by means of the partial secondary scheme. In this way, all the selectors in the first rank are maintained at high occupancy, with consequent economy in the total number of selectors.

If a full secondary system were employed, the average occupancy of the whole group of first rank selectors would be only slightly increased, at the expense of very many more secondary finders and their attendant wiring and cabling. It has been found that the most economical results are obtained when approximately half the primary finders are connected direct to 1st selectors and the traffic from the remainder is concentrated by means of secondary finders. The two classes of primary line finders are, for convenience, designated regular and auxiliary finders respectively.

Before considering in detail the circuit—Fig. **3**—and the facilities provided by the new line finder system, brief mention may be made here of the main principles and requirements upon which the circuit arrangements have been designed. These are :—

(1) Minimum delay in extending any calling loop to a selector.
This has been accomplished by divided starting arrangements, permitting two, three or more finders to hunt simultaneously as may be required when subscribers in the same group originate calls at the same time.

(2) Provide for either single fee or multi-fee metering.

(3) Eliminate booster battery from subscriber's private normal wires—this prevents the remote, yet otherwise possible, false operation of final selectors.

(4) Prevent booster battery from causing false operation of finders.
For this purpose, cuprous oxide rectifiers are employed in series with the PA and PB relays.

(5) Ensure maximum occupancy of 1st selectors.
This is accomplished by a system of partial secondary trunking.

(6) Entire elimination of any possibility of dual connections.

Investigations also readily demonstrated that finders of the 200-point type were more economical than those of 25-, 50- and 100-point types. It was also clear that the two-motion selector was particularly suitable, since it provides the speediest means of testing 200 sets of contacts with a minimum of contacts wiped per call.

In regard to the secondary finders, it was established that the general case would be best met by 50-point uniselectors, although on installations of small sizes, 25-point secondary uniselectors would be satisfactory.

Facilities provided.

(1) Connects a calling line to a selector.
(2) Connects normal traffic direct from the line finder to a selector.
(3) Connects peak traffic *via* the line finder and a secondary finder to its associated selector. The secondary arrangements approach full availability conditions and increase the average occupany of the selectors.
(4) Two or more line finders may hunt simultaneously through the instrumentality of divided starting arrangements and a plurality of primary control sets, which are automatically regulated in accordance with the traffic.
(5) Any number of control sets, and consequently any number of finders may be arranged to hunt simultaneously, by changing primary start relay set.
(6) Gives uniform loads to control sets.
(7) Gives an alarm if a control set fails.
(8) Busies faulty equipment and completes the call *via* a partner control set.
(9) Gives a plurality of controls at each stage.
(10) Provides full preselection of finders.

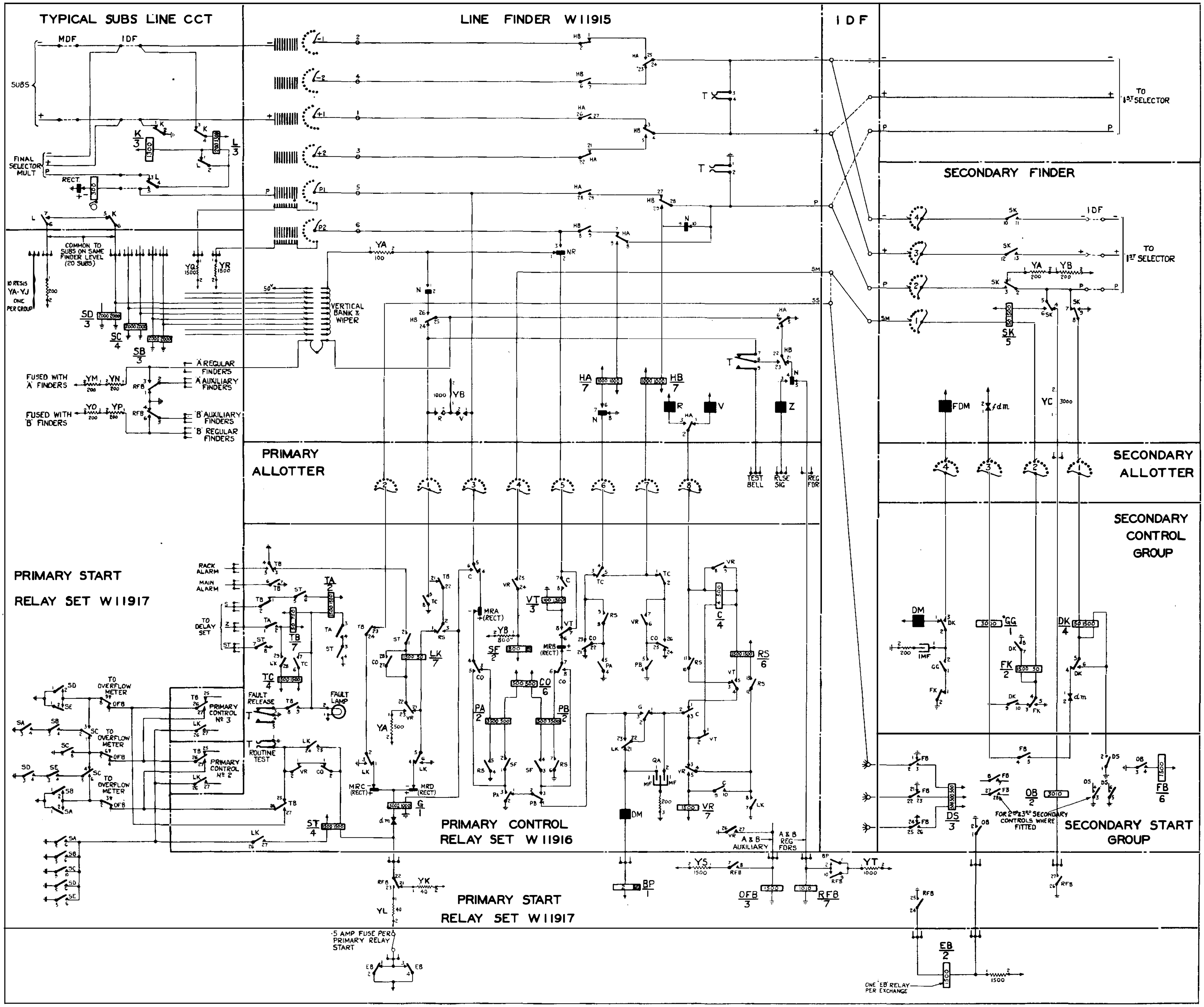


FIG. 3.—LINE FINDER CIRCUIT.

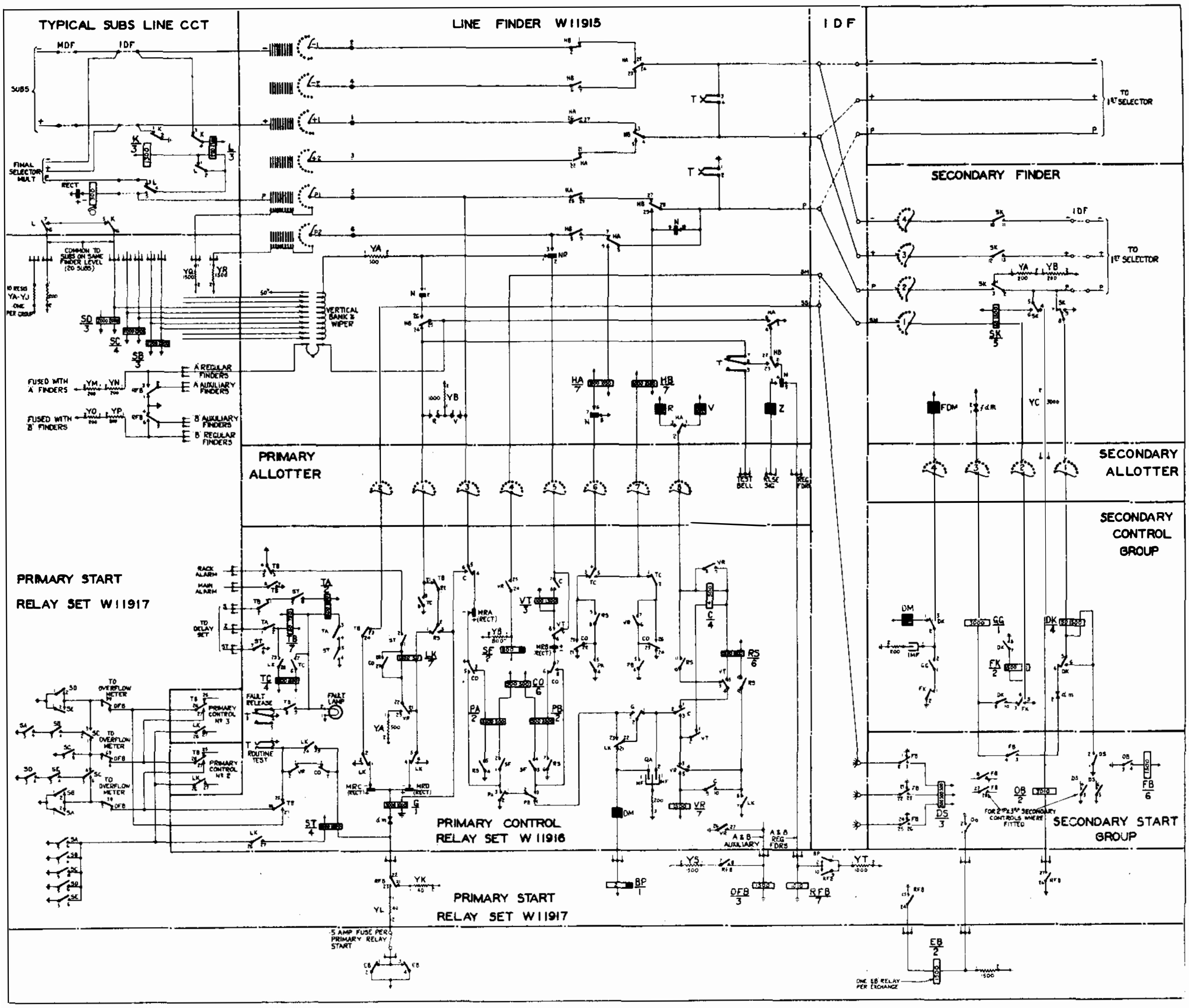


FIG. 3.

(11) Gives overflow metering when all finders in a group are simultaneously engaged.

(12) Prevents continuous rotation of allotters when all finders are simultaneously engaged.

(13 Reduces " stealing " to a minimum by preventing double searching on a particular level of line finders.

(14) Reduces to a minimum the time taken to find the calling line. Average time 0.5 seconds.

(15) Gives full line finder 1st selector I.D.F. facilities, enabling any line finder or secondary finder to be jumpered to any 1st selector for load distribution.

(16) Provides test bell facilities to distinguish readily between " odd " and " even " switching of line finders.

(17) Provides individual release of line finders.

(18) Gives release magnet alarm in the event of line finder failing to restore.

(19) Provides divided fusing of line finders to prevent traffic dislocation.

(20) A subscriber's faulty line or equipment has no influence on the service to other subscribers on the same finder level.

(21) Provides for busying line finder or secondary finder from associated selector or busying of line finder by inserting busy marker in the test jack of selector or line finder.

(22) Provides for automatic self routining of finders.

(23) Provides for manual routining of line finders by insertion of a busy marker in the test jack springs of the primary control set.

(24) Suitable for use with any standard 3-wire

booster metering system.
(25) Provides for single or multi-fee metering.
(26) Gives immediate guard to the private normal wire of calling subscriber's line.
(27) Eliminates booster metering connection to the private normal wire, *i.e.*, prevents a remote, yet otherwise possible, false operation of final selectors.
(28) Eliminates false switching to a subscriber, *i.e.*, if testing an engaged line having booster battery on release trunk, the line finder will not switch through.
(29) Employs battery testing principles throughout.
(30) Does not employ sequence adjustment of relay springs, *i.e.*, " X " and " Y " contacts eliminated.
(31) Provides a standard grade of service with maximum economy.

Circuit Operation.

Subscriber's Line Circuit.—When a subscriber's line is looped to initiate a call, the line relay operates *via* its 1300-ohm winding. At disconnected contacts L3 and 4, the private normal wire is immediately guarded against intrusion, whilst the corresponding private contacts of the finder multiple are " marked " with battery *via* winding of relay K, 200-ohm winding of relay L and operated contacts L4 and 5. Simultaneously the particular level of the vertical bank is marked with battery *via* the 200-ohm resistance, operated contacts L6 and 7 and normal contacts K5 and 6, and the corresponding relay SA, SB, SC, SD or SE is also operated over the same circuit. With the operation of any of these latter five relays, the start relay ST, in the primary control relay set, operates and causes a preselected finder to hunt and extend the calling line to its associated 1st selector. The detailed operation of the finder is explained later.

Immediately the finder extends the line through to the selector, earth is fed back over the private wire to operate the calling subscriber's K relay *via* the private bank of the finder, operated contacts L4 and 5, 200-ohm winding of relay L, etc., relay L also being held operated. At this time dialling tone is transmitted to the calling subscriber, who may then complete the call.

Metering.—As previously mentioned, both single fee and multiple fee metering are provided for on the booster principle. The subscriber's meter is connected from the finder bank private wire direct to earth through a small metal rectifier. For multi-fee metering, the meter is operated one or more times according to the number of separate metering impulses, which are automatically transmitted according to the destination of each call. The method of operation of the meter will be clear from the attached schematic diagram, Fig. **4**.

The subscriber's line and cut-off relays being normal, current is prevented from passing from earth *via* the meter winding, due to the potential of the negative plate of the metal rectifier tending to

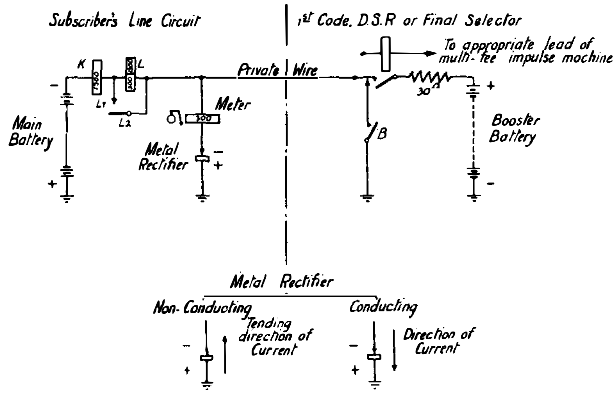


Fig. **4**.

be lower than its positive plate, under which condition the rectifier is non-conducting. When a subscriber's line is switched through to a final selector and the called subscriber replies, one or more booster metering impulses are transmitted for the metering operation, during which the private wire is intermittently raised from earth potential to approximately 50 volts positive. Hence, the negative plate of the rectifier being at higher potential than the positive plate, the subscriber's meter is operated and released a number of times corresponding to the impulses transmitted.

Incoming Calls.—On incoming calls the subscriber's K relay operates in series with the switching relay of the final selector, and this disconnects the line relay, clearing the line for conversation.

Line Finding.—As previously mentioned, each group of 200 subscribers' lines is served by a common group of from 12 to 30 line finders, arranged to be fully pre-selected by means of allotters. Each group of line finders is divided into two sub-groups, regular line finders and auxiliary line finders. Whilst a 1st selector is directly connected to the regular line finders, the auxiliary finders gain access to a 1st selector *via* secondary finders of the uniselector type. Generally the regular and auxiliary finders are pro vided in approximately equal numbers for each group. The reason for this sub-division of the finders is to ensure maximum occupancy of the 1st selectors and consequent economy in selector quantities. The auxiliary finders are only brought into service when all the regular finders are simultaneously engaged, the control being entirely automatic.

The line finding apparatus in each group of finde· switches comprises the following :—

(1) Primary start relay set.
(2) Primary control relay sets and allotters.
(3) Primary line finders (two-motion selectors).
(4) Secondary start group.
(5) Secondary control group and allotters.
(6) Secondary line finders (uniselectors).

Primary Start Relay Set.—Referring to the diagram, it will be seen that various contacts of the line and cut-off relays of the twenty subscribers on each level are commoned together. The L6 and 7 contacts are commoned to battery through a 200-ohm resistance, whilst the K5 and 6 contacts are commoned to one winding of the five double wound start relays, SA, SB, SC, SD and SE. For convenience, relays SA and SE are not shown in the diagram. The K5 and 6 commons are also extended to the corresponding first nine level contacts of the vertical bank, the top level contact being connected direct to battery. Thus when a subscriber's line or a number of subscribers' lines on different levels are looped, one or more of the start relays are operated, and, in addition, the corresponding level or levels are "marked" with battery, through the 200-ohm common resistances.

The operation of one or more of the start relays causes one or more finders to hunt for the calling lines. The diagram provides for the simultaneous hunting of a maximum of three finders, this being an average quantity, although less or more may be provided as required. The hunting of the finders is controlled by primary control relay sets, three such sets being provided for in the diagram. If only one start relay is operated, only one finder hunts. If any two start relays are simultaneously operated, two finders hunt together, whilst if any three relays are operated, three finders hunt. In all there are 24 possible combinations of single, double and triple operations of the start relays and the particular arrangement of the contacts of these relays ensures that, no matter what combination occurs, the required number of finders is brought into operation.

It will be observed that each of the line start relays is controlled by two levels of subscribers' lines, *i.e.*, a total of forty lines. In the event of two or more subscribers in any forty initiating calls at one and the same time, these calls are rapidly put through by separate finders, which are seized in succession by the automatic stepping action of the allotter, as will appear later.

Primary Control Relay Set, Allotter and Primary Line Finder.—It is convenient to consider these together and to bear in mind that, when a call is being initiated, a preselected finder is immediately caused to hunt, first for the calling level which is marked with "battery" on the vertical bank and, secondly, for the particular subscriber's private bank contact which is marked with battery, *via* operated contacts L4 and 5, 200-ohm winding of relay L and winding of relay K to battery.

Assuming that start relay SA in the primary start set is operated, the circuit for relay ST in the primary control set is completed from earth at operated contacts SA 1 and 2, normal contacts OFB 2 and 1, TB 26 and 25, VR 2 and 1, CO 1 and 2, 1500-ohm winding of relay ST, normal contacts RFB 22 and 21, 40-ohm resistance to battery. Relay ST therefore operates and in turn operates relay LK from earth at normal contacts TB 4 and 3, operated contacts ST 2 and 1, 1500-ohm winding relay LK, normal contacts VR 22 and 21, 50-ohm winding relay LK, normal contacts RS 1 and 2, TB 22 and 21, wiper and bank 1, normal contacts HB 24 and 25, vertical wiper and contacts, the two 200-ohm resistances YN and YM to battery.

With the operation of relay LK the vertical magnet circuit is completed as follows:—Battery through vertical magnet V, normal contacts HA, bank and wiper 8 of allotter, 500-ohm and 4-ohm windings of relay C, normal contacts VT 1 and 2, VR 3 and 4 and operated contacts LK 8 and 7 to earth. At this stage the vertical magnet is not fully energised, due to the 500-ohm winding of relay C. The latter relay, however, operates and, at operated contacts C 9 and 10 and LK 8 and 7, operates VR, which locks up *via* operated contacts VR 5 and 4. The operation of relay VR now causes relay HB to operate from battery on one winding, bank and wiper 7 of allotter, normal contacts TC 1 and 2, operated contacts VR 7 and 6 and normal contacts CO 25 and 24 to earth. Relay HB short-circuits the 50-ohm winding of relay LK from earth at operated contacts LK 5 and 6, 50-ohm winding LK, normal contacts RS 1 and 2, TB 22 and 21, wiper 1 and contact of allotter, test jack T, operated contacts HB 23 and 22 and normal contacts HA 4 and 5 to earth. Relay LK is however held operated from battery on 500-ohm resistance YA, operated contacts VR 23 and 22, 1500-ohm winding LK, operated contacts ST 1 and 2 and normal contacts TB 3 and 4 to earth.

Vertical Stepping Action.—The operation of relay VR also short-circuits the 500-ohm winding of relay C and thus causes the vertical magnet to be fully energised in series with the 4-ohm winding of relay C, normal contacts VT 1 and 2, operated contacts C 3 and 2, normal contacts G 1 and 2, operated contacts LK 22 and 23, and normal contacts PB 1 and 2 and PA 1 and 2 to earth.

The wipers of the finder switch are therefore stepped to the first level and, assuming that the calling level is the second, another vertical step is required. Simultaneously with the stepping of the wipers to the first level, the vertical interrupter contacts V close, and a 1000-ohm resistance battery is then fed *via* bank 3 and wiper of allotter, operated contacts 5 and 6 of relay C (which remains steadily operated during the vertical stepping action on account of its 500-ohm winding being short-circuited by operated contacts VR 8 and 9) to the 1000-ohm winding of relay G, which then operates. The operation of relay G opens the vertical magnet circuit at disconnected contacts G 2 and 1, thus releasing the vertical armature and so opening the vertical interrupter contacts, hence also releasing relay G. With the release of relay G, the vertical magnet is again fully energised, causing the wiper to be stepped to the second level, which in this case is the calling level. A circuit for relay VT is then completed from the "marking" battery on the second level of vertical bank, vertical wiper, 100-ohm resistance YA, rotary off-normal contacts NR, bank and wiper 5 of allotter, operated contacts C 7 and 8 and both windings of relay VT in series to earth. By this time relay G will have again operated to disconnect the vertical magnet circuit, following which relay G will also be released.

With the release of relay G, a circuit is now completed for relay RS from battery through the vertical magnet, normal contacts HA 1 and 2, bank and wiper 8 of allotter, operated contacts VR 8 and 9, winding of relay RS, operated contacts VT 5 and 4, normal contacts 1 and 2 of relay C (now restored), normal contacts G 1 and 2, operated contacts LK 22 and 23, normal contacts PB 1 and 2 and PA 1 and 2 to earth. Relay RS therefore operates and locks up on its other winding and operated contacts RS 13 and 12, LK 8 and 7 to earth. The operation of relay RS now causes relay HA to operate from battery on one winding, operated off-normal contacts N 6 and 7, bank and wiper 6 of allotter, normal contacts TC 4 and 3, operated contacts RS 9 and 8 and normal contacts CO 22 and 21 to earth. Relay VT is now caused to be released by a shunting action from earth at operated contacts HA 5 and 6, HB 25 and 26, operated off normal contacts N 2 and 1, whilst at operated contacts HA 3 and 2, the rotary magnet is introduced in place of the vertical magnet.

Rotary Stepping Action.—The rotary magnet is now fully energised from battery through the magnet winding, operated contacts HA 3 and 2, bank and wiper 8 of the allotter, operated contacts RS 11 and 10, normal contacts VT 3 and 4, C 1 and 2, G 1 and 2, operated contacts LK 22 and 23, and normal contacts PB 1 and 2, PA 1 and 2 to earth. The wipers therefore cut-in on to the first set of contacts, whereupon the rotary interrupter contacts, R, make and complete the following circuit to operate relay G:—Battery, 1000-ohm resistance YB, operated R contacts, bank and wiper 1 of allotter, normal contacts TB 21 and 22, operated contacts RS 2 and 3 and 1000-ohm winding of relay G to earth. Relay G operates to disconnect the rotary magnet circuit at operated contacts G 3 and 2, thus in turn releasing relay G. Assuming that the calling line terminates on the fifth set of contacts in the level and that the calling number is an odd one, then the fifth contact of P1 bank will be marked with battery. The interaction of the rotary magnet and relay G therefore continues until the wipers reach the marked contact, whereupon the hunting action is arrested due to the operation in turn of relays PA and CO as follows:—

Battery through winding of calling subscriber's relay K, 200-ohm winding relay L, operated contacts L 4 and 5, P1 bank and wiper of finder switch, bank and wiper 3 of allotter, normal contacts C 5 and 4, metal rectifier (conducting in this direction), normal contacts CO 4 and 3, 3500-ohm winding relay PA and operated contacts RS 5 and 4. Relay PA operates and locks up on its other winding in series with relay CO, *via* operated contacts SF 2 and 1 and PA 3 and 2. Note—Relay SF was caused to operate when relay VR operated, over the following circuit:—Battery, winding of relay SF, operated contacts VR 24 and 25, bank and wiper 4 of allotter, strapping SM and SS at I.D.F. (since the operation of a regular finder is being considered), bank and wiper 2 of allotter, normal contacts TB 23 and 24 and operated contacts LK 2 and 3 to earth. The operation of relay CO disconnects the circuit of relay HB at operated contacts CO 25 and 26. Relay HB therefore releases and the calling subscriber's loop is then extended to the selector from earth and one winding of relay A on the selector, positive line, normal contacts HB 4 and 3, operated contacts HA 27 and 26, positive wiper and bank of finder, calling subscriber's looped line, negative bank and wiper, normal contacts HB 2 and 1, operated contacts HA 25 and 24, negative line, the other winding of relay A of the selector to battery. The A relay of the selector therefore operates and in turn operates relay B, which returns earth over the private wire to hold relay HA *via* operated contacts HA 8 and 9.

With the operation of relay CO, relay LK is also caused to release due to its 1500-ohm winding being short-circuited by operated contacts CO 27 and 28. The release of relay LK also releases relays RS and VR at restored contacts LK 8 and 7, and disconnects the circuit of relay SF at restored contacts LK 1 and 2. Relay SF, being fitted with a copper slug, releases after a brief delay and thus opens the holding circuit of relay CO and PA at restored contact SF 2 and 1. The delay in restoring relay CO and PA is to ensure adequate overlap between the return of earth over the P-wire, to hold relay HA on one winding, before the circuit of the other winding is disconnected at restored contacts CO 21 and 22 and PA 5 and 4.

It will be observed that, as both relays HA and HB are operated during the rotation of the wipers the circuit to the A relay of the selector is maintained opened, thus precluding any interference with other lines when passing over engaged contacts. The function of the metal rectifiers MRA and MRB, which are in series with the relays PA and PB, is to prevent false operation of the finders when passing over the P1 and P2 wires coincident with the application of the booster battery metering impulses. Under this condition the P-wires could be temporarily at positive potential with respect to earth, and the particular connections of the rectifiers renders them non-conducting.

If the calling number had been an even instead of an odd number, as assumed above, relay HA would have been released instead of relay HB and relay PB would have been operated instead of relay PA.

Preselection of next finder: Regular finder available.—The release of relay LK also energises relay G from battery on 40-ohm resistance YK, normal contacts RFB 21 and 22, allotter interrupter contacts LC, 3000-ohm winding relay G, metal rectifier MRD, normal contacts LK 4 and 5, 50-ohm winding relay LK (inoperative under this condition), normal contacts RS 1 and 2, TB 22 and 21, wiper and bank 1 of allotter and, either, normal contacts HB 24 and 25, operated contacts HA 6 and 5 to earth, or normal test jack contacts T, operated HB 23 and 22, normal contacts HA 4 and 5 to earth. Relay G operates and completes the allotter magnet circuit from battery, winding of relay BP, magnet winding, normal contacts LK 21 and 22, operated contacts G 2 and 3 and normal contacts PB 1 and 2, and PA 1 and 2 to earth. The armature of the allotter is therefore attracted and, simultaneously with the engagement of the pawl with the ratchet wheel, the interrupter contacts LC open and thus release relay G, whereupon the wipers of the allotter are stepped to the next set of contacts. This interaction between relay G and the driving magnet continues until the allotter wiper 1 does not encounter full earth, whereupon the allotter stops and thus preselects a free finder associated with that particular contact.

It will be observed that, since in this case it has been assumed that a regular finder is available, the allotter hunts over the sets of contacts on which the auxiliary finders are terminated, because of the earth fed back from the normal RFB contacts in the primary start relay set, vertical bank and wiper, normal contacts HB 25 and 24, bank and wiper 1 of allotter, normal contacts TB 22 and 21 and RS 2 and 1, 50-ohm winding of relay LK, normal contacts LK 5 and 4, rectifier MRD, 3000-ohm winding of relay G, interrupter springs of allotter, normal contacts RFB 22 and 21, 50 ohms resistance to battery.

All regular finders simultaneously engaged.—In this case, the sets of contacts of the allotter associated with regular finders will all be earthed; consequently the allotter will pass over these contacts. Relay RFB, however, will be operated, thus operating relays OB and FB in the secondary start set and so removing the commoned earth at disconnected contacts FB 1 and 2, 21 and 22 and 24 and 25 from the contacts of bank 2 in the primary allotter. The preselection of auxiliary finders is performed by means of a double test by relay G. Thus, if a particular auxiliary finder is engaged, the associated contact on bank 1 of the primary allotter will be earthed, thus operating relay G and causing the allotter to step on. On the other hand, assuming a particular auxiliary finder to be free but that all the corresponding groups of secondary finders are simultaneously engaged, then the busying earth will be put back from the secondary start group to the contacts of bank 2 on the primary allotter. Under this condition relay G again operates and causes the allotter to step on until both a free auxiliary finder and a free secondary finder are preselected. This precludes the possibility of an auxiliary finder being actuated unless a free secondary finder, and consequently a selector are available.

Secondary finder apparatus.—Before dealing with the operation of the secondary finder apparatus, it will be convenient to assume that, in the present case, a total of not more than 25 finders will suffice for each group of 200 subscribers' lines. In this case, only one allotter is provided for each primary control relay set and the regular and auxiliary finders are connected to alternate sets of contacts of the allotter. If the number of finders is less than 25, the spare allotter contacts on bank 1 are earthed, or they may be cross-connected to provide a double appearance on the allotter bank contacts of some, at any rate, of the finders. When traffic considerations require that more auxiliary than regular finders are required, the excess auxiliary finders are connected to the allotter contacts immediately following the alternate sequence of regular and auxiliary.

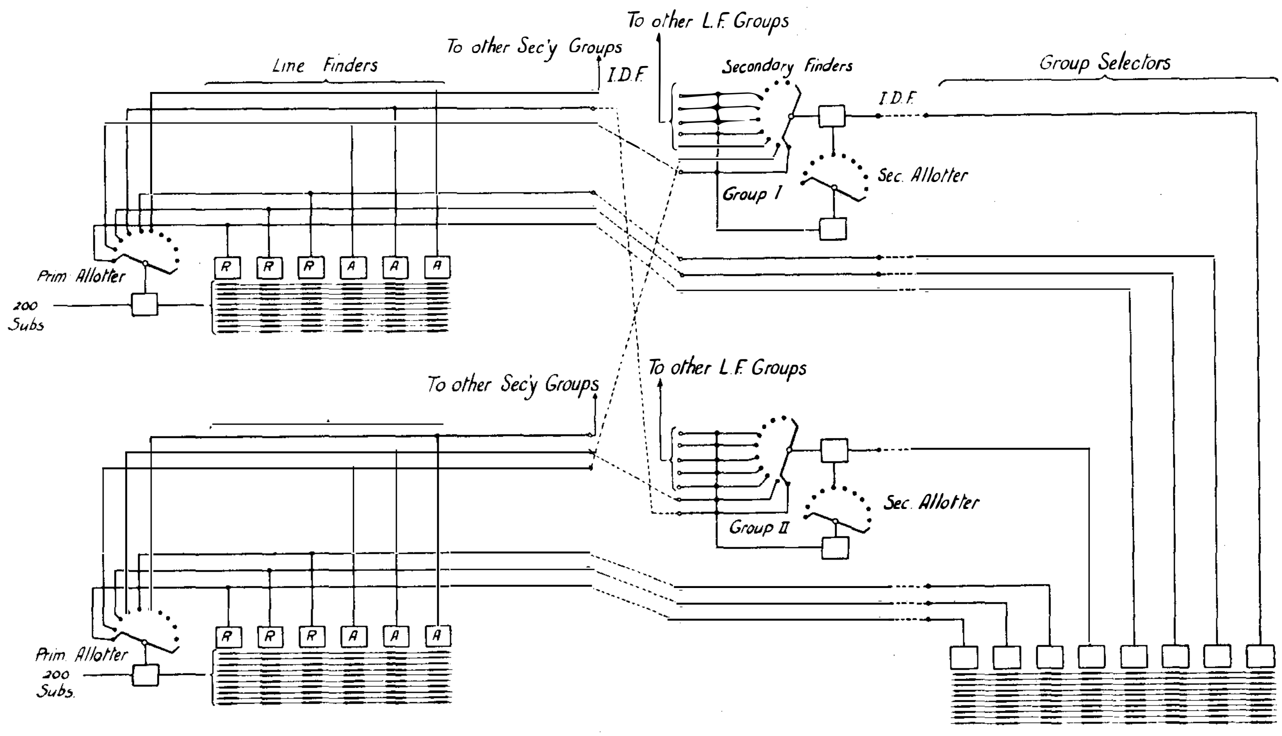
Normally, when the traffic is light, only the regular finders can be preselected, the auxiliary finders being busied from earth at normal contacts RFB 1 and 2 and 4 and 5 in the primary start set. When the traffic is heavy, causing all the regular finders to be simultaneously engaged, relay RFB in the primary start relay set is caused to be operated in the following manner: The last regular finder having switched through, relay BP operates in series with the allotter driving magnet when it commences to hunt to preselect another finder. If the regular finders are all engaged, earth is removed from the commoned off-normal contacts N 4 and 5, which are now disconnected. Consequently, with the operation of relay BP, relay RFB operates and locks up *via* operated contacts RFB 9 and 10.

The operation of relay RFB now operates relay OB as follows :—Earth at operated contacts RFB 26 and 27, winding of relay OB, 3000-ohm resistance YC, normal contacts SK 4 and 5, SK 1 and 2, and the 200-ohm resistances YA and YB to battery. The operation of relay OB in turn operates relay FB, which thus removes, at disconnected contacts FB 1 and 2, 21 and 22, and 24 and 25, the commoned busying earth from the alternate even contacts of bank 2 of the primary allotters. Simultaneously, the battery feed to the auxiliary finders is established at operated contacts RFB 2 and 3, and 5 and 6, in the primary start set. When the primary control seizes an auxiliary finder, relay DS in the secondary start group is operated from battery on one of its windings, operated FB contacts, the particular even contact and wiper of bank 2 of the allotter, normal contacts TB 23 and 24, and operated contacts LK 2 and 3 to earth. The operation of relay DS now causes one, two or three (depending upon the particular arrangement in accordance with traffic requirements) secondary finders to hunt simultaneously to find the particular primary auxiliary finder being used, as follows :—At operated contacts DS 1 and 2, earth is extended through both windings of relay DK in series, wiper and bank 1 of secondary allotter, normal contacts SK 8 and 7, 2 and 1, the 200-ohms resistances YA and YB to battery. Relay DK operates and in turn operates relay GG of secondary control group from battery, interrupter contacts of secondary finder, bank and wiper 3 of secondary allotter, winding of relay GG, operated contacts DK 9 and 10, normal contacts FK 3 and 4, 1500-ohm winding of relay FK and operated contacts DK 7 and 8 to earth. Under this condition, relay FK does not operate on account of the high resistance of relay GG. The operation of relay GG now fully energises the driving magnet of the secondary finder *via* bank and wiper 4 of secondary allotter, operated contacts DK 3 and 2, GG 2 and 1, and normal contacts FK 1 and 2 to earth. When the armature of the secondary finder is attracted, the interrupter contacts are opened to release relay GG, thus disconnecting the driving magnet and causing the wipers to take one step. This interaction between relay GG and the driving magnet continues until the wipers reach the contacts associated with the particular primary auxiliary finder, whereupon relay SK of the secondary finder operates over the following circuit :—Earth at operated contacts DK 8 and 7, both windings of relay FK in series, wiper and bank 2 of secondary allotter, 50-ohm winding of relay SK, wiper and bank 1 of secondary finder, bank and wiper 4 of primary allotter, operated contacts VR 25 and 24, winding of relay SF to battery. When relay FK short-circuits its 1500ω winding relays SK and SF operate and are held operated at operated contacts FK 4 and 5 to earth, until the primary control relay set is released. Whilst relay SK is then held by the earth returned over the P-wire from the selector, relay SF in the primary control set and relay FK in the secondary control set are both released, thus causing the primary allotter to preselect another primary finder and, in general also, causing the secondary finder to preselect another secondary finder in readiness for the next call. The preselecting feature of the primary allotter has already been dealt with, the corresponding action of the secondary allotter being as follows :—

So long as relay RFB remains operated, relays OB and FB will also be operated, provided any secondary finders are disengaged. Therefore, immediately a call is switched through a secondary finder to its selector, relay GG operates from battery, interrupter contacts of the secondary finder, winding of relay GG, operated contacts FB 4 and 5, interrupter contacts of secondary allotter, normal contacts DK 4 and 5, 50-ohm winding of relay DK (inoperative on account of high resistance of relay GG) wiper and bank 1 of secondary allotter and operated contacts SK 8 and 9 to earth. The driving magnet of the secondary allotter is therefore fully energised *via* normal contacts DK 1 and 2, operated contacts GG 2 and 1 and normal contacts FK 1 and 2 to earth. The interaction of the driving magnet and relay GG therefore continues until wiper 1 of the allotter encounters battery *via* the normal contacts SK 8 and 7, SK 2 and 1 and the 200-ohm resistances YA and YB of a free secondary, instead of earth on operated contacts SK 8 and 9 on engaged secondaries, whereupon relay GG fails to operate and thus causes the hunting action to cease.

It is important to observe that each secondary start group provides three access points from the primary allotters and is arranged to control two or three secondary allotters as determined by traffic considerations.

The plurality of secondary allotters causes a corresponding number of secondary finders to hunt simultaneously for the auxiliary line finder or finders marked by the primary allotter or allotters. The



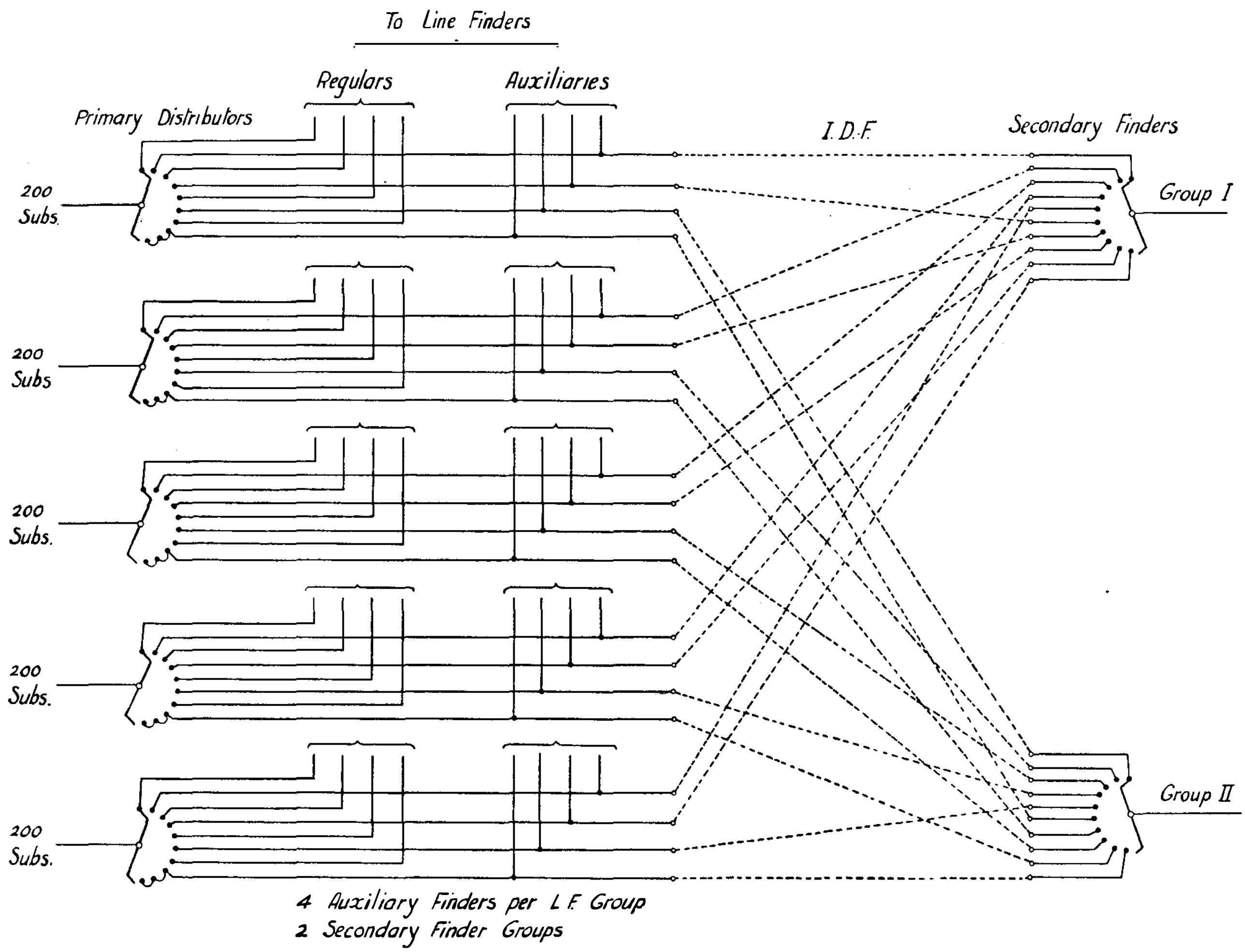
Trunking Arrangements of Partial Secondary Scheme

FIG. 5.

simultaneous hunting of two or three secondary finders reduces the delay in finding to a minimum. The multi-access points enable more than one primary allotter to switch to the same secondary group, thereby taking maximum advantage of the simultaneous hunting action. Any spare contacts of the secondary allotters may be commoned on bank 3 to the last secondary finder in the group, or, alternatively, they may be cross-connected to separate finders, which would then appear on two contacts of the bank.

When the total number of line finders in a group of 200 subscribers' lines exceeds 25, two primary allotters are fitted per control relay set. In this case the regular finders are connected to the first allotter and the auxiliary finders to the second allotter, an additional relay then being provided in the allotter to introduce the auxiliary finders when all the regular finders are simultaneously engaged. However, it will be only in cases of exceptionally heavy traffic that more than a total of 25 finders will be required per group of 200 subscribers' lines.

Maximum Accessibility to 1st Selectors ensured by Partial Secondary Trunking Scheme.—The employment of the partial secondary principle ensures that the regular line finders, selected by the earlier choices and which naturally carry the bulk of the traffic, have direct access to 1st selectors. The auxiliary line finders, selected by the later choices and which carry lower values of traffic, share access to 1st selectors with the auxiliary line finders of other groups. In this manner, maximum occupancy of the 1st selectors is obtained. Fig. **5** shows the general arrangement of the partial secondary trunking scheme, whilst Fig. **6** shows typical cross-connections between the auxiliary line finders and the secondary finder banks. It must be borne in mind that Fig. **6** is typical only, and that on an average exchange of about 3000 lines, there would be approximately 7 auxiliary finders in each of 15 groups and 4 groups of secondary finders. Fig. **6** however serves to show the principle, from which it will be observed that, assuming the extreme case in which not only are all the regular finders



Typical Cross Connections between Line Finders & Secondary Finder Banks - Partial Secondary Trunking Scheme

Fig. 6.

engaged in each group, but also that there is only one 1st selector free on the whole exchange, an auxiliary finder in each LF group will be preselected and the last available secondary finder will be held in readiness to hunt for the particular calling line finder, when the next call is made. Assuming now that this last call is put through and that the whole of the 1st selectors remain engaged, continuous rotation of the allotters is prevented in the following manner.

Prevention of Continuous Rotation of Allotters.

One EB relay is provided per exchange and is normally prevented from operating, when the regular finders in any group are all engaged, by the simultaneous operation of relay RFB in the primary start set and relay OB in the secondary start group. When, however, all the secondary line finders, and therefore all the 1st selectors are simultaneously engaged, all the OB relays in the secondary start groups will be normal, the circuits being opened at disconnected contacts SK 4 and 5. Under this condition relay EB operates and thus disconnects the common battery feed to all the primary allotters on the exchange, *via* operated contacts EB 1 and 2 and EB 3 and 4 in parallel.

The secondary allotters are also prevented from continuous rotation, since the OB and FB relays are all normal, thus disconnecting the circuit for the interrupter relay GG at the normal contacts FB 4 and 5.

Overflow Metering.

An overflow meter may be associated with each primary control relay set, one or other of these being actuated in the event of any call not being able to be put through. These meters are primarily controlled from relay OFB in the primary start relay set. Whilst battery is fed to relay OFB at operated contacts RFB 7 and 8 (when all the regular finders are simultaneously engaged), relay OFB does not operate until the last auxiliary finder in the group is not only off-normal but has actually switched through and the contacts VR 26 and 27 are opened. The whole of the finders in the group remaining engaged, the next call that is originated in the group causes one or other of the three overflow meters to be actuated.

Primary Control Set Alarm Signal.

If for any reason an originating call is not immediately switched through to a 1st selector, due to any abnormal condition arising in the line finding apparatus, both individual rack and main alarm signals are given in the following manner. With the operation of the start relay ST, which normally causes a preselected line finder to hunt for the calling line, the circuit for the delayed alarm set is completed at operated ST 7 and 8 and the " S " pulse then operates relay TA *via* normal contacts TB 2 and 1 and operated contacts ST 5 and 6. Relay TA locks up from battery on the 750-ohm winding of relay TB, 1500-ohm winding of relay TA and operated contacts TA 3 and 4 and ST 3 and 4 to earth, but relay TB remains normal under this condition. The operation of relay TA also prepares a circuit to the " Z " pulse lead *via* operated contacts TA 1 and 2 for the 50-ohm winding of relay TB and also for relay TC, *via* operated contacts 28 and 29 of relay LK (already operated). The " Z " pulse occurs three seconds after the " S " pulse and, if in the meantime the line finder has not switched through to the 1st selector, the " Z " pulse causes the operation of relays " TB " and " TC," both of which lock up *via* operated contacts TB 9 and 8 and normal contacts af fault release jack T. The alarm lamp also lights, whilst the rack and main alarm signals are given *via* operated contacts TB 5 and 4 and 6 and 7 respectively. This particular primary control set remains locked out pending inspection, whilst at operated contacts TB 26 and 27, the next primary control set is switched in for the purpose of routing the call *via* another allotter and finder. With the locking-out of the defective control set, the associated distributor is prevented from stepping on, due to the circuits for both windings of the interrupter relay GG being disconnected at operated contacts TB 23 and 24 and TB 21 and 22. This ensures that the particular line finder employed, which might have been the cause of the call not going through, is also locked-out, being busied *via* bank and wiper 1 of the allotter and operated contacts TC 8 and 9 to earth. Subsequently, after the cause of the trouble has been detected and remedied, the apparatus may be reintroduced into service by momentarily opening the fault release jack T.

Automatic Self-Routining of Finder Switches.

By inserting a busy marker in the routine test jack of the primary control set, the line finders not in use may be routined in rapid succession, the finders being automatically stepped to the tenth level and rotated to the eleventh contact, then automatically releasing. Both the regular and auxiliary finders may be routined but, to routine the auxiliaries, each regular finder must first be busied out by inserting individual busy markers into the regular finder test jacks. As the wipers of each finder reach the 11th contacts, either or both the PA and PB relays are operated to operate relay CO, thereby releasing relays LK, VR, RS, SF, etc., and, since neither relay HA nor relay HB are held operated, the release magnet Z is energised to release the finder.

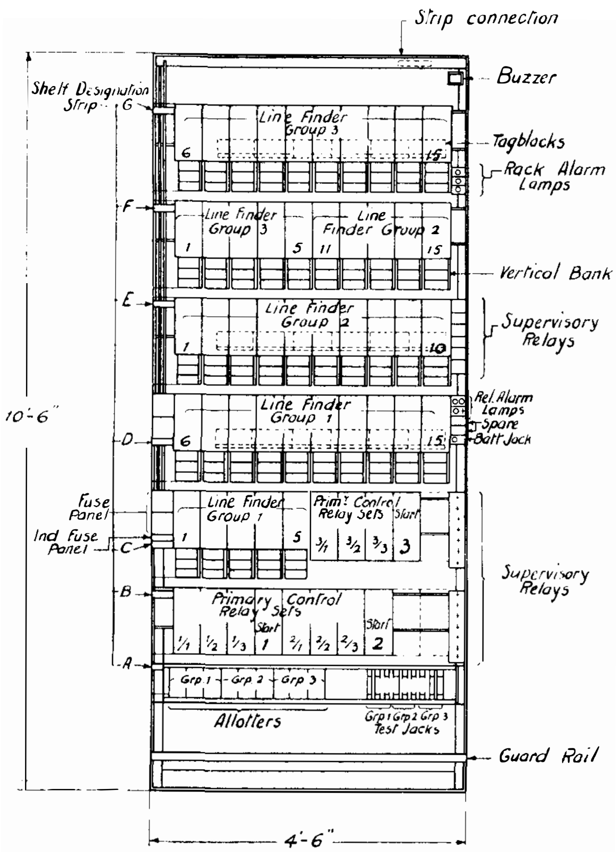
Referring to the diagram it will be observed that, when the auxiliary finders are being routined, the regulars are " busied " on bank 1 of the allotter *via* normal contacts 7 and 6 of test jack T, operated contacts HB 22 and 23 and earth at normal contacts HA 4 and 5, since relay HB is held operated *via* normal contacts N 9 and 10 and the busy marker in the test jack.

The circuit for operating relays PA and PB, upon reaching the 11th contacts, is established *via* the 1500-ohm resistances YQ and YR. The provision of the second resistance ensures immunity from any possible tendency towards delayed cut-off of the rotary action upon reaching the 11th step, which might possibly arise if two finders arrive at the same time.

The routining may, of course, be carried out at any time without interfering with the service, since any finder that is being routined will pick up and switch through to a 1st selector if it encounters a "marked" contact. The allotter would then step on and the routining of the remaining finders would proceed.

Mounting Arrangements.

The new line finder equipment is arranged to be mounted on the standardised single-sided racks, the subscriber's L and CO relays and the line finders being mounted on separate racks. The L and CO relays are strip-mounted and are cabled direct to the I.D.F. The primary line finders, together with their complement of controlling relays and allotters, are mounted on the same rack, a typical arrangement being shown in Fig. **7**. As will be seen, this rack comprises three groups of finders. Fifteen finders, one primary start relay set, three primary control relay sets and three allotters are shown provided for each group. The battery feeding bus-bars and fuse panels are accommodated on the left hand side, whilst the supervisory relays and alarm lamps are fitted on the right hand side.



Line Finder Rack

Fig. **7**.

The secondary finders, together with their controlling relay sets and allotters, are mounted together in the form of self-contained shelves. Whilst on the smaller exchanges these shelves of secondary apparatus may be accommodated in any available space on the primary finder racks, on the larger exchanges they are mounted on separate racks.

Economies effected.

The graphs given in Figs. **8** and **9** show the economies effected by the new line finder system in comparison with the homing rotary line-switch system. Fig. **8** includes the cost of the subscriber's

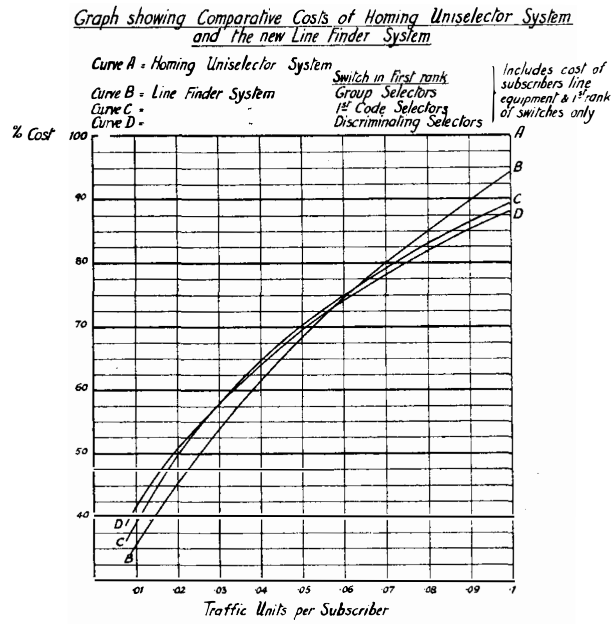


Fig. **8**.

line equipment and first rank of selectors only, whilst Fig. **9** includes the whole of the automatic apparatus, *i.e.,* subscriber's line apparatus and all ranks of selectors, including the final selectors. The graphs indicate the effect of traffic intensity upon the relative cost, and since a traffic value of 0.035 T.U. per subscriber's line may be regarded as an average value, the average economy is substantial. It is only on very few occasions that an average traffic value of over 0.1 T.U. per subscriber's line is encountered in practice.

The effect on economy of the cost of the 1st selectors is also brought out by the curves B, C and D. The cost of various types of 1st selector are in the following order, beginning with the least costly: —10/10 group selector, 10/20 group selector, 1st code selector, discriminating selector repeater.

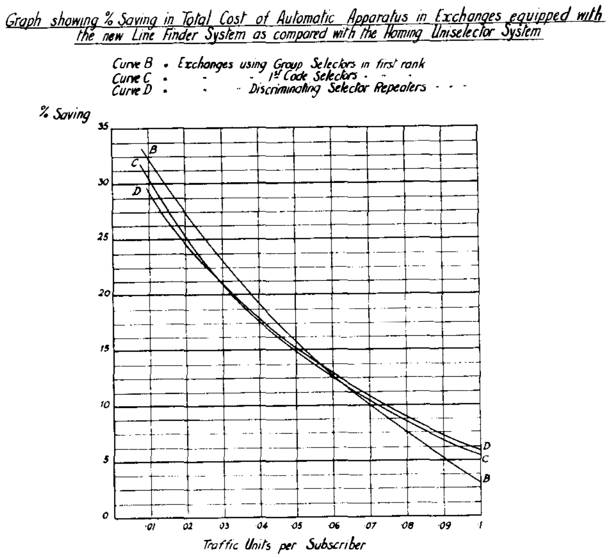


FIG. 9.

As may be supposed, the economy in first cost of the automatic apparatus also tends to economy in mounting space and hence reduces the size of exchange building that is required. Actually, a saving of approximately 30% in floor space will be effected in an average exchange equipped with line finder apparatus, as compared with the uniselector system. This figure is on the basis of both types of apparatus mounted on the standardised single-sided racks.

As previously mentioned, a saving in maintenance costs will also result, since practically all the switching apparatus will be one type, namely, the standard two-motion selector, instead of two, as in the case of the uniselector system. This will be obvious from Table I., which gives the quantities of uniselectors and two-motion selectors required for an average exchange equipped with the different systems :—

TABLE I.

3,000 LINES EXCHANGE. CALLING RATE 0.035 T.U. PER SUBSCRIBER.

	Uniselector system.	New Line Finder System.
Preselector—single-motion.	3,000	Nil
Line Finders—two-motion.	Nil	255
Primary Allotters—single-motion.	Nil	45
Secondary Line Finders—single-motion.	Nil	42
Secondary Allotters — single-motion.	Nil	9
1st. Group selectors.	163	162
Summary.		
Single-motion selectors.	3,000	96
Two-motion selectors.	163	417

These figures are also interesting in that they bring out the rather striking fact that the new finder system enables 513 selectors to give the equivalent service provided by 3163 selectors on the uniselector system.

Table II. shows how the saving in number of 1st selectors varies with the calling rate and size of exchange, this saving being of considerable magnitude at the higher calling rates. It may be remarked that these economies in first rank selectors are due to the partial secondary trunking scheme incorporated in the new finder system.

TABLE II.

TU/Sub.	L.F. (200 Pt.)	New Line Fdr. System.		Uniselector System.	
		Sec. Fdrs. (50 Pt.)	1st Sel.	Unisels. (25 Pt.)	1st Sel.
1,000 *Lines.*					
.02	60	10	40	1000	35
.04	90	24	64	1000	65
.06	120	32	92	1000	95
.08	145	38	113	1000	125
.10	175	52	137	1000	156
5,000 *Lines.*					
.02	300	30	180	5000	160
.04	450	80	280	5000	315
.06	600	108	408	5000	472
.08	725	140	515	5000	625
.10	875	207	632	5000	780
10,000 *Lines.*					
.02	600	54	354	10000	315
.04	900	150	550	10000	625
.06	1200	204	804	10000	944
.08	1450	266	1016	10000	1250
.10	1750	396	1246	10000	1560

Conclusion.

It will thus be clear that the line finder system is an important advance in the securing of substantial economies in first cost and upkeep of future automatic exchanges, and also in the giving of enhanced flexibility and improved service. It is of interest to observe that this advance has been secured solely by improvements in the trunking arrangements in conjunction with the adaptation of advanced circuit principles, without resorting to any new form of switching mechanism and that, whilst the new system requires additional two-motion selectors, this increase is much more than off-set by the saving effected due to the elimination of a uniselector from each subscriber's line.

It will be apparent that the present advance has been mainly brought about by the constant efforts that have been made towards standardisation and simplification of automatic telephone apparatus. In the past, the Department's earlier automatic apparatus was successfully adapted in successive stages to meet ever-widening demands, culminating in the huge expansion for Director working on a very large scale. So now, at the present time, the two-motion selector has again been readily adapted to meet new demands, and that with very satisfactory results.

FURTHER PROBLEMS IN AUTOMATIC TRUNKING—SOME INTERESTING SOLUTIONS BY MEANS OF THE CALCULUS.

N. A. Hawkins, A.M.I.E.E.

Outline of Contents.

(*a*) *Introduction.*

PERSONS engaged in any branch of engineering were, in their student days, introduced to the mysteries of the Infinitesimal Calculus and to its application to electrical and civil engineering. The readers of this Journal will also be familiar with its application to telephone transmission theory, but very few are aware of the uses of the calculus in problems connected with automatic trunking. This is no doubt due to a dearth of well-known literature on the subject.

A number of people now engaged on trunking work have, at various times, asked the author how the values of traffic capacity, used in Post Office design, for cases of full availability have been determined. Since the calculus is applied under certain circumstances it is proposed to indicate briefly the steps taken in determining traffic quantities before its use.

When evaluating Erlang's expression, it has been found simplest to choose a constant value of traffic and by the development of the successive terms in the expression $1 + A + \frac{A^2}{2!} + \ldots\ldots\ldots\ldots \frac{A^x}{x!}$ to determine the grade of service for various numbers of switches, from the theory

$$\text{Grade of Service} = \frac{\frac{A^x}{x!}}{1 + A + \frac{A^2}{2!} + \ldots\ldots\ldots\ldots \frac{A^x}{x!}}$$

A and x being the traffic and number of selectors respectively. It will be appreciated that it is not possible to find directly by this means the traffic capacity of a given number of selectors for a given grade of service. For automatic exchange design it is most important that the traffic capacity of a group of selectors for a given grade of service be known. In order, therefore, to determine this from figures obtained when using the above method, Taylor's Theorem is applied; some mention of this theorem will be made under item (*c*) of this article.

(*b*) *Use of Grinsted's Approximation.*

In Part 4, Volume 23 of this Journal, it was stated that Grinsted's approximation to Erlang's theory was most nearly true for good grades of service. The evaluation of the Erlang expression becomes very tedious when the values of total traffic and number of selectors become large and, since for all practical purposes we do not require values resulting in a grade of service worse than approximately 1 in 100, a large amount of the work involved would be unnecessary. Grinsted's approximation is therefore used and is applied by considering a number of selectors sufficiently great, for the given value of traffic, to assume that the value of the grade of service obtained is equal, to a high degree of accuracy, to that which would be obtained when evaluating the Erlang expression. A little practice shows what relation is necessary between the number of selectors and total traffic when the above holds and it is now proposed to indicate how Grinsted's approximation is applied, by considering a total traffic of 30 traffic units.

It will be remembered that the theory of W. H. Grinsted is Grade of Service $= \dfrac{\frac{A^x}{x!}}{e^A}$ A, x and e being total traffic, number of selectors and the base of Naperian logarithms respectively.

Now if $A = 30 \log e^A = 30 \times 0.4342945 = 13.0288350 = \log 10686.48 \times 10^9$

Assuming that this theory is sufficiently accurate when $x = 50$ we have,

$$\frac{A^x}{x!} = \frac{30^{50}}{50!} \text{ and } \log \frac{A^x}{x!} = 50 \times 1.4771213 - 64.48307 49 = \log 2.360424 \times 10^9$$

From Grinsted's approximation therefore,

$$\text{Grade of Service} = \frac{2.36 \times 10^9}{10686.5 \times 10^9} = 0.000022088$$

To get a closer approximation we can determine the value of $\dfrac{A^{x+1}}{(x+1)!}$ and therefore from $1 + A + \dfrac{A^2}{2!} + \ldots\ldots\ldots \dfrac{A^x}{x!} = e^A - \left[\dfrac{A^{x+1}}{(x+1)!} + \ldots\ldots\ldots a\right]$ obtain more closely the value of the denominator in the Erlang expression.

$$\text{Now } \frac{A^{x+1}}{(x+1)!} = \frac{A^x}{x!} \times \frac{A}{x+1}$$

$$= \frac{2.36 \times 10^9 \times 30}{51} = 1.39 \times 10^9.$$

Therefore $\dfrac{A^{x+1}}{(x+1)!} + \ldots\ldots\ldots\ldots a = 2 \times 10^9$ approximately.

$$\text{Hence } \sum_{x=0}^{x} \frac{A^x}{x!} = 10^9(10686 - 2) = 10684 \times 10^9$$

$$\text{and Grade of Service} = \frac{2.3604 \times 10^9}{10684 \times 10^9} = 0.000022093$$

This now gives a starting point to the evaluation, for by subtracting $\dfrac{A^x}{x!}$ from $\displaystyle\sum_{x=0}^{x} \frac{A^x}{x!}$ we get $\displaystyle\sum_{x=0}^{x=x-1} \frac{A^x}{x!}$, the denominator in the expression $\dfrac{\frac{A^{x-1}}{(x-1)!}}{1 + A + \frac{A^2}{2!} \ldots\ldots\ldots\ldots \frac{A^{x-1}}{(x-1)}}$, the numerator of which is obtained from $\dfrac{A^{x-1}}{(x-1)!} = \dfrac{A}{x!} \cdot \dfrac{x}{A}$

Hence by successive reduction we can determine values enabling the grade of service for any number of selectors with the given value of traffic offered to be obtained.

By carrying out a number of evaluations of this kind for different amounts of total traffic, a series of values is obtained for the grade of service with different numbers of selectors. If we were to consider any definite grade of service, such as 1 in 500 $= 0.002$, it would be found that, except in very few cases, no direct information would be available as to the number of selectors required to give this grade of service with the given amounts of total traffic. For example, with a total traffic of 30 T.U., 45 selectors will give a grade of service of 0.00232 and with a total traffic of 60 T.U., 80 selectors will give a grade of service of 0.002199. We could find, however, by trial and error what values of total traffic offered to the groups of 45 and 80 selectors respectively which will cause a grade of service of 0.002, but this is a very lengthy process and also unnecessary as shown in the next few paragraphs.

(c) *Use of Taylor's Theorem.*

Since it is desired to find what alteration is necessary in the value of total traffic A, when the value B obtained from the expression $B = \dfrac{\frac{A^x}{x!}}{\sum_{x=0}^{x} \frac{A^x}{x!}}$ is adjusted to meet the required condition for the given number of selectors x, we can say that for the present purpose x is constant and therefore that A is dependent on B or rather B is a function of A. Expressed symbolically $B = f(A)$.

Now Taylor's Theorem can be applied to any case where having given the value of a function for a particular value of the variable, it is required to find the value of the same function for a slightly different value of the variable.

In this case therefore we have,

$$B = f(A) \text{ and } B + \delta B = f(A + \delta A)$$

where δB is the increase in the value of B for an increase of δA in the value of A.

Applying Taylor's theorem this can be expressed as,

$$B + \delta B = f(A) + \delta A\, f'(A) + \frac{(\delta A)^2}{2!} f''(A) + \ldots (1)$$

where $f'(A)$ is the first differential coefficient of $f(A)$ with respect to A and $f''(A)$ is the second differential coefficient of $f(A)$ with respect to A.

If the value of δA is small the value of the third and subsequent terms will be negligible and can therefore be omitted.

Hence $B+\delta B=f(A)+\delta A\, f'(A)$

or $\delta B=\delta A\, f'(A)$ ....(2)

It will be shown later that the value of $f'(A)$ can easily be determined for any given case. It therefore follows that if either B or A is changed slightly the new value of A or B can be obtained. The above approximation (formula (2)) only applies where δA or δB are small and should greater accuracy be required it is necessary to evaluate the third term in expression (1).

(*d*) *Determination of $f'(A)$ and $f''(A)$.*

Considering, firstly, Erlang's theory which has been adopted as standard for Post Office design in all cases of full availability where standard grade of service conditions apply. This theory may be expressed in the form,

$$B=\frac{\dfrac{A^x}{x!}}{1+A+\dfrac{A^2}{2!}+\dots\dots\dfrac{A^x}{x!}}$$

where B is the proportion of lost calls or grade of service,

A is the total traffic offered,

x is the number of selectors in the group.

$$\text{Then}\quad f(A)=B=\frac{\dfrac{A^x}{x!}}{1+A+\dfrac{A^2}{2!}+\dots\dots\dfrac{A^x}{x!}}$$

$$\text{and } f'(A)=\frac{df(A)}{dA}=$$

$$\frac{\left[1+A+\dfrac{A^2}{2!}+\dots\dots\dfrac{A^x}{x!}\right]\dfrac{xA^{x-1}}{x!}-\dfrac{A^x}{x!}\left[1+A+\dfrac{A^2}{2!}+\dots\dots\dfrac{A^{x-1}}{(x-1)!}\right]}{\left[1+A+\dfrac{A^2}{2!}+\dots\dots\dfrac{A^x}{x!}\right]^2}$$

$$f'(A)=\frac{x\cdot\dfrac{A^{x-1}}{x!}}{1+A+\dfrac{A^2}{2!}+\dots\dots\dfrac{A^x}{x!}}-\frac{\dfrac{A^x}{x!}}{1+A+\dfrac{A^2}{2!}+\dots\dots\dfrac{A^x}{x!}}+\frac{\left(\dfrac{A^x}{x!}\right)^2}{\left(1+A+\dfrac{A^2}{2!}+\dots\dots\dfrac{A^x}{x!}\right)^2}$$

$$f'(A)=\frac{x}{A}\left[\frac{\dfrac{A^x}{x!}}{1+A+\dfrac{A^2}{2!}+\dots\dots\dfrac{A^x}{x!}}\right]^2-B+B^2$$

$$f'(A)=B\left|\frac{x}{A}-1+B\right|\text{..........................(3)}$$

It therefore follows that

$$f''(A)=\frac{d\,f'(A)}{dA}=B\left[-\frac{x}{A^2}+\frac{dB}{dA}\right]+\left[\frac{x}{A}-1+B\right]\frac{dB}{dA}$$

$$f''(A)=B\left[-\frac{x}{A^2}+B\left(\frac{x}{A}-1+B\right)\right]+B\left|\frac{x}{A}-1+B\right|$$

$$f''(A)=B\left[-\frac{x}{A^2}+\frac{Bx}{A}-B+B^2+\frac{x^2}{A^2}-\frac{2x}{A}+1+\frac{2Bx}{A}-2B+B^2\right]$$

$$f''(A)=B\left|2B^2+\frac{x}{A}(3B-2)-3B-\frac{x}{A^2}+\frac{x^2}{A^2}+1\right|\text{..................(4)}$$

It is also interesting to note the form of the first and second differential coefficients with respect to A of Grinsted's approximation. This, it will be remembered, can be used as sufficiently approximate to Erlang's theory when the grade of service is good and is expressed as,

$$B=\frac{\dfrac{A^x}{x!}}{e^A}$$

where B, x and A have their usual significance and e is the base of Naperian logarithms.

$$\text{Then}\quad B=f(A)=\frac{\dfrac{A^x}{x!}}{e^A}=\frac{A^x}{x!}e^{-A}$$

$$\text{and } f'(A)=\frac{df(A)}{dA}=\frac{x!\left[e^{-A}\times A^{x-1}+(-1)e^{-A}A^x\right]}{(x!)^2}$$

$$f'(A)=\frac{e-A^x}{x!}\left[\frac{x}{A}-1\right]$$

$$f'(A)=B\left|\frac{x}{A}-1\right|\text{................................(5)}$$

Similarly,

$$f''(A)=\frac{df'(A)}{dA}=B\left[\frac{-x}{A^2}\right]+\left[\frac{x}{A}-1\right]\frac{dB}{dA}$$

$$f''(A)=\frac{-Bx}{A^2}+B\left|\frac{x}{A}-1\right|^2$$

$$f''(A)=B\left|\left(\frac{x}{A}-1\right)^2-\frac{x}{A^2}\right|\text{.................(6)}$$

Returning to expression (2) it is seen that in the case of Erlang's theory

$\delta B=\delta A\, f'(A)$

and substituting the value of f' (A) from expression (3)

$$\delta B = \delta A . B \left[\frac{x}{A} - 1 + B \right] \qquad (7)$$

Further, when the grade of service is good, expression (5) is sufficiently accurate and then

$$\delta B = \delta A \; B \left[\frac{x}{A} - 1 \right] \qquad (8)$$

(*e*) *Practical Applications.*

In the first place considering the variation in the value of total traffic for a known variation in grade of service,

Example 1. It is found that when $A = 30$ and $x = 45$, $B = 0.00232$ and if it is required to know the value of A when $B = 0.002$ we have from

$$\delta B = \delta A . B \left[\frac{x}{A} - 1 + B \right]$$

$$\delta B = 0.002 - 0.00232 = -0.00032$$

and therefore

$$-0.00032 - \delta A \cdot 0.00232 \quad \frac{45}{30} - 1 + .00232$$

$$\text{and} \quad \delta A = \frac{-0.00032}{0.00232\,(0.50232)} = -.2746$$

To see what error is involved by assuming that the third and successive terms in expression (1) are negligible we have

$$\delta B = \delta A \; B \left[\frac{x}{A} - 1 + B \right] + \frac{(\delta A)^2}{2\,!}$$

$$B \left[2B^2 + \frac{x}{A}(3B - 2) - 3B - \frac{x}{A^2} + \frac{x^2}{A^2} + 1 \right]$$

$$-0.00032 = \delta A \cdot 0.00116538 + \frac{(\delta A)^2}{2\,!} \cdot 0.000588830737$$

from which $\delta A = -0.2969$

The correct value of A to produce a loss of 0.002 is therefore 29.703 traffic units.

Example 2. In this case it is desired to ascertain what is the effect on the value of B when A is varied slightly

When $A = 60$ and $x = 80$ $B = 0.002199$

To find the effect on B when A is increased to 60.5. Then $\delta A = 0.5$. Hence as a first approximation from

$$\delta B = \delta A . B . \left[\frac{x}{A} - 1 + B \right]$$

$$B = 0.5 \times 0.002199 \left[\frac{80}{60} - 1 + .002199 \right]$$

$$= 0.0010995 \times .3355323$$

$$= .0003689$$

and therefore B will be 0.0025679

To obtain closer accuracy the term $\frac{(\delta A)^2}{2\,!} f''(A)$ must be included. This has the value $\frac{(\delta A)^2}{2\,!} f''(A)$

$$= \frac{(0.5)^2}{2\,!} B \left[2B^2 + \frac{x}{A}(3B - 2) - 3B - \frac{x}{A^2} + \frac{x^2}{A^2} + 1 \right]$$

which becomes $\frac{(\delta A)^2}{2\,!} f''(A) = 0.00002504$

and therefore a more accurate value of B is

$$B = .0025679 + 0.00002504$$

or $B = .0025929$

It will be appreciated that calculations similar to these can be applied in the cases where the grade of service is good by using the simpler expressions deduced from Grinsted's approximation.

(*f*) *Last Contact Traffic and* $\frac{dC}{dA}$

In an article entitled " Problems in Automatic Trunking—Last Contact Traffic " (Volume 23, Part 4 of this Journal), some mention was made of the theoretical determination of last contact traffic and of the uses to which known values of last contact traffic can be applied. An expression was derived showing the value of last contact traffic in terms of grade of service B, total traffic A and number of selectors x and was given in the form

$$\text{last contact traffic} = B \left[\frac{x}{1 - B} - A \right] \qquad (9)$$

Now last contact traffic = traffic offered to last contact − lost traffic or if C = last contact traffic

$$C = AB_1 - AB \qquad (10)$$

where B_1 is the proportionate loss at the $(x - 1)$th contact.

Differentiating this expression with respect to A we have,

$$\frac{dC}{dA} = A \frac{dB_1}{dA} - A \frac{dB}{dA} + B_1 - B$$

$$\text{Now } B_1 = \frac{Bx}{A(1 - B)}$$

$$\text{and} \quad \frac{dB_1}{dA} = \frac{A(1 - B)x \frac{dB}{dA} - Bx \left[(1 - B) - A \frac{dB}{dA} \right]}{A^2(1 - B)^2}$$

$$\text{and since} \quad \frac{dB}{dA} = B \left[\frac{x}{A} - 1 + B \right]$$

$$\therefore \frac{dB_1}{dA} =$$

$$\frac{ABx(1-B)\left[\dfrac{x}{A}-1+B\right]-Bx(1-B)+AB^2x\left[\dfrac{x}{A}-1+B\right]}{A^2(1-B)^2}$$

$$\frac{dB_1}{dA}=\frac{ABx\left[\dfrac{x}{A}-1+B\right]-Bx(1-B)}{A^2(1-B)^2}$$

$$\frac{dB_1}{dA}=\frac{x}{A(1-B)^2}\frac{dB}{dA}-\frac{Bx}{A^2(1-B)}$$

$$\text{Hence }\frac{dC}{dA}=A\frac{dB_1}{dA}-A\frac{dB}{dA}+B_1-B$$

$$\frac{dC}{dA}=A\left[\frac{x}{A(1-B)^2}\frac{dB}{dA}-\frac{Bx}{A^2(1-B)}-\frac{dB}{dA}\right]+B_1-B$$

$$\frac{dC}{dA}=\frac{dB}{dA}\left[\frac{x}{(1-B)^2}-A\right]-\frac{Bx}{A(1-B)}+B_1-B$$

but $B_1=\dfrac{Bx}{A(1-B)}$ and therefore

$$\frac{dC}{dA}=\frac{dB}{dA}\left[\frac{x}{(1-B)^2}-A\right]-B\ldots\ldots(11)$$

Clearly then if we increase the values of dA, dB and dC above the infinitessimal limit the resulting expression will not be very inaccurate when applied to practical cases. Replacing dA, dB and dC by δA, δB and δC respectively we get

$$\frac{\delta C}{\delta A}=\frac{\delta B}{\delta A}\left[\frac{x}{(1-B)^2}-A\right]-B$$

$$\text{or }\delta C=\delta B\left[\frac{x}{(1-B)^2}-A\right]-B\delta A\ldots\ldots\ldots\ldots\ldots\ldots(12)$$

Generally, both B and δA will be small, so that the term $B\delta A$ can be neglected and as a result

$$\delta C=\delta B\left[\frac{x}{(1-B)^2}-A\right]\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(13)$$

This expression can be applied to all cases where the grade of service is reasonably good and where δB is not too large, as will be shown in the succeeding paragraphs.

(g) *Application of* $\dfrac{\delta C}{\delta B}$ *to practical problems.*

Example 1. To determine the variation in last contact traffic for any grade of service slightly different from that at which the last contact traffic is known.

Consider the case of 8 T.U. offered to a group of 17 circuits giving a grade of service of 0.002127. It is known that the last contact traffic = 0.019232 T.U. It is required to find the value of the last contact traffic when the traffic has been varied so that the resulting grade of service is 0.002.

From expression (13)

$$\delta C=\delta B\left[\frac{x}{(1-B)^2}-A\right]\text{ where }A=8\ x=17\ B=0.002127\text{ and }\delta B=-0.000127$$

$$\text{then }\delta C=-0.000127\left[\frac{17}{(1-0.002127)^2}-8\right]$$

$$\delta C=-0.000127\ (17.072-8)$$

$$\delta C=-0.001152$$

Hence new value of last contact traffic = 0.019232 − 0.001152 = 0.01808

In order to show what accuracy is given we can determine the value of $B\delta A$ for it is known that a grade of service of 0.002 is obtained when a total traffic of 7.95 T.U.* or more correctly 7.946 T.U. is offered to 17 circuits fully available.

The value of δA is therefore 0.054 and the error in assuming that $B\delta A$ is negligible is 0.002 × 0.054 = 0.000108, the correct value of last contact traffic being 0.01808 − 0.000108 = 0.01792 or 0.018 T.U. correct to three decimal places.

Example 2. Having given a value of last contact traffic differing slightly from that for a known value of total traffic and grade of service, to determine the grade of service.

Consider the case when $x=25$, $A=15$, $B=0.005011$. Here last contact traffic = 0.05074 T.U. To find the grade of service when the last contact traffic has increased to 0.052 T.U.

$$\text{From }\delta C=\delta B\left[\frac{x}{(1-B)^2}-A\right]$$

$$0.00126=\delta B\left[\frac{25}{(1-005011)^2}-15\right]$$

from which $\delta B=.000123$

and therefore the new grade of service is 0.005011 + .000123 = 0.005134.

It must of course be borne in mind that to obtain closer accuracy in either of the cases for which examples have been quoted it would have been necessary to determine the value of δA.

(h) *Conclusion.*

Throughout this article an attempt has been made to indicate not only how the calculus can be applied to the theories upon which plant quantities are determined in Post Office design, but to illustrate

* *This value has been extracted from T.I. 25, Part 12A.*

also how the resulting mathematical deductions can be used in many instances.

It is appreciated that the resulting accuracy is dependent upon the smallness of the given differences, but nevertheless good results have been obtained with comparatively abnormal given conditions.

Such mathematical determinations as these are mainly applicable when finding theoretically what happens when the grade of service changes, but the author has no doubt that with the naturally increasing demands for automatic exchanges and the consequent gain in experience of traffic and its relation to exchange design some further uses will be found for the methods described.

A COMPLETE SOLUTION OF THE WHEATSTONE BRIDGE OR MURRAY LOOP.

THOS. WOODHOUSE, Preston.

IT is the usual practice to solve these bridges by correlating the current values in all their branches and the method is well known. It is tacitly assumed generally that the points on the bridge, where the galvanometer is connected, have been brought to the same potential when no current will flow through the galvo : and the bridge is said to be balanced.

The unknown resistance of any branch except the galvo circuit, see Fig. 1(*a*), may then be obtained from the proportion :—

$$\frac{P}{Q} = \frac{S}{R} \quad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

It is not essential that the bridge should be balanced in this manner to calculate the resistance of any single unknown branch, which might even be the galvo circuit, and the following method could be adopted. Campbell's Star to Mesh Transformation Theorem postulates that a star of " n " rays in a network of conductors can be replaced by a mesh of $\frac{n(n-1)}{2}$ conductors without affecting the conductivity of the whole system.

The mesh formed by the conductors P, Q and G in the bridge network shown in Fig. 1(*a*) may therefore be replaced by the 3-ray star p, q, g in Fig. 1(*b*) if

$$Pp = Qq = Gg = \frac{PQG}{P+Q+G}$$

The total resistance between points A and B in Fig. 1(*b*) is then

$$= g + \frac{(q+S)(p+R)}{p+q+R+S}$$

Substituting for p, q and g to prove the resistance of the bridge

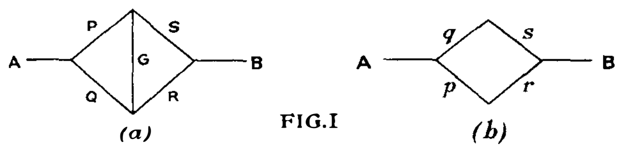


FIG.I

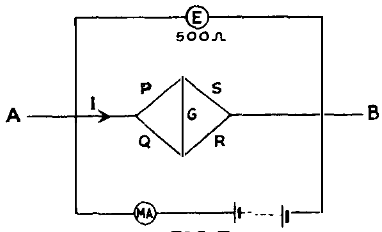


FIG.II

$$= \frac{PQ}{P+Q+G} + \left\{ \frac{\dfrac{G^2PQ}{P+Q+G} + \dfrac{GPR+GQS+RS(P+Q+G)}{1}}{\dfrac{G(P+Q+R+S)+(P+Q)(R+S)}{1}} \right\}$$

$$\equiv \frac{G(P^2Q+PQ^2+PQR+PQS)+PQ(P+Q)(R+S)+G^2PQ}{(P+Q+G)\,G(P+Q+R+S)+(P+Q)(R+S)} + \frac{(GPR+GQS)(P+Q+G)+RS(P+Q+G)^2}{\text{L.C.M.}}$$

$$= \frac{(GPQ+PQR+PQS+GPR+GQS)(P+Q+G)+RS(P+Q+G)^2}{(P+Q+G)\,G(P+Q+R+S)+(P+Q)(R+S)}$$

$$= \frac{G(P+S)(Q+R)+PQ(R+S)+RS(P+Q)}{G(P+Q+R+S)+(P+Q)(R+S)} \quad \ldots(2)$$

Any one unknown branch may now be evaluated if the resistance of each of the other four branches is known.

The potential difference between the points A and B, Fig. **2**, should be measured on a high resistance voltmeter, say Detector No. 4, whilst the current flowing into the bridge at A is observed when,

$$I = \frac{E}{\frac{G(P+S)(Q+R)+PQ(R+S)+RS(P+Q)}{G(P+Q+R+S)+(P+Q)(R+S)}}$$

from Ohm's Law.

e.g., when E indicates 1 volt and the current through MA = 12 milli-ampères

$$\frac{10}{1000} = \frac{1}{\text{Resistance of Bridge}}$$

whence $R = 100$ ohms.

if $P = 100$, $Q = 1000$, $G = 100$ and $S = 10$ ohms.

From equation (2),

$$\text{Resistance of Bridge} = \frac{P+Q+R+S}{(P+S)(Q+R)}$$

when G has a maximum value,

and
$$= \frac{PQ}{P+Q} + \frac{RS}{R+S}$$

when G is a minimum.

In the particular case where G may have any unknown value between a minimum and maximum it is necessary that the following proposition should exist if the resistance of one other unknown branch is required.

$$\frac{(P+S)(Q+R)}{P+Q+R+S} = \frac{PQ}{P+Q} + \frac{RS}{R+S}$$

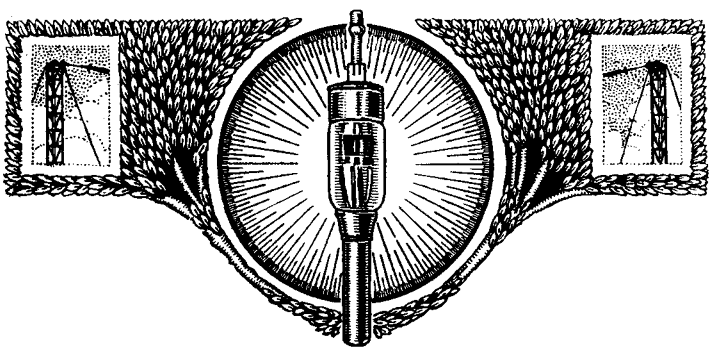
$$= \frac{P}{Q} = \frac{S}{R} \quad \ldots\ldots\ldots \quad \ldots\ldots\ldots\ldots\ldots\ldots(3)$$

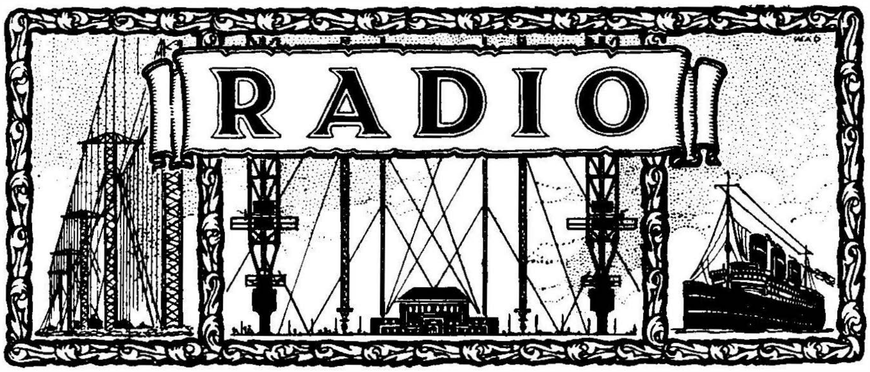
and $R = S$ if $P = Q$.

An identical value for the resistance of the bridge network may be deduced by arranging the sums of the currents meeting at each node as a determinant and proving for the potential difference between the points A and B.

Equation (3) is the condition for balance in the practical case, as stated previously, when no current flows through the galvo; which may be disconnected or short-circuited without affecting the conductivity of the bridge network.

Similar mathematical treatment can be applied to more complicated networks—vide A. Morris discussion of "A New Network Theorem" in the *I.E.E. Journal*, Vol. 63, March, 1925—and it is considered that the solution will prove of general interest.





A CONTINUOUSLY LOADED CABLE FOR USE AT HIGH FREQUENCIES.

F. E. NANCARROW and H. STANESBY.

THIS article describes and gives the results of electrical tests upon a continuously loaded cable developed for use at the Receiving Stations (in this country) of the Long Wave Transatlantic Telephony Circuit.

At the Receiving Station many open wire transmission lines are used to convey the energy collected by the various parts of the widely spaced antenna system to the receiver. Here the various portions are passed through attenuating and phase shifting networks before being combined into a single output and fed into the receiver proper. It was conceived that it would be advantageous, both constructionally and electrically, if a cable could be designed to match the impedance of the open wire transmission lines and used for the final termination within the building housing the receiver.

The open wire transmission lines have a characteristic impedance approximating closely to $600 /0^{\circ}$ ohms, and hence the problem was to obtain a continuously loaded cable which would have a similar impedance at frequencies in the region of 60 to 70 kc and be suitable for the purpose in view. The maximum length of the cable which it was proposed to use in any one circuit was of the order of 50 yards and hence the attenuation of such a cable was not of primary importance. Messrs. Siemens Brothers of Woolwich submitted a design which met the requirements, and it is this cable which is described.

Description of Cable.—Fig. 1 shows the internal

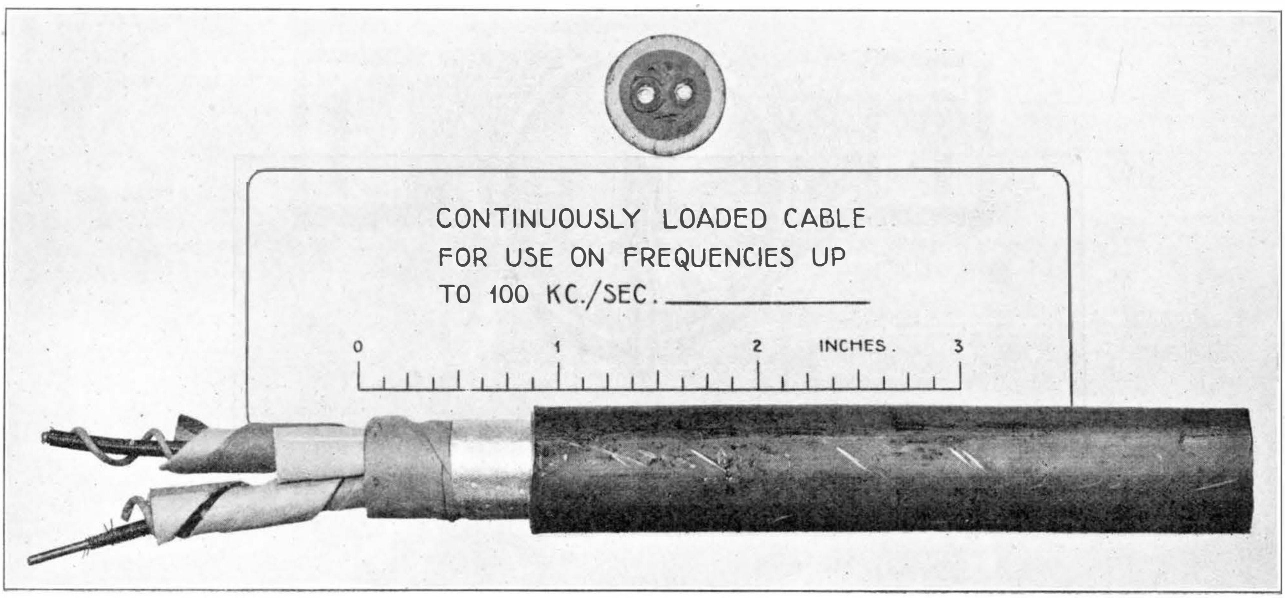


FIG. 1.

construction of the cable. The conductor is of 40 lb. copper wire loaded with two layers of 8 mils diameter unannealed silicon iron wire. Each conductor is air-spaced with a special whipping of string and covered with two layers of paper wrapping. The conductors are then twinned and formed up with the two paper spacers to ensure a round section, and lapped with five layers of paper followed by a final layer of metallised paper which is in contact with the lead sheath. The overall diameter of the cable is 0.62 inch, the sheath having a thickness of 0.08 inch.

Method of Measurement.—The cable was bought in two 1100 yard lengths and tests were carried out on each length at frequencies varying from 20 to 100 kc with certain of the measurements extended to 300 kc. A bridge, constructed in the Radio Laboratory, in which the elements are so screened and connected that the effects of stray capacities are eliminated, was used for the measurements. The impedance at one end of the cable was obtained at various frequencies, first with the far end open-circuited and then short-circuited, and, using this data, the characteristic impedance, attenuation and phase constants calculated from the following relationships :—

$$Z_0 = \sqrt{Z_f Z_c}$$

$$\beta l = \tfrac{1}{2} \text{ arc tanh } \frac{2h \cos \Phi}{1 + h^2}$$

$$\alpha l = n\pi + \tfrac{1}{2} \text{ arc tanh } \frac{2h \sin \Phi}{1 - h^2}$$

where Z_0 = characteristic impedance.
Z_c = impedance with far end short-circuited.
Z_f = impedance with far end open-circuited.
α = phase constant per unit length in radians.
β = attenuation constant per unit length in nepers.
l = length.
n = an integer depending upon the length of the cable.

$$h \,\underline{/\Phi} = \sqrt{Z_c / Z_f}$$

Results of Measurement.—The results are given in the table below and are also depicted graphically in Figs. **2**, **3**, **4** and **5**.

SECTION 1.

Frequency Kilocycles/second.	Characteristic Impedance.	Attenuation constant Nepers/Mile.	Phase Constant Radians/Mile.
40	$621.9 \ \backslash 1^{\circ}19'$	0.455	8.36
50	$573.2 \ \backslash 4^{\circ}48'$	0.666	10.38
60	$571.1 \ \backslash 2^{\circ}26'$	0.911	12.4
70	$574.9 \ \backslash 3^{\circ}15'$	1.194	14.41
80	$574 \ \backslash 2^{\circ}39'$	1.517	16.39
90	$592.1 \ \backslash 3^{\circ}33'$	1.84	18.32

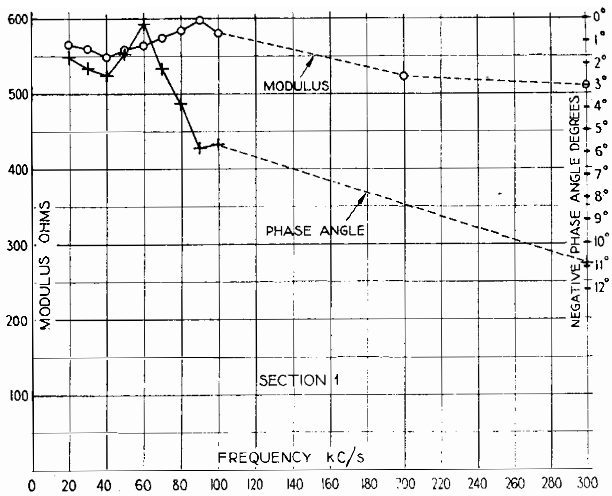


FIG. **2**.—VARIATION OF CHARACTERISTIC IMPEDANCE WITH FREQUENCY. SECTION 1.

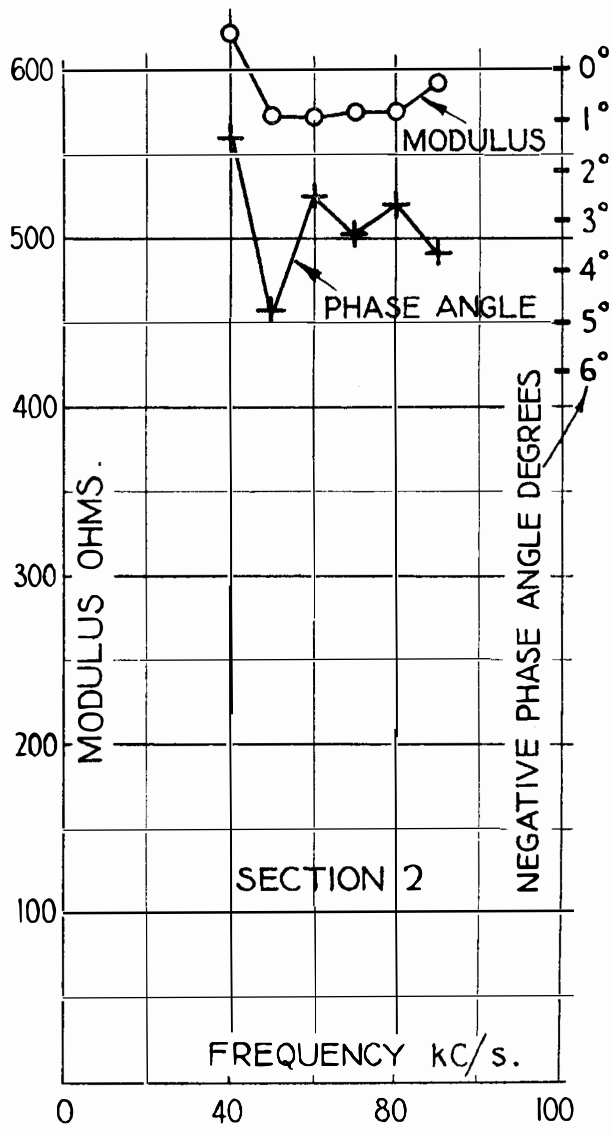


FIG. **3**.—VARIATION OF CHARACTERISTIC IMPEDANCE WITH FREQUENCY. SECTION 2.

SECTION 2.

Frequency Kilocycles/ second.	Characteristic Impedance.	Attenuation constant Nepers/ Mile.	Phase Constant Radians/ Mile.
20	$566\ \backslash 1^{\circ}43'$	0.160	4.22
30	$559.2\ \backslash 2^{\circ}12'$	0.288	6.675
40	$547.8\ \backslash 2^{\circ}32'$	0.462	8.40
50	$557.8\ \backslash 1^{\circ}32'$	0.675	10.47
60	$562.8\ \backslash 0^{\circ}15'$	0.92	12.52
70	$573.4\ \backslash 2^{\circ}13'$	1.20	14.54
80	$583.6\ \backslash 3^{\circ}45'$	1.51	16.52
90	$596.9\ \backslash 5^{\circ}41'$	1.85	18.49
100	$579.7\ \backslash 5^{\circ}33'$	2.22	20.28
200	$522.2\ \backslash 8^{\circ}8'$	—	—
300	$511.1\ \backslash 10^{\circ}56'$	—	—

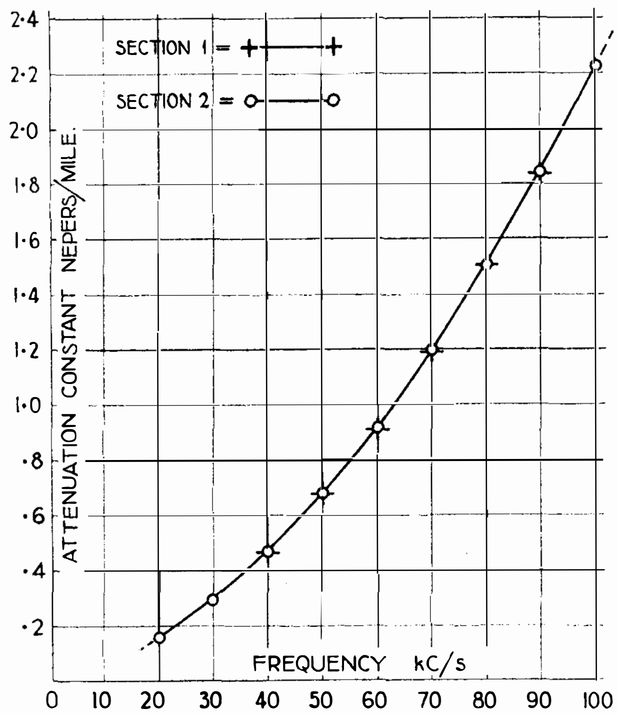


FIG. 4.—VARIATION OF ATTENUATION CONSTANT WITH FREQUENCY.

The agreement in the results for the two sections of the cable, particularly in regard to those for the attenuation constant, demonstrates the utility of the bridge for measurements of this nature.

The irregularity in the characteristic impedance, which is not similar for the two lengths, probably arises from slight variation in the inductance, and hence in the characteristic impedance along the cable, causing internal reflections which manifest themselves as irregularities in the impedance frequency characteristic.

At a frequency of 70 kc the attenuation is 1.2

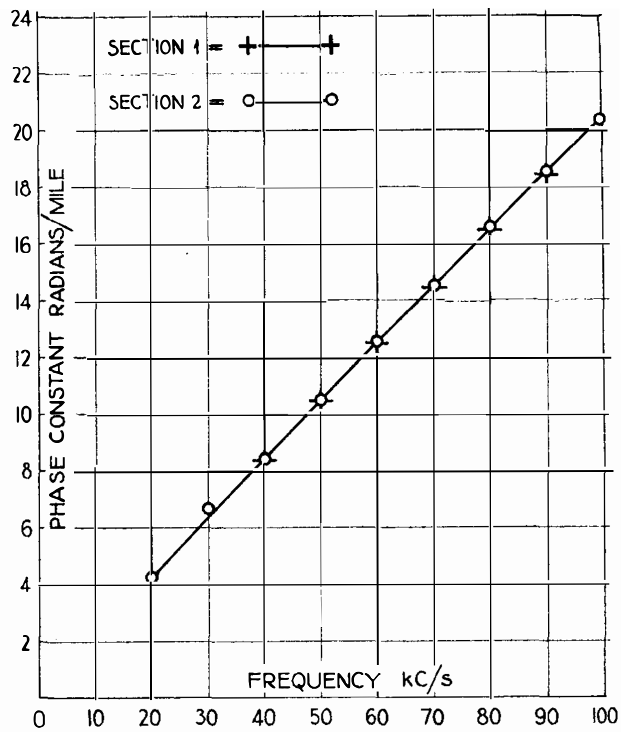


FIG. 5.—VARIATION OF PHASE CONSTANT WITH FREQUENCY.

nepers per mile, so that the interposition of a length of 50 yards into the transmission line circuit would result in a loss of 0.034 nepers (0.3 db). Assuming that this length is terminated at one end by the radio receiver having an input impedance of $600\ /0^{\circ}$ ohms, then the far end of the cable will present an impedance Z to the open wire transmission line which may be calculated from the expression :—

$$Z = Z_0 \frac{Z_R + Z_0 \tanh P}{Z_0 + Z_R \tanh P}$$

where Z_0 = characteristic impedance of cable.
Z_R = terminating impedance.
P = total propagation constant.

If the values for section 2 of the cable are substituted in this expression Z becomes $607\ \backslash 2^{\circ}32'$, a value which approximates closely to the impedance of the open wire line.

Whilst this cable was developed for the particular purpose already described, and affords an interesting example of the application of continuously loaded cable in the realm of high frequencies, it is thought that it may have other applications in the frequency range more familiar to telephone engineers.

One such possible application occurs to the writers of this note, namely, the negotiation of power or water crossings in carrier circuits, whereby the impedance irregularities arising from reflection at the junction points would be avoided by the use of lengths of this type of cable.

THE HEPTODE—A NOVEL THERMIONIC VALVE.

E. J. C. Dixon, A.C.G.I., B.Sc., D.I.C.

A DESCRIPTION was given in recent issues of this Journal* of the apparatus used by the Post Office for generating high frequencies of great constancy for the control of Short-Wave Radio Transmitters. The output from the control equipment is at a low power level and it is necessary to raise the power level to the order of kilowatts before it is radiated at the antenna. It is an essential feature of the high-frequency amplifier that the output power shall have the same frequency as the input power, which implies that the amplifying stages of a short-wave radio transmitter must have no tendency towards self-oscillation. In practice it is difficult to ensure that there shall be no tendency towards self-oscillation, owing to the reactive coupling between the output and the input circuit due to the valve inter-electrode capacity. In a transmitting triode the anode-grid capacity is of the order of 20 $\mu\mu$F, which is comparable in size with the tuning capacities of the circuit. The following notes describe a novel type of valve† which has been designed to overcome the disadvantages inherent in the triode, while taking advantage of the symmetry of the double-acting circuit commonly called the "push-pull" circuit.

The Push-pull Circuit.—The push-pull circuit employs two valves which go through similar oscillation cycles, but with a phase difference of 180 degrees with respect to each other. The two grids are connected to the ends of the input circuit and the centre point is connected to a point of zero potential with regard to the high frequency potentials, usually *via* a bye-pass condenser to the earthed framework of the transmitter. The two anodes are connected in a similar manner to the output circuit, the high tension supply being introduced at the centre point. With a symmetrical lay-out of the circuit components in the screened framework of the transmitter it is possible to balance their stray capacities to earth and thus reduce the number of unknowns in the circuit. A simple push-pull valve would thus consist of a single cathode, two control grids, one on either side of the cathode and two anodes similarly arranged. The cathode would emit in the direction of one anode during one half of the high frequency cycle and towards the second anode during the second half of the cycle. Its dimensions could therefore be the same as those of each of the cathodes in the two triodes which the push-pull valve would replace.

The reaction potential on the first grid from its anode would be in opposite phase to that anode potential and, in order to balance the reaction potential, an equal and opposite potential can conveniently be derived from the second anode, which is 180 degrees out of phase with the first. This can be effected by means of a stabilising grid on the

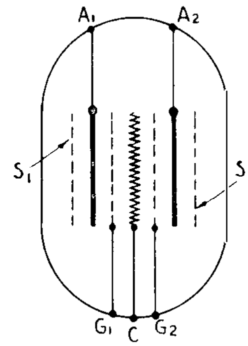


Fig. 1(*a*).

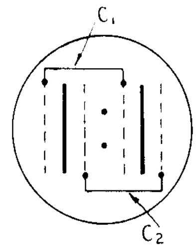


Fig. 1(*b*).

Diagram of Electrode Arrangement.

remote side of the second anode and a short cross-connection to the first grid. The capacity of the stabilising grid to the second anode can be arranged to be equal to that between the first anode and grid and the cross-connection may be duplicated in order to reduce its inductance. A complete electrode assembly of this type thus includes seven electrodes

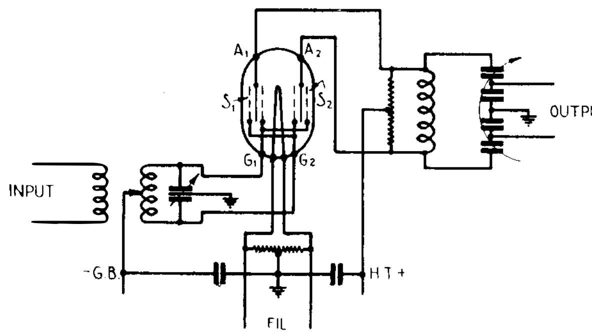


Fig. 2.—Typical Circuit Diagram.

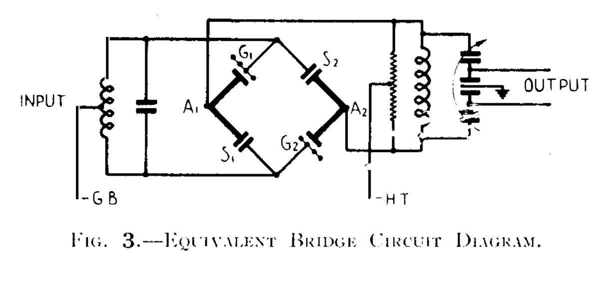


Fig. 3.—Equivalent Bridge Circuit Diagram.

* *Journal P.O.E.E., Vol. 24, Parts 2 and 3.*

† *Brit. Pat. Specn. 352,994. July, 1931.*

—hence the name "Heptode" for the double-acting balanced thermionic valve.

Diagram of the Heptode.—A diagram of the electrode arrangement is shown in Fig. **1***a*, in which C designates the cathode, G_1, G_2 the control grids, A_1, A_2 the anodes and S_1, S_2 the stabilising grids. Fig. **1***b* represents a plan view and shows the cross-connections C_1, C_2.

A typical circuit diagram is shown in Fig. **2**, in which the input is inductively coupled to the grid circuit and the output is capacitively coupled to the anode circuit, while the centre points of both circuits are bye-passed to earth through condensers. To those who are familiar with bridge circuits a comparison of the circuit shown in Fig. **2** with the equivalent circuit shown in Fig. **3** will make the operation of the heptode quite clear.

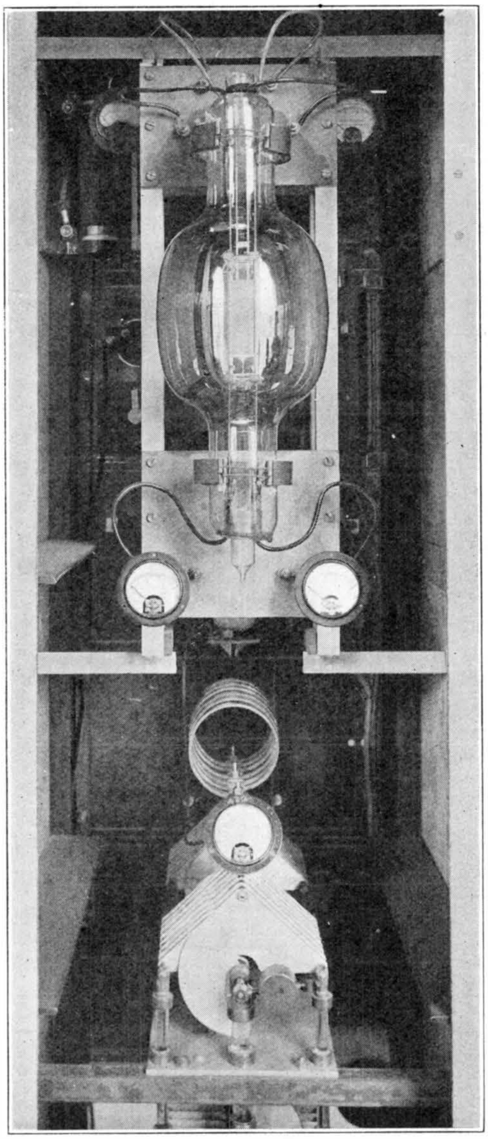


FIG. **4**.—VALVE, THERMIONIC, NO. 63 IN EXPERIMENTAL TRANSMITTER.

Valve Thermionic No. 63.—Considerable experience has been gained by the Radio Section of the Post Office with heptodes of 250 watts dissipation

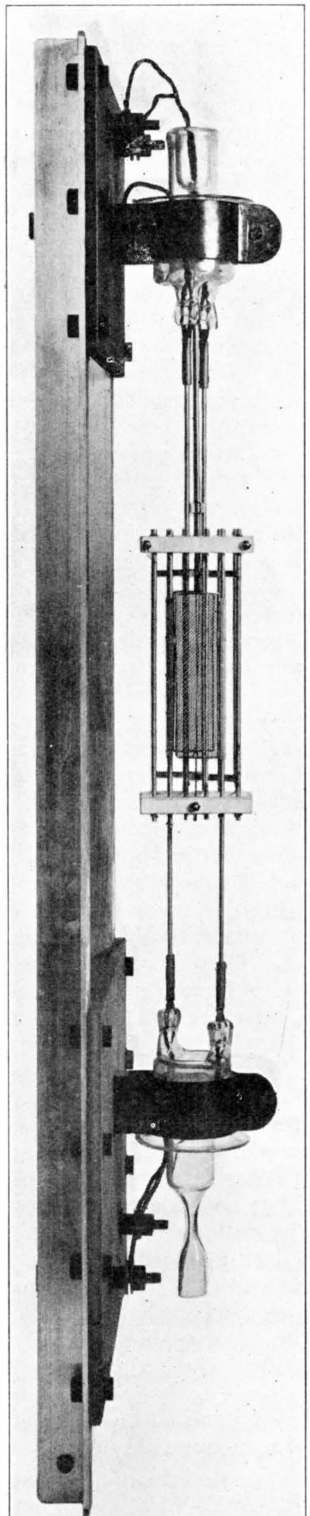


FIG. **5**(*a*).—END VIEW OF HEPTODE ASSEMBLY.

per anode in radiation cooled glass envelopes, both in experimental and commercial circuits at frequencies up to 18,000 kc/sec. A valve of this type (V.T. No. 63) can be accommodated in a rack of standard width and two feet depth, and is usually mounted on a plug-in framework so that it can readily be removed from circuit. Fig. **4** shows the valve, as made by Messrs. Edison Swan Electric Co., in an experimental set-up at Dollis Hill. The valve is shown with the filament and grid seals uppermost and the anode circuit is mounted below the valve. The grid circuit is coupled to the previous stage, which, in this case, is the output of the frequency doubler rack and is screened from the anode circuit. A valve of this type can handle nearly a Kilowatt D.C. input at frequencies of the order of 10,000 kc/sec and is capable of providing sufficient output to excite two triodes, each of 3 kw dissipation, connected in a push-pull circuit.

Design Adjustment and Test.—The most simple form of design is a system of planar electrodes grouped about a loop cathode, and an end elevation of such an assembly is shown in Fig. **5***a*. The electrodes are supported on a series of parallel rods of molybdenum, some of which are extended to form leads and, at the same time, to support the assembly from the glass " feet " which are to be fused to the valve envelope. The assembly is rigidly spaced by bars of a fired insulator known as " lavite," which are in turn rigidly connected together by molybdenum bolts. A front view of the assembly is shown in Fig. **5***b*, in which the filament leads spaced by a lavite insulator, the adjacent grid leads and, at the lower end of the assembly, the anode leads can be distinguished. The side electrodes seen in end-on view in Fig. **5***a* are screens to prevent bombardment of the glass envelope by emission from the filament during the process of evacuation. While these screens affect the distribution of the field around the electrode assembly, they are not essential parts of the balanced system and are only included to simplify the process of manufacture of the valve.

The method of adjustment is to connect the assembly in circuit as shown in Figs. **2** and **4**, apply high frequency excitation to the input and, with H.T. disconnected, measure the circulating current in the output circuit. The size of the stabilising condenser is then adjusted by altering the number of cross-wires in the grids S_1 and S_2 until the out-of-balance current in the output circuit is a minimum. It will be seen that the stabilising grid of the valve shown in Fig. **5***b* has only three cross wires. The assembly is then enveloped, baked and exhausted, and the complete valve can be checked in the same manner as the assembly. A neat method of checking the balance when the electrodes are dissipating energy (" hot balance test ") has been devised by A. J. Symonds, of Rugby Radio Station, and consists of observing the output and D.C. input meter indications for values of anode tuning condenser near the point of resonance. For a perfectly balanced system the maximum output reading will coincide with the minimum input reading, while for unbalanced systems the maximum and minimum readings will be displaced along the tuning condenser scale. Fig. **6** shows typical balance curves and gives criteria for estimating whether the stabilising capacity is too small or too great. The practical test applied to high-frequency amplifying stages is

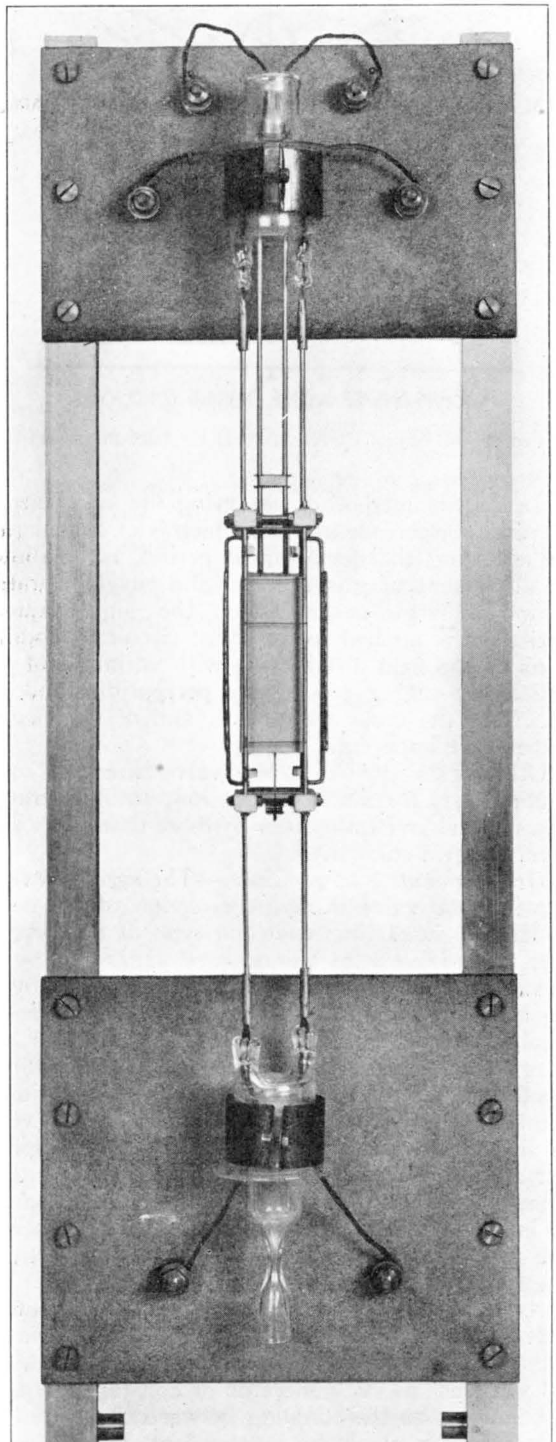


FIG. 5(*b*).—FRONT VIEW OF HEPTODE ASSEMBLY.

to apply the H.T. without the grid excitation and reduce the grid bias voltage to zero. The stage should not self-oscillate at any setting of the grid and anode tuning condensers.

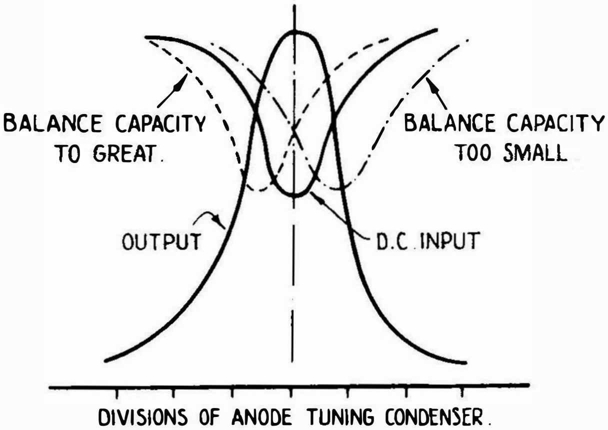


FIG. 6.—BALANCE CURVES FOR H.F. AMPLIFYING STAGE.

An elegant method of observing the field distribution in the electrode system, which is of considerable value during the development period, is to allow a small amount of gas to enter the envelope until a glow discharge occurs when the high-frequency excitation is applied to the input circuit. Modifications of the field distribution with variation of grid and anode tuning are readily perceptible and the effects of the cross-connections and of the electron screens are apparent.

Other tests applied to the valve are the usual routine tests for filament emission, static characteristics (which must not differ by more than 12½%) and reversed grid current.

Development to larger sizes.—The logical development of the valve is in the direction of the cooled anode in insulating envelope type of construction and two different techniques are suggested by the metal tube in silica envelope valves, and by the de-mountable valves constructed of porcelain and steel. Neither of these techniques, however, has progressed to the stage at which it could readily be applied to the design of a heptode and experiments are limited at the moment to radiation cooled valves in silica envelopes of about one kilowatt dissipation per anode. A valve of this type, constructed by Messrs. Mullard Radio Valve Co., is shown in Fig. 7, in which it will be noted that no electron screens are necessary owing to the refractory properties of the silica envelope.

Applications of the Heptode.—The use of the valve has been described only for radio transmitter amplifying circuits, but it has also considerable possibilities as a generator of constant frequency oscillations, as the coupling between the output and input circuits would be independent of the valve. Its field of use might also be extended to small valves in receiving circuits, but the possibilities in this direction have yet to be investigated.

An alternative and well-known method of preventing back coupling in amplifying valves is by the use of a screening grid between the control grid and anode of an ordinary triode. This method finds large application in receiving valves and it is also used to some extent in transmitting valves. The development of large-sized screened grid transmitting valves is still in progress, but such valves possess one inherent disadvantage in that the anode impedance is necessarily very high. The heptode on the other hand has the same latitude in anode impedance as a simple triode, and it is possible to construct such valves with relatively low impedance. To obtain an efficient circuit it is essential that the impedance of the anode circuit external to the valve should be of the same order as the internal impedance of the valve. On long and medium waves it is possible to obtain this order of impedance in the anode circuit, but on short waves this is impossible, and it is on such wave-lengths that the heptode is likely to find its most useful application.

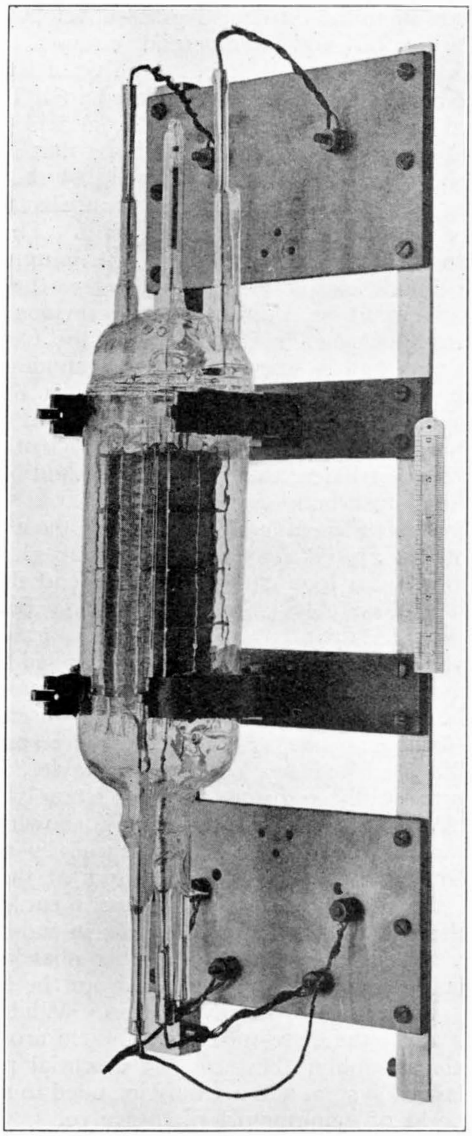


FIG. 7.—S.V. 2000—EXPERIMENTAL HEPTODE IN SILICA ENVELOPE.

NOTES & COMMENTS

HISTORY OF THE POST OFFICE ENGINEERING DEPARTMENT.

THE Council of the Institution of Post Office Electrical Engineers has had under consideration the question of arranging for the compilation of a History of the Post Office Engineering Department, but came to the conclusion that it was not possible to undertake such a task at the present time. The Council feels, however, that it would be very unfortunate if information of historical value which is at present available should be lost merely through the lack of any organisation for the collection of such valuable literary material. The Council wishes to announce, therefore, that it has decided to arrange for the filing and indexing of any memoirs or information of historical value which may be offered to the Institution.

The Council would be glad to hear from any reader who may be in possession of documents of the nature referred to which he considers would be of historical value or if he would be good enough to write a few notes on any particular question of historical interest with which he may have been associated. The period in regard to which information is most valuable is that preceding the publication of the P.O.E.E. Journal, *i.e.*, prior to 1908.

At the present time any document or record in connection with the life and work of Samuel Alfred Varley would be welcomed. Varley was active in the electrical world during the 1870 period and if any reader is in possession of any item of personal or historical interest regarding Varley the Secretary would be glad to hear from him.

Communications on this subject should be addressed to :

The Secretary,
Institution of P.O. Electrical Engineers,
Engineer-in-Chief's Office, G.P.O.,
Alder House, London, E.C.1.

MR. A. J. STUBBS.

Readers of the Journal will be interested in the announcement that Mr. A. J. Stubbs was ordained at Rochester Cathedral, on the 20th December, as curate of All Saints Church, Chatham. Mr. Stubbs is now seventy years of age and one feels considerable satisfaction in hearing of at least one case of a pensioned officer who has distinguished himself in another sphere. He is being presented with an album signed by the 329 subscribers who combined in a presentation of a cheque from the congregation of Woodside Parish Church, Croydon, which Mr. Stubbs has served for nearly a quarter of a century as lay reader and churchwarden.

BACK NUMBERS OF JOURNAL.

Offers are made occasionally by retiring members to dispose of their sets of the Journal. The Editor will be pleased to record the names of any members who desire to avail themselves of such offers.

TRANSMISSION UNITS SCALE.

Messrs. Siemens Bros. has asked us to announce that the Scale giving the relationship between the Units generally used in Telephone Engineering, which appeared on page 259 of the October issue, can be obtained from them in the form of a blotter.

AGNER KRARUP ERLANG.

With the growth of automatic telephony and the consequent increase of interest in trunking problems, the name of Erlang has become familiar to readers of this Journal. It may perhaps be of interest, therefore, to give a little information regarding the actual personality behind this name.

Erlang was born in 1878 and entered the service of the Copenhagen Telephone Company in 1909. His speciality was the use of probability calculations on telephone problems and his work on this subject has been translated into many languages. His principal contribution to this field was the development of a theory for the traffic capacity of circuits when the actual number of circuits available is

AGNER KRARUP ERLANG.

restricted. The expression which he obtained by the method of statistical equilibrium for this case is quite simple and forms the basis of the design curves used by the British Post Office.

Erlang also acquired a reputation as a constructor of measuring instruments for audio frequencies and was the author of an essay dealing with the theory of telephone cables published in the Danish Journal "Elektroteknikren," in 1911. Other publications of Erlang's are :—

Calcul des probabiltiés et conversations téléphoniques. Revue Générale de l'Electricité t XVIII, p. 305, Paris, 1925.

New Alternating Current Compensation Apparatus for Telephonic Measurements. Journal of Inst. of E.E., 1913, Vol. 51, page 794.

Etude théorique élémentaire sur le Transformateur d'un Appareil Téléphonique. Vie Technique et Industrielle, Oct., 1927.

How to reduce to a Minimum the Mean Error of Tables. The Napier Tercentenary Memorial Volume. Royal Society of Edinburgh, 1915.

Solution of some Problems in the Theory of Probabilities of Significance in Automatic Telephone Exchanges. The Post Office E.E. Journal, 1918, p. 189.

Lösung einiger Problems der Wahrscheinlichkeitsrechnung von Bedeutung für die selbsttätigen Fernsprechämter. Elektrotechnische Zeitschrift, 1918, Heft 51.

Solution de quelques problèmes de la théorie des probabilitiés présentant de l'importance pour les bureaus téléphoniques automatiques. Annals des Postes, Télégraphes et Téléphones, Nr. 4, Juillet-Août, 1922. (See also Appendix to a paper of G. F. O'dell: The influence of traffic on automatic exchange design. 1920. Professional Paper No. 85).

Calcul des probabilités et conversations téléphoniques. Revue Générale de l'Electricité t XX, p. 270, Paris, 1926.

Application du calcul des probabilités en Téléphonie. Annales des Postes, T. et T. Nr. 7, Juillet, 1925.

Démonstrations de la loi Maxwell, proportion fondamentale de la théorie des gaz. Le Vie Technique et Industrielle, Mai, 1926, p. 72.

Some Applications of the Method of Statistical Equilibrium. 6th Congress of Mathematicians, Copenhagen, 1925.

Quelques applications de la méthode de l'équilibre statistique dans la théorie des probabilités. Anales des Postes, T. et T. Sept., 1928.

Mr. Erlang died on the 3rd February, 1929, after an operation and a few days' illness.

While Erlang made such striking contributions to Telephony, he was a man of charming personality and of extremely modest bearing. His death at such an early age is to be widely regretted.

ECONOMY 60 YEARS AGO.

By the courtesy of Mr. A. B. Gilbert the Board of Editors has obtained a number of extracts from the minutes of a Conference of Engineers of the Northern Division held at York in July, 1872. The extracts have such an up-to-date application that the Board feels that readers will appreciate some notes regarding them. Lack of space prevents their complete publication.

Apparatus.—It may seem odd at this date to read of a choice having to be made between double current Morse instruments and Direct Sounders or Writers, but the evidence shows that problems in economics were not considered as being outwith the scope of the Engineering Department of that period. This is further exemplified by the references to the measures taken to effect savings in the number of cells required on circuits. The efforts resulted in the saving of 4300 cells.

Open Lines.—The conference dealt with such matters as the following :—

The necessity for measuring lines with a view to the setting up of reliable records of the plant.

The numbering of poles and marking them to show the year of erection.

The frequency of line inspections. Linemen to walk main routes once per week and immediately after storms; loops and spurs and offices at intervals of not less than two months.

That no larch poles be painted unless the Department be compelled to do so by Public Bodies or private individuals having control of the roads.

Method of paying gangs.

Uniforms and Satchels for Linemen.

Report forms *re* Survey of Offices and road lines.

Revision of Inspectors' Sections and Linemen's lengths.

Tools.—Complaint is made of the quality and unsuitability of the tools supplied. The result of experiments with Marshall's Patent Borer, Digger and Spanish Spoons is referred to. The Digger was a failure, but the Borer and Spoons appear to have found considerable favour.

These references indicate very clearly that " Bar and Spoon " methods were early to the fore and the knowledge of the Department's return to them under present day conditions would no doubt gladden the hearts of the 1872 conference.

Cost of Works.—" That the estimates of Costs of Works upon which the Works Orders are based shall not be exceeded without in the first instance an addendum having been obtained authorising the further expenditure."

The extracts unfortunately do not state the number of the T.E. form referring!

Week-end Leave.—Permission was given to Foremen of gangs to use a railway warrant to return to their Headquarters on the Saturday evening and to report for duty at the appointed time on the Monday morning.

There is no reference to the first available train!

W. M. CROWE.

William Miller Crowe, the Chairman and Managing Director of Ericsson Telephones Limited, has retired from 1st October, although he will still retain a seat on the Board of Directors. Mr. Crowe has been with the British Ericsson Company from its inception thirty-three years ago and for twenty-one years has been Chairman and Managing Director. He commenced his London career as Manager for the famous Mr. Edison when the phonograph was first brought to this country in 1892. Six years later he was appointed Manager in London for Messrs. Ericsson, of Stockholm, the well-known telephone manufacturers, whose business in this country at that time was chiefly with the National Telephone Co. In 1903 a private company was formed to take over the factory at Beeston, Notts., owned by the National Telephone Co.—the latter retaining one-half interest.

In 1911 the Post Office took over the National Telephone Co., and then a public company was formed by Ericssons to take over the complete factory, since which time the Company has gone on from success to success.

NEW MEASURING INSTRUMENTS.

Messrs. Elliott Bros. are about to place on the market a new series of measuring instruments which should well meet demands long felt. The first is a Frequency Indicator for use on " Standard Frequency " circuits. The calibration is 48 to 52 periods and the apparatus is fitted with an 18″ scale and the pointer has a swing of 200 degrees, the scale being divided in tenth periods, each tenth occupying nearly ½″ on the scale. It is thus possible to read accurately and easily to 1/10th period, and to estimate very much lower. The instrument operates on induction principles, with opposing resonant circuits tuned to fine limits, and is said to be practically free from wave form and temperature errors. A modified pattern can be used as a recording instrument with a pen movement which has an inappreciable time lag.

The other two instruments are for the purpose of measuring currents in links in distribution boxes and in fuses in feed pillars. The principles of the two pieces of apparatus are the same, the link or fuse being temporarily enclosed in a hinged iron circuit, the jaws of which are opened by a pair of insulated handles. Two opposing transformers are fitted at the pivot ends of the jaws and are connected to a D.C. moving coil indicating instrument which is fitted with a Westinghouse metal oxide rectifier. The instrument has two ranges with suitably marked terminals. The whole outfit weighs only a pound or two. The Link measuring set can be used also for determining the direction of current in the link—from the supply to the load, or vice versa, as sometimes happens. This is accomplished by the use of an additional contact rod, for tapping on to the neutral, connected to a special capacity terminal on the instrument. An increase in deflection indicates that the current is passing through the link in the direction of the arrow marked on the transformer, a decrease the reverse.

TRANSPORT SECTION.

In last issue and also in the Staff Changes given at the end of this number the names of officers transferred and promoted to this new engineering section appear. We take the opportunity of welcoming these officers to the engineering side and trust that not only will they join the Institution and support the Journal, but also contribute to its pages. Motor transport has become an integral part of the Engineering Department organisation and we shall be pleased to lay our pages open for articles dealing with this important branch of the service.

YOUNG PEOPLE'S OWN TELEPHONE EXHIBITION.

An instructive exhibition is being held in the Indian Hall of the Imperial Institute from the 5th to the 23rd January, 1932. Although primarily arranged for young people, the exhibition deals with every phase of communication engineering, and should prove of the greatest benefit to everyone interested in the science. Admission to the exhibition is free.

HEADQUARTER'S NOTES.

EXCHANGE EQUIPMENT.

The following works have been completed :—

Exchange.	Type.	No. of Lines
Tile Hill	New Auto	200
Sheldon (Birmingham)	,,	300
Folkestone	,,	2200
Bristol Central	,,	5030
,, North	,,	1990
,, South	,,	970
,, West	,,	3290
,, Bedminster	,,	875
,, Easton	,,	1485
,, Kingswood	,,	565
,, Stoke Bishop	,,	515
,, Westbury	,,	1080
,, Whitchurch	,,	80
Rottingdean	Auto Extn.	70
Leeds	,,	800
Brighton	,,	2320
Edgware	,,	1500
Colchester	,,	Observation Equipt.
York	,,	Re-arrangements
Coventry	,,	,,
Dorchester	New Manual	540
Staines	,,	1460
High Wycombe	,,	2000
Palmers Green	Manual Extension	800
Northampton	,,	Observation Equipt.
Kilmarnock	,,	240
Norton Grinding Wheel, Newcastle-on-Tyne	P.A.B.X.	30
British Tube Mills, Smethwick	,,	30
McIlroy, Ltd., Reading ...	,,	30
Crane Bennett (London) ...	,,	30
Newcastle-on-Tyne Police ...	,,	30
Nusenbaum, Ltd., Newcastle-on-Tyne	,,	20
Southend Corporation	,,	40
Northern Aluminium, Oxford	,,	30

Orders have been placed for the following :—

Exchange.	Type.	No. of Lines.
Sutton Coldfield	New Auto	1700
Stechford	,,	800
Priory	,,	900
Preston (Torquay)	,,	600
Acocks Green	,,	1800
Kensington	,,	8800
Gerrard	,,	Main Frame
Terminus	,,	4480
Aston Cross	,,	2600
Acomb—York	,,	300
London Trunk (4th Floor Annexe)	,,	Positions
Urmston	,,	Power Plant
Churston	,,	,,
Horsforth, Leeds	,,	,,
Sutton Coldfield	,,	,,
Bury & Darwen	Auto Extn.	Observation Equipt.
Bolton & Rochdale	,,	,,

Exchange.	Type.	No. of Lines.
Farnworth	,,	Observation Equipt.
Bermondsey	,,	Voice Frequency
Fulham	,,	,,
Sloane	,,	,,
Temple Bar	,,	,,
Welbeck	,,	,,
Leeds Central	,,	Additional Selectors
Southampton No. 4	,,	Manual Board
Bermondsey	,,	Toll Control
Hereford	,,	Manual Board
Welbeck	,,	Toll Control
Cosham	,,	200
Hartlepool	,,	210
Four Oaks	New Manual	960
Elmbridge	,,	4180
Ashtead	,,	640
Uxbridge	,,	Power Plant
Wisbech	,,	720
Bury St. Edmunds	,,	780
Burnham	,,	540
Slough	Manual Extension	Observation Equipt.
Windsor	,,	,,
Beaconsfield	,,	,,
Thackery & Co., Leeds ...	P.A.B.X.	30
aily News, London	,,	40
Berkshire County Council ...	,,	30
Phillips J. & N. (M/R) ...	,,	Re-arrangements
Applin & Barrett, Yeovil ...	,,	30

Two new systems of automatic working are being tried experimentally in London and the Provinces. The Standard Telephones & Cables, Ltd., have developed a scheme known as the " Bypath " system which will be adopted at Bethnal Green and Burton-on-Trent; the latter includes two satellite Exchanges.

The Automatic Telephone Manufacturing Company are installing at Arnold (Wembley) and at Wigan, two new telephone exchanges incorporating their " Strowger Common Control " system.

The Bypath and Common Control systems were described in the July issue of the Journal. It is hoped that the Exchanges concerned will be completed and brought into service early in 1933 and it will, of course, be necessary to observe the behaviour of apparatus under practical conditions for some considerable period before individual performance can be judged and a verdict given as to the merits of either system.

Retirement of Mr. R. Halton.

With the retirement of Mr. R. Halton from the Engineering Department of the Post Office, on the 4th November, the Department has lost one of its most energetic and painstaking officers.

Mr. Halton entered the Post Office Service in the Manchester Telegraph Office in 1886 and was transferred to the Engineering Department at Manchester in 1894, then under the charge of Mr. John Doherty. In 1900 he was promoted to an Engineership in the Ipswich Section and during the following nine years was actively engaged in the general development of that area.

In 1909 Mr. Halton was transferred to the Telegraph Section of the Engineer-in-Chief's Office and after two years was appointed to the position of Executive Engineer, Birmingham.

With the formation of the South Midland District in 1912 he was placed in charge of the Technical Section at Reading. During the War period he was very largely occupied in meeting the requirements of the Fighting Services. With a Naval Base at Portsmouth, an important transport base at Southampton and numerous training camps within the District, the time proved a strenuous one and as will be realised there were no fixed hours of duty.

Up to 1928 Mr. Halton was engaged in the telephone development of the District from both a Main and Local point of view and was largely concerned in the successful laying of the London-Southampton-Portsmouth and the London-Bristol Main Backbone Cables.

In 1928 he received his last Departmental reward of efficient service in promotion to Assistant Staff Engineer Lines Section in place of the late Mr. Walter E. Twells. In addition to the supervision of the normal work of the post Mr. Halton performed yeoman service in completing a valuation of all items included in a new Inventory of Line Plant and in this he leaves a record of his work which will remain for many years to come.

Always cheery and ever ready to draw upon his fund of extensive experience to help a colleague, Mr. Halton has, in addition, been associated with several matters of great importance to his colleagues in connection with Salaries, Status and other Service questions. He served on the Executive Committee of the Society of Post Office Engineers for a number of years and held the position of Chairman for three years.

Mr. Halton appeared as a witness before the Industrial Court in 1926 when the case for Executive and Assistant Engineers was presented. This work involved a great amount of self-sacrificing labour on the part of Mr. Halton—willingly given on behalf of all his colleagues.

Our best wishes go to him on his retirement.

MAIN CABLE TESTING & BALANCING COURSE
7th SEPT - 28th NOV 1931

H. Hartshorn, Leicester; J. A. Ditchfield, Blackburn; W. Clarke, Preston; A. G. Coates, Oxford; R. W. Hale, York; A. E. Twycross, Derby; P. G. Bigwood, Stoke-on-Trent; H. Brook, Bradford; S. W. Smith, Bradford; J. W. H. Boon, Newcastle; J. Qeen, Newcastle; J. Bingham, Newcastle; W. McKendrick, Edinburgh; H. A. Buy, Oxford; F. P. Fable, Guildford; C. H. J. Fleetwood, School Staff

E. H. Seymour, London; L. F. J. Brunel, Guildford; G. R. Sudell, Sch. Staff; W. Batchelor, Dundee; R. A. A. Freshwater, London; T. A. Marks, Guildford; A. T. Stovold, Brighton S; H. V. G. Davies, Bournemouth; A. Lee, London; A. G. England, Birmingham; G. E. H. Body, Plymouth; C. D. Scrafton, Newcastle; W. E. C. Roberts, Plymouth; R. E. Robins, Reading; A. G. Veneer, Brighton S; W. O. L. Goodwin, Canterbury W; F. T. Loveland, London; C. Baldey, Canterbury W

J. H. Broadhurst, Canterbury E; E. P. O'Neill, Glasgow; G. A. Yates, Nottingham; W. T. Palmer, E-in-C Lecturer; S. Hanford, E-in-C Lecturer; G. W. Hodge, E-in-C Lecturer; G. T. Crabb, Liverpool; E. W. Lettsome, Bangor; J. Gerrard, Liverpool; F. A. E. Janks, Brighton N; T. P. Steel, York.

Cable Instructional Course at Dollis Hill.

A course in Cable Balancing and Precision Testing was held at Dollis Hill Research Station commencing September the 7th, 1931.

The Course lasted 12 weeks, and was attended by 40 members of the Department's Staff, representative of England, Scotland, Wales, and Northern Ireland.

The first fortnight was devoted to a series of lectures by Mr. W. T. Palmer upon suitable Elementary Mathematics and A.C. Theory. An innovation was the introduction of an examination at the end of this fortnight's work, and the 40 officers mentioned above were the survivors of this ordeal—a three hours' paper consisting of 12 questions on Mathematics and Electricity.

All officers attending were either of Inspector rank, or were Skilled Workmen graded as Acting Inspectors for the duration of the Course.

Three weeks were spent in lectures by Mr. G. W.

Hodge on the methods of measuring capacity unbalances in underground cables and of making selections. Mr. Hodge also gave very lucid explana- of the methods of rebalancing cables and of actual cable design and manufacture.

By the courtesy of the Standard Telephones and Cables, Ltd., parties of students were able to visit the North Woolwich works of that firm to see cables and loading coils in various stages of manufacture.

A fortnight was also spent in carrying out balancing work, using both the Double Bridge and the 15 Position Testing Switch and in wrestling with actual selections—the latter being from Mr. Hodge's repertoire.

Mr. W. T. Palmer again took over the class for the last five weeks, during which time four weeks were spent in consideration of the subject of Precision Testing of cables for fault localisation, including the latest A.C. methods and the study of Impedance frequency curves.

A week's practical work was spent in the Laboratory, when particular attention was given to the Murray and Varley tests for incipient faults.

During the weeks in the Lecture Hall many practical examples were worked out by the class, and a number of interesting slides and films were shown.

The officers attending the course had ample opportunity for discussion and exchange of views both between themselves and with members of the E.-in-C's Headquarter's Staff.

This in itself should help greatly in the matter of co-operation, and should be of undoubted help to those attending the Course when carrying out their duties in the future.

In addition, all felt at the conclusion of the Course, that they had gained a broader outlook and a greater understanding of the working of the Department.

The termination of the Course was marked by a convivial evening which embraced a visit to a Variety Theatre and a supper at a neighbouring hostelry, the lecturers and all members of the class being present.

Accompanying this article is a photograph of the lecturers and members of the class who attended this Course.

Unfortunately, Mr. J. L. Winter, of Belfast, Northern Ireland, who also attended, was inadvertently omitted from this group.

A. G. Coates.

Commendable Conduct in Emergencies.

From time to time one hears, often quite incidentally, of creditable conduct on the part of Engineering Department's workmen in difficult, and sometimes dangerous emergencies. It generally happens that the occasion demands a clear perception of the preventive or remedial measures which are necessary; instant action is usually imperative; hesitation means ruin, and, not infrequently, courage and endurance are required either to save the plant or to maintain the service.

In two recent cases the men concerned have received the appreciation and commendation of the Engineer-in-Chief for their conduct. These are but examples of the kind of good work which emergencies seem always to call forth and which, happily, the men themselves are content to regard as "all in the day's work." It is proposed to chronicle such cases in the Journal as they come to hand.

Southampton Section.

Men concerned.

G. T. Fenner, Acting S.W.I.
H. O. Lewis, S.W.II.
W. Palmer, S.W.II.
R. W. Smith, U.S.W.
L. Doswell, Labourer.

Action.

On 4th August, these men successfully sealed or wrapped up joints in manhole when latter was flooded by sudden inrush of water. Their prompt action in face of danger prevented serious damage to cables and avoided serious delay to Shirley Exchange transfer.

Middlesboro Section.

Men concerned.

A. Chapman, S.W.II.
J. F. Chapman.
J. E. Iles.

Action.

River Leven in flood. A. Chapman waded river waist deep to Stokesley Exchange and finding equipment in danger telephoned for assistance. J. F. Chapman and Iles came through the river, and the men together raised M.D.F. and switchboard and thus maintained the service from interruption.

Mr. William Cruickshank.

Mr. William Cruickshank, Assistant Staff Engineer, of the Research Section, Engineer-in-Chief's Office, who retired from the service on 31st October, 1931, on attaining the age limit, has been Managing Editor of this Journal for 18 years and is well known to many of its readers at home and abroad.

He was born at Keith, Banffshire, on 26th August, 1871, and after a short period as S.C. and T. at Keith, he was transferred to Aberdeen in 1889. At Aberdeen he was employed as special wire telegraphist for the Aberdeen Journal and thus at an early stage of his career became closely associated with journalism. He studied technical subjects at Gordon's College, Aberdeen, and won the City and Guilds of London Institute Silver Medal in Honours Telephony.

He was appointed to the Engineering Department in 1901 and after a short period of service in Manchester, where he succeeded Mr. T. E. Herbert as lecturer at Manchester Technical College, he was appointed Sub-Engineer at Holloway Factory. In 1905 he was transferred to the Engineer-in-Chief's Office and assisted Mr. S. A. Pollock in research

MR. W. CRUICKSHANK.

work on loading coils. He produced the Telegraph Diagram Book in 1906 and the Telephone Diagram Book in the following year. This work was carried out practically in his spare time.

He pursued his studies at the Northampton Institute and after going through the complete course of training in Electrical Engineering, he took first place in the Final Examination in both the D.C. and A.C. courses and third place in Electromagnetic Theory and Vector Calculus. He then joined the teaching staff of the Institute and for fourteen years lectured on Telephony and Telegraphy with outstanding success.

During the early war period he assisted Col. Purves in designing new signal apparatus for the Army in the field. In 1916 he was sent to Chatham and became Chief Signal Instructor to the Eastern Command. After the Armistice he was sent to Cologne and took charge of the installation of a 25-position Exchange for the Headquarters of the Army of the Rhine. For these services he received the personal thanks of the Secretary of State for War.

Mr. Cruickshank organised and installed the Post Office exhibit at the British Empire Exhibition at Wembley in 1924. The exhibit included the first Director, C.C.I., and Tandem models ever erected, manual exchanges, printing telegraphs and a model of the P.O. Tube Railway. For the opening ceremony he proposed and arranged successfully the sending of a message by the King round the world by the Imperial route. This was accomplished in 80 seconds.

He was appointed Executive Engineer in charge of the Telegraph Group of the Research Section in 1924 and in 1928 he succeeded Mr. P. J. Ridd as Assistant Staff Engineer in charge of the groups dealing with telephone transmission, telegraphs, cable research and cable acceptance. He has edited the Research Bulletin since its inception.

For several years Mr. Cruickshank was examiner in Telephony and Telegraphy for the Civil Service Commissioners for the Inspectors and Assistant Engineers' examination. He has written many articles and papers on various subjects and was awarded the I.P.O.E.E. Senior Bronze Medal for his paper on "Voice Frequency Telegraphs." He is Reporter on Telegraph and Telephone Progress for the Institution of Electrical Engineers. He was responsible for and installed the Electrical Communications Section of the recent Faraday Centenary Exhibition at the Albert Hall.

The foregoing is but a sketch outline of Mr. Cruickshank's fine record of zealous and useful service. A strong and honest man in every sense of the term, he throws himself wholeheartedly into every work he undertakes. The greater and more difficult the task, the more he enjoys its accomplishment. He possesses to a high degree some indefinable personal quality which turns colleagues and associates into fast friends, and which earns the love and respect of younger men and subordinates. In spite of the many years he has spent in the Metropolis he still carries about him the refreshing atmosphere of his native Scottish hills and throughout his career he has nobly upheld the best traditions of his countrymen.

Those of his colleagues who have been closely associated with him in the conduct of this Journal will greatly miss him. The consistently high standard and the eminently successful career which the Journal has enjoyed are due in bountiful measure to Mr. Cruickshank's painstaking and farseeing work on its behalf. Contributors and subscribers all over the world will regret his retirement from the Managing Editor's chair at the end of the present volume.

A fine cricketer, an expert swimmer and water polo player, a sound half-back but an indifferent golfer, Mr. Cruickshank has always enjoyed robust health and his fine physical fitness remains unimpaired. He is still a young man mentally and physically and it will be characteristic of him to make as great a success of his retirement as he has made of his official career.

Rather wistfully, we say to him as official colleague, as Managing Editor, but above all as friend —Farewell. We wish it had been possible to defer the occasion for the saying of it a little longer. But no man has better earned his freedom, and colleagues, friends, readers and contributors will all join in wishing him and Mrs. Cruickshank very many years of continued good health and happiness.

J.J.McK.

DISTRICT NOTES.

LONDON DISTRICT.

Growth of Telephone System.

Direct Exchange lines	420,808
Telephone Stations	708,154

Increase during Quarter : 2991 exchange lines and 4377 stations.

During the three months ended 30th September, 1931, the following changes occurred :—

Telephone Exchange.—Net increase of 300 miles overhead and net increase of 59,182 miles underground.

Telephone Trunks.—Net increase of 8,690 miles underground.

Telegraphs.—Net increase of 77 miles underground.

The total single wire mileage at the end of the period under review was :—

Telephone Exchange ...	2,985,158 miles.
Trunks	121,188 ,,
Telegraphs	26,771 ,,
Spares	56,845 ,,

Whitehall Automatic Exchange.—The new Whitehall Automatic Exchange was successfully opened on the 3rd October at 1.30 p.m., the following lines being transferred to the new equipment :—

1429 from the hypothetical exchange on Gerrard.
408 ,, Regent.
428 ,, Gerrard.
23 ,, Victoria.

A total of 1868 junctions and order wires was also transferred.

A short article on Whitehall Exchange is given elsewhere in this Journal.

" Eng " Repair Service on Automatic Exchange.—The Engineering Repair Service instituted on July 15th this year continues to function satisfactorily and is without doubt proving effective in clearing subscribers' troubles expeditiously and quickly bringing to notice common apparatus faults. The fact that subscribers by dialling " ENG " can obtain direct access to the Test Desk, where an immediate test of the line and apparatus can be carried out to ascertain the nature of the conditions causing trouble, is of considerable value in effecting improvement in the service given to each individual subscriber.

Conversion of Manual-Automatic Exchange Traffic to Voice Frequency Working.

Manual Exchanges.—The conversion of the " A " position cord circuits to Voice Frequency working at 64 manual exchanges throughout the District is proceeding rapidly. The exchanges are divided into groups to be converted in priority order and it is hoped to have the first group of five exchanges ready for change-over in January.

Automatic Exchanges.—Spare Keysender " B " apparatus at the working automatic exchanges has been collected by the equipment contractors for conversion to straightforward Junction working and it is anticipated that the first group of 45 junctions will be available early in January. The tuned V.F. Relay sets are being fitted by the Department's staff. As groups of junctions are converted to V.F. working, further quantities of K.S.B. apparatus will be made available for modification to a straightforward junction basis.

Introduction of Trunk Demand Working to Birmingham.

To cater for the first step in the introduction of the " Demand " scheme on the Inland Trunk System, the record positions on the 5th Floor, G.P.O. South, have been provided with additional outgoing multiple and also relay sets for extra record circuits from the London Automatic Evchanges. The Department's engineers have installed a 22 volt S.F.J. Transfer position in the Trunk Exchange 3rd Floor. Circuits from the 5th floor multiple worked on S.F.J. principles to this position are utilised to reverse calls from manual subscribers over the junction route from Trunks to the manual exchange Trunk position, thus ensuring that the Demand operator's answering supervisory lamp is controlled by the subscriber's switch-hook.

Demand working to exchanges in the Birmingham local fee area was inaugurated on Saturday, November 28th. In the meantime a large suite of Demand and Delay positions is being installed under contract on the 4th floor, G.P.O. South. This suite is wired for 50 volt working and it is hoped to transfer all Demand and Record work thereto in April, 1932, thus releasing the 5th floor positions for modification to 50 volt working. It is expected that these positions, after conversion, will be used solely for calls from automatic subscribers in the London Director area.

Toll Control.

Automatic Exchanges.—Rearrangements of the " A " board distribution at Director exchanges in the five mile circle are being carried out by the Department to clear positions ready for the contractors to instal the necessary Relays Sets, Time Checks and Cord circuits for controlling Toll calls from the local exchange, thus giving considerable relief to the Toll " A " exchange.

Manual Exchanges.—Similar rearrangements are in hand at Manual Exchanges in the five mile circle. In these cases the cord circuits, time checks and associated apparatus will be installed by the Department's local staffs. Two entirely new features introduced on these positions are the Time Check circuits which give a visual indication of the actual conversation time on Demand Calls, and the Visual Idle Indicating lamps which indicate only one idle circuit at any instant. Directly this idle circuit is appropriated the next idle circuit lamp is illuminated.

Ford's Works at Dagenham.

As is generally well known, Messrs. Ford are opening a very big factory at Dagenham, Essex. The site is $1\frac{1}{4}$ miles square. One side skirts the Thames; the opposite side of the main road from London to Tilbury. A lead-in of $1\frac{1}{4}$ miles is not often met with, but in this case the offices are at the riverside. Many exchange lines and private wires were required and literally hundreds of extensions. One of the buildings is approximately 1000 feet square; the floor space is kept clear of everything except things essential for motor-car building.

Machinery and furniture were removed from the Manchester Works and brought by special trains to Dagenham. On arrival they were assembled and got ready for work in short time. Telephones were required for use as the furniture was placed in position.

At the outset it was arranged that the external staff should take all the telephone work except the fitting of the switchboard, this being an "Installation" area. Cables and wires were run about the building in all manner of places to avoid fouling the machinery to be used. Telephones were placed at selected spots, connected up and left so that when the furniture was placed in position the telephone was lifted on to the table and service was available at once.

The success of the work by the Post Office brought from the chief representative of Fords in this country the statement that he was well pleased with what had been done and turning to his colleagues remarked:

"*Who says that a State service cannot be efficient?*"

Messrs. Baldry, Chief Inspector, and Hawkes, Inspector, were responsible for the work.

Teleprinter Working.

The number of circuits in the C.T.O. modified to Teleprinter working is increasing apace, and there are now 290 working positions so equipped.

Two recent events of widespread interest, the General Election in October and the feverish activity in Dublin in November have necessitated provision of special telegraph facilities. It is pleasing to note that the plant installed for these occasions met the demands upon it without difficulty or hitch.

A S.T. & C. 12-channel Voice Frequency Telegraph equipment has been installed in the C.T.O. The equipment is of a new pattern and has been provided to facilitate the release of physical circuits on the long underground cables to the north. The Voice Frequency equipment has been provided by the S.T. & C. Ltd., and the accompanying batteries, generator, etc., were provided by the Engineers of the London District. The system provides for the C.C.I. new standard frequency spacing of 120 cycles. The present equipment has a capacity for 18 channels, and it is possible to extend the racks to cover a total equipment of ten sets of 18 channels each. A description of the special features of this new equipment will no doubt appear in a later issue of the Journal.

SOUTH MIDLAND DISTRICT.

Diversion of P.O. Plant.

Guildford.

The main London-Portsmouth Road passes through the towns of Guildford and Godalming and during the summer months the traffic carried by this road is exceptionally heavy. Very bad congestion occurs at week-ends and it is a common occurrence for a line of vehicles a mile in length to be held up owing to congestion in Guildford High Street. Somewhat similar conditions, but less serious, occur at Godalming.

With a view to diverting the bulk of the traffic from the narrow Guildford and Godalming streets the Surrey County Council are constructing a by-pass road, which commences at a point approximately one mile N.E. of Guildford and rejoins the present Portsmouth Road at Milford. The latter place is approximately two miles S.W. of Godalming, so that when the new road is completed both Guildford and Godalming will be by-passed.

The new by-pass road crosses the Hog's Back near the old Toll Gate at Compton Lane and, owing to the steepness of the hill, a cutting approximately 120 feet wide and 40 feet deep is being made, so that the old Guildford-Farnham Road will be carried on a bridge above the new road.

In order that the cutting and bridge work could be carried out as quickly as possible a temporary road was made on the adjoining fields, so that the whole of the Guildford-Farnham Road could be cut through and the bridge constructed without hindrance from traffic.

The following P.O. plant was affected by these operations:—

London-Southampton-Main overhead trunk route, 58 wires.
London-Southampton-Main trunk cable, 254/20 M.T.
Guildford-Reading-Basingstoke trunk cable, 74/70 Quad.
Guildford-Aldershot-Farnham trunk cable, 54/70 M.T.

The alterations necessary to the overhead route presented no difficulties, but the cables, which are all loaded and balanced, required special treatment, as approximately 120 feet of the two duct lines would have to be cut out.

In the case of the 74/70 and 54/70 cables it was decided to draw out one length of each (176 yards), and to make good the circuits by providing four 15 pr/20 aerial cables erected on four poles sufficiently high to avoid fouling the crane used for the bridge works.

The remaining cable, 254/20 M.T., carries a large number of important telegraph, and side and phantom telephone circuits, the latter being repeatered at Guildford, and in view of the expensive and tedious work involved in providing a special cable, tapping out, numbering, diverting, etc., and also the fact that 27 special circuits for the Schneider Trophy arrangements were working through the cable, it was decided to try and keep the cable intact whilst the road and bridge works were in progress.

To support across the cutting the 120 feet length of cable, the weight of which is approximately ½-ton, it was necessary to provide two short stout poles, with back stays, and to erect between them three 7 strand suspension wires, and to sling the cable in a similar way to an aerial cable.

In view of the weight of the cable and the fact that it was fixed at either side of the cutting, it was necessary to ensure that there should be no sag in the suspension wire. This was effected by erecting the top two suspension wires six feet above the ground and lashing them to the lower suspension wire which was at ground level and carried the cable. Then by adjusting the lengths of the slings the cable was carried across at the same level as the duct line.

The cable was wrapped to prevent possible damage, but in order to facilitate the road works the Surrey County Council decided on blasting operations, and as this work was carried out underneath and close to the cable special protection had to be provided. A tight wrapping around the cable would not have prevented the cable from being hit and damaged, and it was therefore decided to provide a cage approximately two feet in diameter made up of expanded metal and slung from the suspension wire so that the cable was totally enclosed.

The cable will probably remain suspended in this manner for approximately six months, and the arrangement for protection and suspension has so far proved quite satisfactory.

Although the cable will to a certain extent hinder the bridge works, the Surrey County Council Engineer, on learning of the importance of the circuits concerned, readily agreed to the proposal and has given every assistance possible, particularly in regard to preventing possible damage to the cable.

Apart from the inconvenience which would have been caused by having a large number of important circuits diverted into temporary cables for a long period, the retention of the cable in its original position has resulted in a large saving in labour costs.

NORTH EASTERN DISTRICT.

Laying of Three 4" Steel Pipes Across River Ouse at Boothferry.

Owing to the failure of the armoured trunk cables across the River Ouse at Boothferry and the evident insecurity arising from the use of this type of cable, it was decided to lay three 4" steel pipes at a point some little distance to the west of the existing crossing and to draw in lead-covered cable of the ordinary type.

The laying of these pipes proved to be a much more difficult job than was anticipated, as the contractor's original proposal to pull the pipes across the river bed by means of a traction engine and steel hawser attached to the pipes by a torpedo head failed after several trials, and ultimately that method had to be abandoned.

The procedure successfully adopted was that of providing a rail runway in the fields adjoining the river bank, on which the whole length of the three pipes, screwed and welded, necessary for the crossing, was laid.

Fig. 1.—General view showing commencement of Runway.

This runway led to the river bank and then sloped down to the river bed.

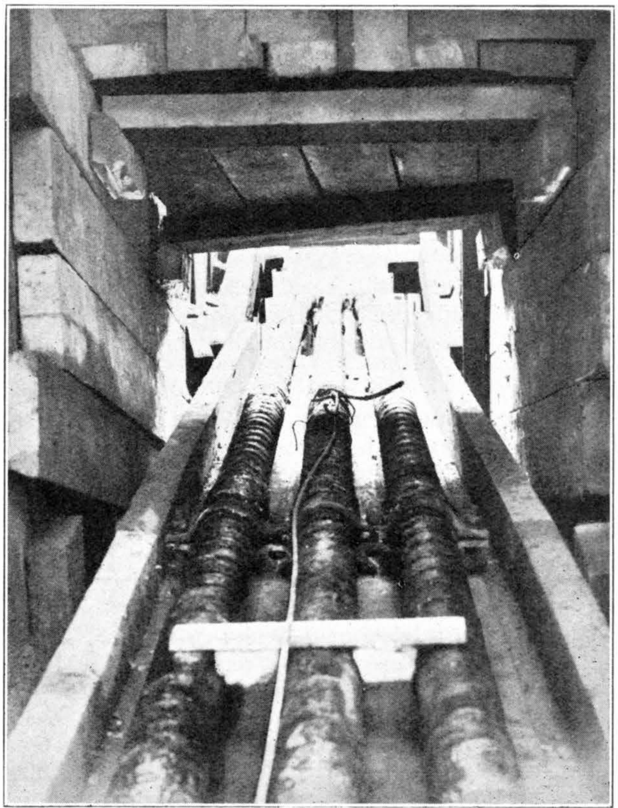


Fig. 2.—Pipes down Chute to Water.

Before the pipes left the runway, steel hawsers were attached to the pipes at different points in the length, and, as the pipes entered the river, the other ends of the hawsers were fastened to barges.

After the first barge had proceeded a distance across the river, along the route already dredged, the second barge took up its position to " hold up " the second length of pipe, and so on, until six barges were

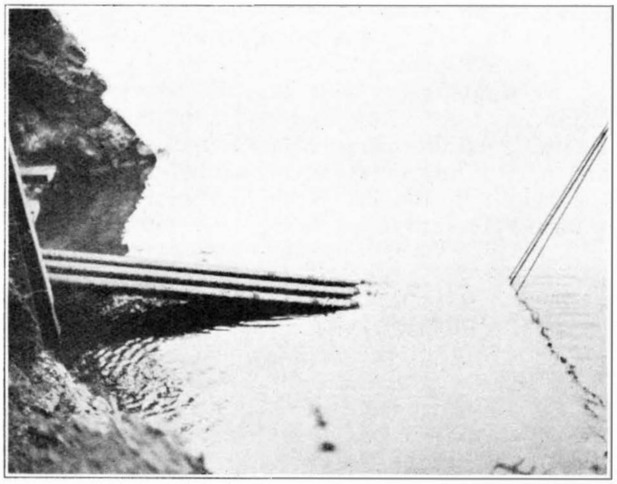


Fig. 3.—Pipes being drawn down Chute into water with Suspension Hawser from first boat.

strung across the river, each holding up a length of pipe.

At a given signal, the barges simultaneously lowered their lengths into the trench, and the crossing was complete.

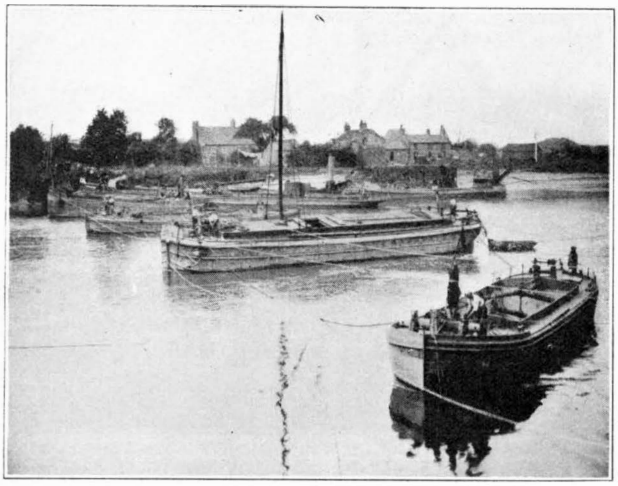


Fig. 4.—The barges in position.

The tests proved that the whole length of pipes was satisfactorily laid and the cable was then drawn in, tested, and found to be in order.

Erection of Poles by Crane fitted on 3-Ton Albion Lorry.

The forward movement as regards costs could only lead in the direction of the greater utilization of machine-power instead of man-power, and one of the greatest strides in that movement was taken when it was decided to endeavour to cut man-power out of the work of handling poles during erection and recovery.

Between Chalk Hill and Grimsby recently it was

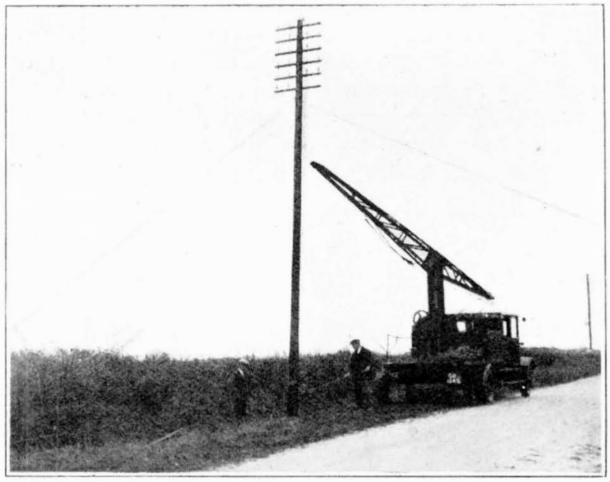


Fig. 1.—Crane on 3-ton Albion lorry. Lifting Jack in position.

necessary to effect pole renewals, and the work was suitable for the trial of the 3-ton Albion lorry fitted with jib crane.

The poles to be renewed were first lifted clear of the ground level by means of pole jacks and pushed by a jack to the side of the hole to make room for the erection of the new pole.

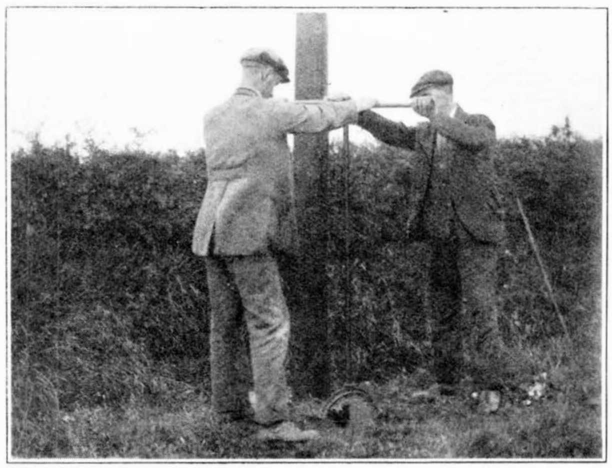


Fig. 2.—Enlarging holes with Augur.

As the diameter of the new pole was larger than that of the recovered pole, the pole hole was enlarged by using a 14″ Iwan Augur. After this enlargement, the lorry was jacked up, and the new pole was lifted by the crane and jockeyed into position immediately over the pole hole, lowered into the hole and the ground punned and finished off. The wires were changed over, and the recovered pole lowered to the ground.

The work in question also provided for the erection of A poles at some points in place of the existing single poles.

The same procedure was followed as regards the lifting of the existing pole out of the ground, but the pole hole now vacated would not, of course, take the A pole, and it was necessary, therefore, to enlarge that hole to approximately *half the size* of the pole hole ordinarily required for an A pole, owing to the fact that the crane could lift the A pole vertically in such a way as to drop it into position: the hole was then filled and punned, wires changed over, and the recovered pole dropped in the manner already illustrated by the photographs.

It is of interest to know that the maximum working load of the crane is 1 ton and the maximum operating radius measured from the central pillar, and when lifting over the side of the lorry, is 9′ 6″. The height of the lift is approximately 20′, thus allowing poles up to 40′ being dealt with.

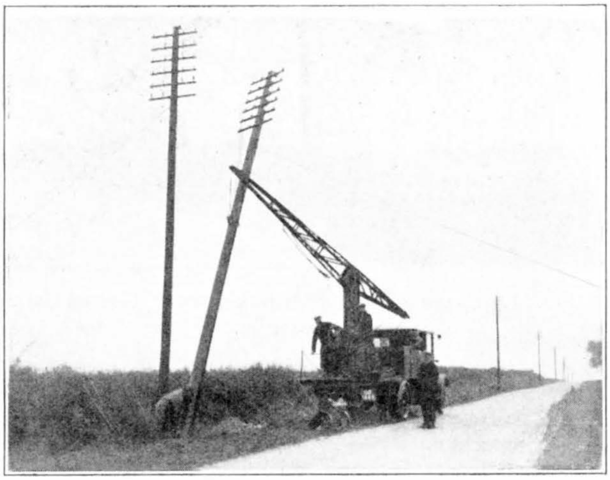


Fig. 3.—New pole being lowered into position.

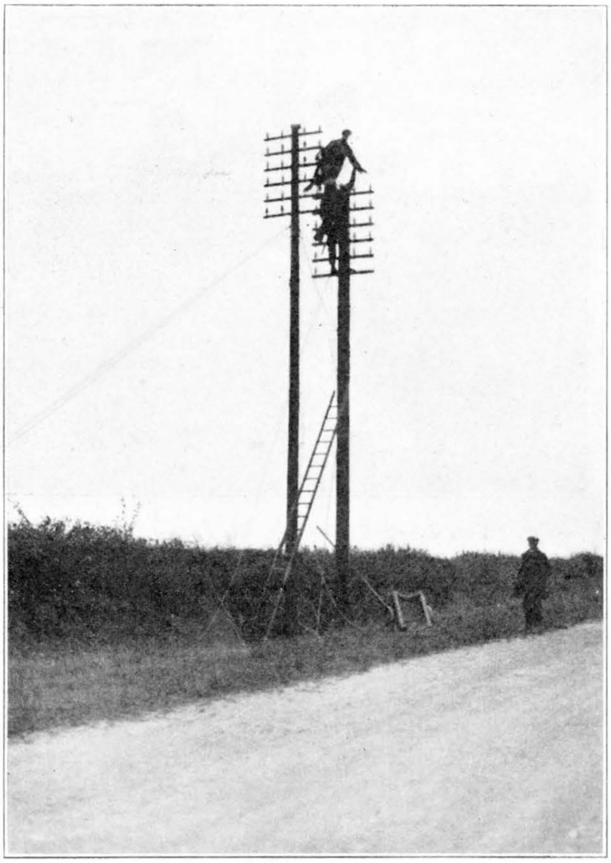


Fig. 4.—Changing over the wires.

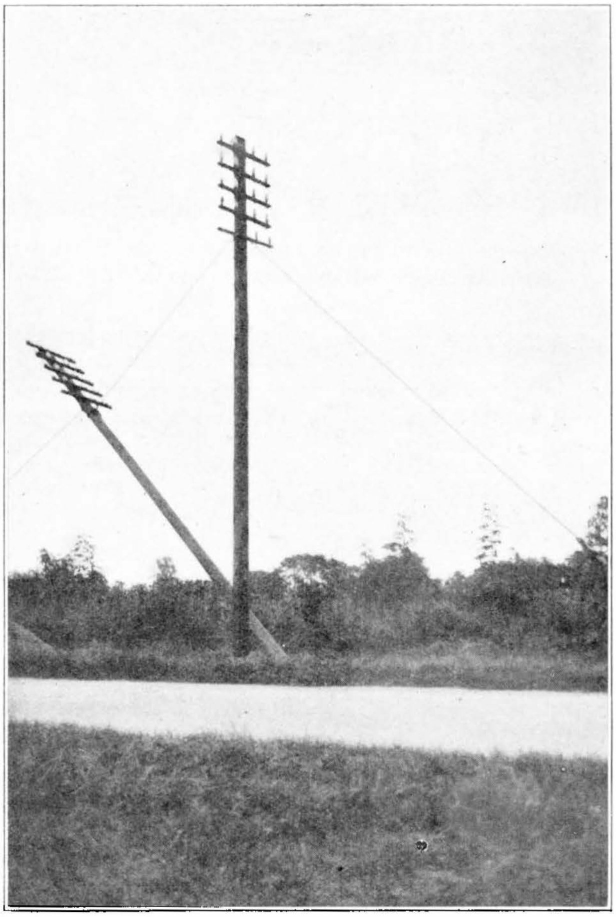


Fig. 5.—Lowering recovered pole.

This is only a brief statement of the use of the crane lorry, which cuts out all risks of accident to the men in the handling of poles of the sizes referred to, and consequently the "safety first" policy is being considerably furthered by the utilization of the crane lorry method of erecting and recovering poles.

It does not require much imagination to appreciate the possibilities which lie before us in this forward movement, as the saving of man-labour has not only a direct financial effect upon costs, but an indirect beneficial effect upon the men, which in turn must prove to be to the financial advantage of the Department, inasmuch as it is reasonable to assume that the less power you take out of man, the longer he will last as an effective unit in our organisation.

NORTH WESTERN DISTRICT.

Visit to the North Regional Station (B.B.C.).

On a fine day in September members struck a new note and visited Moorside Edge. The approach, which was made from the Lancashire side, gave one that top of the world feeling which is experienced on the moors. On arrival, guides were provided, who first of all pointed out the items of interest outside the station, including the 500 feet masts. These are massive structures and are built up in seven sections The stay connections present a neat and efficient appearance. The wires on smaller poles carry the modulated current from the output valves to the Transformer Hut where it is passed to the aerial.

The station building is a one storeyed affair and appears strong enough to withstand the most severe weather. Ample accommodation is provided and everything looked spick and span. The lay-out in the various rooms was admired, particularly in the transmitting hall where are housed the transmitters for both the National and Regional aerials. The valves, which are in cascade of seven, had a low tension current of the astounding value of 1100 amps. Our guide mentioned the water cooling device and we spotted a temperature of 84°C. Broadcasting was taking place on one of the aerials and members saw the station under working conditions. The transmitting hall was strangely quiet except for the faint strains of music from the " listening " room.

In the engine room are four Diesels, each of 345 h.p., three of which are used when both transmitters are in action. In the event of a breakdown of the prime movers, a 220v/2000 A.H. battery is available to maintain the station for 1½ hours. We were impressed by the " batteries " of motor-generators which supply the H.T. Each set consists of a motor directly-coupled to two generators, each of the latter having two windings and two sets of commutator segments. Each winding generates 300 volts and, the four sets of windings being in series, a total voltage of 1200 is supplied without the special need of a highly insulated machine. (This arrangement was introduced, it is believed, for the first time by the Department at Rugby). The maximum voltage to frame is only 300. One set is for the North Regional, one for the North National and one is a standby.

The many safety devices for the protection of the staff and the apparatus were interesting. Our imagination was again aroused by the label " Ice melting plant." This apparatus allows the aerial wires to be earthed at one end and a low tension current passed along just sufficient to warm the wires of the aerials.

The station is started up half an hour before transmission commences and members had the opportunity of seeing the preliminary preparations for tuning up the second transmitter. These included visits by the engineers on duty to various rooms for the purpose of throwing in numerous switches and checking meters according to a routine plan based on " Safety first."

The party also saw the microphone and the gramophone which will be used to provide a programme in the event of the complete failure of the land lines connecting the studios with the station.

The visit was unique, full of interest and was consumated by an excellent tea at the " Flying Horse," Rochdale.

Retirement of Mr. S. Upton, M.I.E.E.

Mr. S. Upton.

Stephen Upton, Assistant Superintending Engineer, North Western District, who retired on the 31st August, 1931, began his service as a telegraphist at Grimsby in 1887. In 1896 he was transferred to the Engineering Department as a Junior Clerk, and by 1900 had attained Engineer rank, finally becoming Assistant Superintending Engineer in 1928. During these years he acquired wide experience in telegraph and telephone practice in London and the Provinces as well as in Ireland.

His entry into the Engineering Department coincided with the acquisition of the Trunk Service in 1896, and from 1902 to 1909 he was engaged in telephoning London in competition with the old N.T. Company. He was soon grappling with automatics and carried out two of the earliest transfers to Auto. working—Accrington in 1914 and Blackburn in 1916.

Stephen Upton had always a very keen interest in educational work, and while still a telegraphist did pioneer work in connection with technical classes and examinations. Throughout the many years he was in charge of Engineering Sections he maintained a lively personal interest in the recruitment and training of his staff, regarding this as not the least important of a Sectional Engineer's managerial responsibilities.

In I.P.O.E.E. matters his enthusiasm was unbounded. In addition to having been a member of the Council he contributed many papers and could always be counted upon to attend the meetings of the local Institution and, what is more, to take a valiant part in the discussions.

He was as excellent on paper as in the realm of practical engineering. Himself rapid, bright, trenchant and concise in style, and a scrupulous grammarian, he was impatient of anything less than the best in official correspondence; and an I.P.O.E.E. afternoon that will long be remembered was when he read a paper entitled "Official correspondence and Report Writing."

He respected traditions; particularly the ancient tradition that "Manners maketh the man." Very approachable, sympathetic, genial and courteous, unsparing of self, he possessed in a unique degree the faculty of laying himself alongside all sorts and conditions of men. The little leisure he could snatch from a very full official life he devoted to practical sociology and kindred aims, to which he now looks forward to giving all his energies.

SOUTH WALES DISTRICT.

Retirement of Mr. G. S. France.

A long career in the Service was brought to a close by the retirement of Mr. G. S. France, Sectional Engineer in charge of the Cardiff Section, at the end of September. Entering the Service at Liverpool in 1887, Mr. France was transferred to the Engineering Department in 1891 and after various moves was stationed in Birmingham, where he reached the rank of Assistant Engineer in 1911. In 1915 he was promoted Executive Engineer and was given charge of the Cork Section. He remained in Ireland until the formation of the Irish Free State, when he was transferred to Cardiff. In addition to his capabilities as an engineer and administrator, Mr. France possessed a happy and genial disposition and was universally esteemed by everyone who knew him.

Expression was given to the high regard held of Mr. France at a well-attended smoking concert on the 31st October, when he was presented with gifts of silver plate by Mr. T. Devereux, senior Assistant Engineer in the Cardiff Section, in the unavoidable absence of Mr. Terras, Superintending Engineer. Representatives of all engineering grades testified to the happy relations which had always existed between Mr. France and the whole of the Staff, and to the regret at his retirement. Particularly gratifying was the presence at this function of the Head Postmaster of Cardiff and the District Manager, both of whom paid a glowing tribute to the generous cooperation they had invariably received at the hands of Mr. France. It is pleasing to record that he retires in the full vigour of bodily health.

SOUTH WESTERN DISTRICT.

Retirement of Major W. M. Batchelor.

A large and representative gathering assembled at a smoking concert at St. Stephen's Restaurant, Bristol, on 26th October, to take official leave of Major W. M. Batchelor, D.S.O., M.C., Superintending Engineer. The Chairman of the evening was Mr. A. Gray, Assistant Superintending Engineer, and the guests included Mr. Blandford Harris, Postmaster-Surveyor of Bristol, Mr. E. F. Simmons, of H.M. Office of Works, and Mr. A. Bristow, District Manager.

Major Batchelor, who is a well-known figure in Bristol social circles, had a distinguished career in the Post Office. He joined the Central Telegraph Service in 1885, was transferred to the Engineering Department in 1892, and was Assistant Superintending Engineer in the N.E. and E. Districts before being promoted to Bristol in 1927. He rendered conspicuous service with the R.E. Signals during the war and was awarded the Distinguished Service Order and the Military Cross.

After the evening had been opened with musical items, the presentation of a fitted "Compactum" wardrobe was made by the Chairman on behalf of the Staff of the South Western District. In a felicitous speech, the Chairman referred to the admirable work carried out by Major Batchelor during his Official career, and echoed the general feeling of the Staff in wishing him a long and happy retirement.

Supporting speeches were made by Mr. Blandford Harris, Mr. R. C. Balcombe, Sectional Engineer, Taunton, and Mr. D. Williams, Staff Officer, and included references to Major Batchelor's courteous and sympathetic treatment of his Staff, and to the athletic prowess which enabled him to remain a member of the Tennis Club First Team to the exclusion of many younger aspirants!

Major Batchelor in reply expressed his appreciation not only of the personal gift, but more especially of the sentiments which had been expressed. He said that his work in the South Western District had been facilitated by the harmonious way in which the Staff worked together, and by the cordial relations which existed between the Department and all outside bodies. He paid a special tribute to the loyal assistance given him by the Assistant Superintending Engineers, Messrs. A. Gray and J. Baxter.

An excellent and varied musical programme, provided by local amateur and professional talent, was concluded by the singing of "Auld Lang Syne."

Bristol Automatic Area.

Automatic working in the Bristol Area was inaugurated at midnight on 28th November, 1931, by a successful simultaneous transfer from five existing manual switchboards to ten new automatic exchanges.

The old exchanges closed down were Stoke Bishop, Westbury-on-Trym, Kingswood, Whitchurch, and, last but not least, the old Central Exchange, reputed to be the first Central Battery Exchange in Europe.

Some idea of the extent of the operations will be gathered from the following schedule of the ten new exchanges now working :—

Exchange.	Initial Equipment Uniselectors.	Ultimate Capacity.
Central	5310	9600
West	3515	5400
North	2160	4300
Easton	1620	3000
Westbury	1260	2700
South	1170	2600
Bedminster	990	2000
Kingswood	630	1400
Stoke Bishop	630	1200
Whitchurch	95	300

Six further exchanges, namely, Pill, Filton, Frenchay, Fishponds, Keynsham, and Long Ashton, will be converted to automatic working in due course.

The transfer of the trunk exchange from the Head Post Office to the new exchange at Telephone Avenue was effected on October 10th, and the operations on the 28th November were divided into two main stages, *i.e.*, :—

(*a*) An advance transfer of junctions and short trunks at 7 p.m.

(*b*) The main transfer of subscribers together with the remainder of the junctions at midnight.

The system is not "director," but standard 5-digit Strowger employing discriminating selector repeaters, and the Bristol Area is unique in that it is the first in Great Britain in which the entire Strowger equipment is mounted on pressed steel channel shelves on single-sided racks.

The fine new building at Telephone Avenue will accommodate not only the Central Automatic Equipment and the combined trunk and auto-manual switchroom, but also the repeater station, which is not yet completed. The manufacture and installation of the exchange equipment was carried out by the Automatic Telephone Manufacturing Co. of Liverpool, and the repeater apparatus is being provided by the General Electric Company.

It is hoped that it will be possible to publish a descriptive article on the Bristol automatic equipment in the next issue of the Journal.

Main Cabling by Direct Labour.

The Engineer-in-Chief has decided that the Bristol-Yeovil-Dorchester cabling and loading shall be carried out by direct labour, and a special organisation is being set up to ensure that the work is completed with a maximum of expedition and economy. These will be the first cables to be laid in this District under the Trunk Reorganisation Scheme, and will consist of 20 lb. conductors in quad formation. The cable at the Bristol end will contain 160 pairs, tapering to 74 pairs at Dorchester. Provided that the specified unbalance limits will not thereby be exceeded, it is intended that all joints shall be made on a systematic basis, with the exception of a single test selected joint in the centre of each loading coil section.

Faraday Centenary.

In connection with the Exeter Faraday Centenary Celebrations, an Exhibition has been arranged to take place at the new Science Laboratory, Exeter University College, on December 10th-12th, 1931. A Post Office Engineering exhibit is to be provided which will include many features similar to those of the P.O. display at the Faraday Exhibition in the Albert Hall, London, in October last. It is hoped to give a full account in the next issue of the Journal.

D.A.B.

SCOTLAND EAST DISTRICT.

A Robust Main Cable.

We of the Scotland East Engineering District had an experience recently which may be worth while relating outside local channels. So much care and attention is given to balanced and loaded cables that we are inclined to look upon them as being particularly vulnerable, and it was surprising when we discovered one robust specimen which successfully withstood the ravages of nature .

The cable between Edinburgh and Newcastle is a composite one of 170 pairs, and in addition to carrying long distance trunks and telegraphs it is an essential link in the Trans-Atlantic telephone service. This cable is in the main road south from Edinburgh to Newcastle *via* Galashiels, and at a point 13 miles S.E. of Edinburgh the sandy sub-soil was washed away as a result of serious flooding, which occurred during the afternoon of the 17th August, and the road subsided at two places. One of the breaks extended from one side of the road to the other and varied in depth from 10 to 25 feet. The other break was more localised, but at each the cable and 2-way duct were found exposed and unsupported for approximately 12 yards.

A breakdown gang was despatched to the scene of the washout and emergency measures were taken to avoid a serious breakdown. The ducts were broken off and the cable was suspended from poles lashed together and placed across the gaps. When the filling-in operations were completed, split 2-way ducts seated on a bed of reinforced concrete and protected on top by concrete were installed to restore the duct line. The cable was not damaged, but it had acquired about 18″ of slack which could not be easily handled and it was cut out at the nearest joint without interrupting any of the many working circuits.

The accompanying photographs taken on the 18th August show the breaks in the roadway and the position of the P.O. duct and cable in relation thereto.

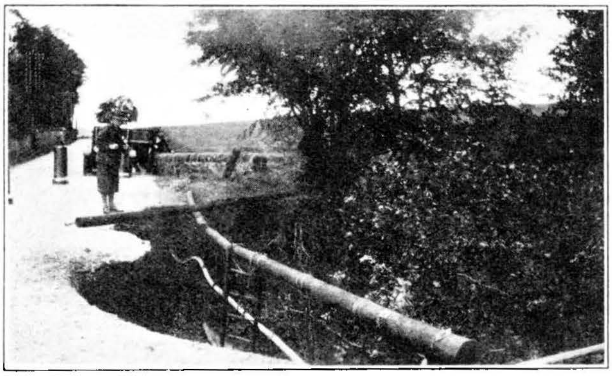


FIG. 1.—SUBSIDENCE NO. 1. VIEW FROM EAST.

The gaps were filled in with stones and the road was re-opened for traffic late in the afternoon of the 18th.

As a matter of interest it should perhaps be explained that the heavy rain was not alone responsible for the flooding. The Moorfoot Hills, which rise to a height of over 2,000 feet, are on one

FIG. 2.—SUBSIDENCE NO. 2. VIEW FROM SOUTH EAST.

side and at some distance from the road there is a valley of considerable extent in the high land. As the soil in this valley is of a peaty nature there is a natural reservoir draining a large area which fills up and periodically every two or three years bursts and empties itself. Assisted by the abnormal rainfall, this is what happened on the 17th August when the

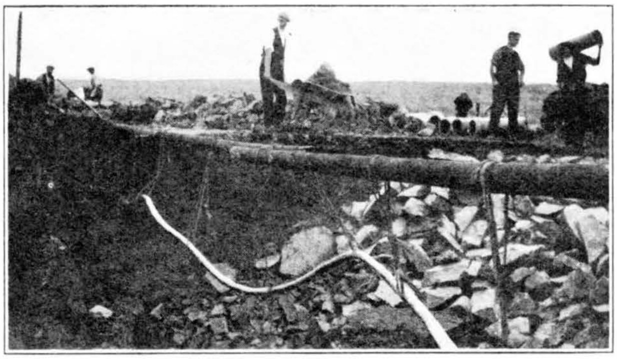


FIG. 3.—SUBSIDENCE NO. 2. VIEW FROM NORTH WEST.

roads from the hills were transformed into rivers. No system of drainage could cope with such conditions. It was, as a matter of fact, the presence of a stone culvert which indirectly caused most of the damage. This drain crossed the road and the rush of water through it started the shifting of the sub-

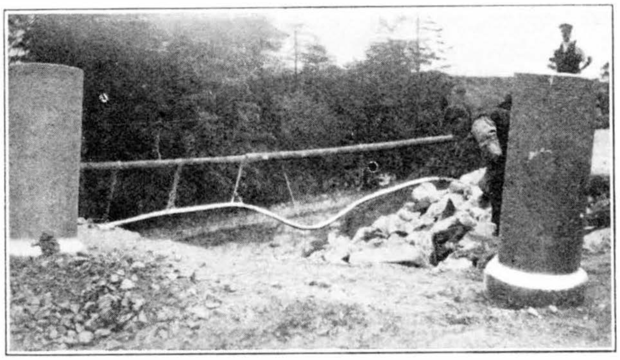


FIG. 4.—SUBSIDENCE NO 2. VIEW FROM SOUTH WEST, SHOWING EH—JH—NT CABLE SLUNG ON POLES.

soil, the drain broke away piece by piece and the undermining process continued until eventually the entire surface of the road collapsed.

ROBT. R. RAE.

THE INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS.

NORTHERN CENTRE.

A paper on " District Accounting " was read on the 18th November, 1931, by Mr. T. Fewster. The author laid stress on the need for a clear understanding of the accounting requirements by all grades, in order that their work should be valuable and fruitful. He outlined the responsibilities of the Superintending Engineer in regard to bulk and detail control of funds, and traced the processes from the preparation of the Annual Estimates to the issue of Allotments, and thence through the systems of bulk and detail control of funds. The progress of Maintenance and Works expenditure under Labour and Stores was then traced from the Primary Voucher to the Cost Statement; and it was shown how the costing information was " thrown up " in the course of the financial accounting. The various steps from Estimate to Authorization of a Works Order, and the progress to " closing " of a Works Order were outlined. Some useful lantern slides accompanied the paper, which provoked an interesting discussion in which several members took part. The discussion was opened by Mr. P. D. Mathie, an A.G.D. auditor visiting the District, who said the paper was valuable in giving an idea of unity in the accounting system. He regarded the preparation of Primary Vouchers as the foundation stone of sound accounting, and appealed to all grades to use the information the accounting system provided and not to leave it to the " next man in the chain " to take the initiative.

Mr. Fewster's paper describes the District Accounting system in a simple, direct manner and the paper can be regarded as being particularly useful to all who wish to obtain a general knowledge of the Departmental system as practised in the Districts.

Annual Dinner.

The Northern District Annual Dinner will be held on Saturday, the 27th February, 1932.

SOUTH WESTERN CENTRE.

The first meeting of the Session was held at the Royal Empire Society Rooms, Bristol, on October 26th, 1931, when over 50 members attended to hear the annual address, delivered by Major W. M. Batchelor. The speaker touched on many aspects of Departmental work, with special reference to costs and to the recruitment and training of staff, and an interesting discussion followed.

The second meeting of the Session, presided over by Mr. P. T. Wood, was held on November 17th, 1931, when Mr. W. Ware read a paper entitled " A Commercial Wireless Coast Station." The paper dealt in a comprehensive manner with the purpose, design, equipment, and operation of the Portishead and Burnham Radio Stations, and was fully illustrated with lantern slides. The interest of the audience in the subject was evidenced by the keen discussion which followed, which indeed had to be curtailed owing to lack of time.

The theoretical information contained in Mr. Ware's paper was supplemented by practical contact with the plant described when on Saturday, 21st November, 1931, a party of 33 members visited Portishead Radio Station. Mr. Wilson, engineer-in-charge, and members of the staff explained and demonstrated the apparatus, and those able to be present enjoyed a most successful and informative afternoon.

D.A.B.

NORTH WALES CENTRE.

As far as can be gathered, the more intimately social atmosphere is not always conspicuous at formal meetings of the I.P.O.E.E., but the 1931-32 Session of the North Wales Centre opened auspiciously on 18th October with an item which, though not on the printed programme, was acclaimed with unanimous approval. Mr. J. G. K. Donaldson, recently promoted, relinquished his offices and terminated a long period of service to the Centre in particular and the Institution in general at the close of the last Session. The membership readily fell in with the Chairman's happy suggestion that suitable opportunity should be taken to mark the appreciation of the services rendered by the late Secretary. In the presence of the large gathering which attended the first meeting of the Session, Mr. R. A. Weaver asked Mr. Donaldson to accept a solid silver cigarette box and chromium plated lighter. The box bore a simple inscription : " J. G. K. Donaldson, I.P.O.E.E., 1925-1931," but the Chairman left no doubt as to the wealth of time and devotion that those years had evoked to guide the North Wales Centre to the highest aggregate membership on record in the Centre, and to a sustained interest of an enviably high order.

Characteristically, Mr. Donaldson, in reply, sought to devolve some of the speaker's encomiums and paid tribute to the generous assistance he had received from many of the members, especially from Mr. G. H. Carrier, who for a number of years past had voluntarily undertaken the responsibility of the lantern arrangements.

At the present time, when so many by-paths to the main road of experience are being opened up and vistas of the heights of new development revealed, the promise of a discussion on the Trunk Telephone Re-organisation Plan is perhaps the most intriguing that could be offered to the Telephone Engineer and the Traffic Executive. The offer was accepted by a large gathering to hear the Headquarter's Paper and included the District Managers from Chester (Mr. A. L. Barclay) and Birmingham (Mr. J. L.

Parry) together with representatives of their staffs, to whom the Chairman offered a hearty welcome.

To the author (Mr. J. S. Elston, A.M.I.E.E.) also the North Wales District is always prepared to accord a warm welcome as one born (actually) and bred (officially) within its borders, and the Chairman briefly recapitulated Mr. Elston's earlier connection with the District, recalling papers read 26 years ago (when the Institution itself was very young), and later, the titles bespeaking the versatility of a progressive career.

Although copies of the paper had been circulated, Mr. Elston left them to be assimilated at leisure and with an easy skill developed the intricacies of his projected diagrams to a logical and lucid conclusion in a lengthy, but never uninteresting, extemporary lecture that earned very hearty approbation.

Considerable interest was evinced in the explanation, which was given by Mr. W. H. Brent, of the constructional aspect of the new Aerial Cable system as revealed in the unfolding of an excellent series of films.

Time for discussion was unfortunately curtailed by the length of the major addresses, but sufficient was forthcoming to leave no doubt as to the fulfilment of the meeting's first anticipations, and an interest was aroused which can only be whetted by the adoption of the principles which had been expounded in the District which offers such favourable facilities for their further extension.

J.T.W.

THE INSTITUTION OF P.O. ELECTRICAL ENGINEERS.

Officers of Colonial and Foreign Telegraph Administrations who are engaged in Electrical Engineering Works may be admitted as Colonial and Foreign Corresponding Members respectively, after application.

Subscription payable annually in advance on 1st April in each year :

Colonial Members	... ...	£1 0 0
Foreign ,,	... ...	£1 10 0

These sums include Annual Subscription to the Journal of P.O. Electrical Engineers and the supply of all Professional Papers issued during the period covered by subscription.

Forms of application for Colonial and Foreign Membership can be obtained on application to

The Secretary,
Institution of P.O.E. Engineers,
G.P.O. (Alder House), E.C.1,

or the undermentioned gentlemen who have kindly agreed to act as representatives of the Institution in their respective countries :—

R. Badenach, Esq., B.Sc. (Melb.),
Chief Engineer's Office,
Postmaster-General's Department,
Treasury Gardens,
Melbourne, C.2,
Australia.

H. C. Brent, Esq.,
District Telegraph Engineer's Office,
Wellington, N.Z.

N. N. Banerjee, Esq., A.M.I.E.E. (Ind.),
Divisional Engineer, Telegraphs,
Calcutta West Division,
8, Wellesley Place,
Calcutta,
India.

A. T. Kingston, Esq., M.B.E., A.M.I.E.E.,
Office of the Chief Engineer,
Telegraphs & Telephones,
C.T.O.,
Colombo,
Ceylon.

A. G. Kellaway, Esq.,
P.O. Box 1077,
Johannesburg,
South Africa.

E L. Jephcott, Esq., A.M.I.R.E.,
Chief Engineer's Department,
G.P.O. Box 391,
Salisbury,
South Rhodesia.

BOOK REVIEWS.

"Principles of Electricity." By Leigh Page, Ph.D. and Norman Ilsley Adams, Jr., Ph.D. Chapman and Hall, Limited. Pp. 620. Price 21/-.

This book is designed to provide students with a comprehensive training in the subject of electricity. It assumes a general knowledge of physics and the calculus. The first twelve chapters are devoted to electro-magnetism. The theory of alternating currents is discussed in Chapter XIII., whilst Chapter XIV. is devoted to A.C. and D.C. measurements. The next chapter is devoted to coupled circuits, filters and the transmission of alternating current over lines. Chapter XVI. discusses the properties of electro-magnetic waves whilst the final chapter is devoted to the peculiarities attending alternating currents of high frequency.

As a text-book dealing with the theoretical considerations encountered in practically every one of the many branches of electrical engineering, the book has everything to recommend it.

"Essentials of Electricity : Direct Currents." By W. H. Timbie. Chapman and Hall, Limited. Pp. 306. Price 12/-.

This useful little book sets forth in simple language the elementary theory of electricity and various aspects of its application in direct current electrical engineering. Each chapter concludes with a summary of the contents and is followed by a number of problems on the subject of the chapter.

"Electricity and Magnetism." By S. G. Starling, B.Sc., A.R.C. Sc., F.Inst.P. Longmans, Green and Co., Ltd. Pp. 345. Price 6/-.

This book is intended for students for Intermediate or Higher School Examinations. A small knowledge of the calculus is desirable, but alternative methods are given so that a student may be able to follow the work without it. The book covers the syllabus of the City and Guilds Examination and it can be recommended to students of the subject.

W.S.P.

OUTLINE NOTES ON TELEPHONE TRANSMISSION THEORY.

W. T. PALMER, B.Sc., Wh.Ex., A.M.I.E.E.

[*This Series will be published in book form in July next.*]

SECTION 10—*continued.*

(3) Cross-Talk Mesurement—Near and Distant End—Correction Factors.

Cross-talk between two circuits can be expressed by giving the ratio of the induced power (or voltage, if the circuits are of equal impedances) to the inducing power (or voltage). Thus in Fig. **36**, if an alternating voltage of 10 volts impressed on AB induces at CD (by virtue of unbalance capacity couplings, etc.) a voltage of 0.01 volt, then the cross-talk between AB and CD is $\frac{0.01}{10} \times 10^6$ millionths = 1000 millionths, or *1000 units of cross-talk,* where one unit of cross-talk is a ratio of one—millionth. This is known as *near-end* cross-talk. The ratio of the voltage appearing at C′D′, due to the voltage at AB and compared with it, is known as *distant-end* cross-talk and is also expressed in " millionths."

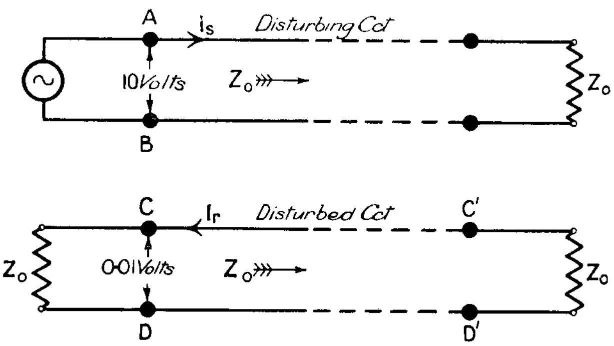


FIG. **36**.

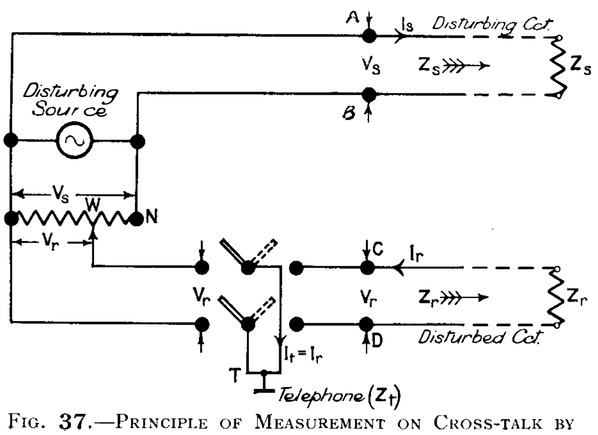


FIG. **37**.—PRINCIPLE OF MEASUREMENT ON CROSS-TALK BY COMPARISON.

Cross-talk can also be expressed as an attenuation, in decibels or nepers, since it is a ratio of current, voltage or power. This is perhaps a preferable method when repeatered cables are concerned, since most of the other transmission factors (repeater gains, terminal losses, etc.) of the system will be expressed in decibels or nepers. Thus, in the foregoing example where the cross-talk is 1000 millionths, if P_s be the applied power at AB and P_r the power induced in CD, then for equal impedances, Z_0, of the two circuits :—

$$10 \log_{10} \frac{P_s}{P_r} = 10 \log_{10} \frac{I_s^2 Z_0}{I_r^2 Z_0} = 20 \log_{10} \frac{I_s}{I_r}$$

$$= 20 \log_{10} \frac{V_s}{V_r}$$

represents the near end *cross-talk in decibels.*

$$i.e., \; 20 \log_{10} \frac{V_s}{V_r} = 20 \log \frac{10}{.01}$$

$$= 20 \log_{10} \frac{10^6}{1000}$$

$$= 60 \text{ dbs.}$$

$$\left\{ \text{or} \quad 20 \log_{10} \left(\frac{10^6}{\text{Number of cross-talk units}} \right) \right\}$$

A *cross-talk attenuation of 80 dbs* corresponds to 100 " units " of cross-talk, and so on. (See Section 10 pp. (1)).

Measurement of Cross-Talk.—This can be carried out by means of a potentiometer arrangement such as that shown in Fig. **37.** V_s is a constant p.d. of mixed frequency (to represent speech conditions approximately) and the resistance MN is placed across the source V_s in parallel with the circuit AB. A known fraction of this voltage is tapped off by MW and a telephone T is placed across MW by the switch S. This switch places T alternately across MW and the circuit CD, in which a p.d., V_r, is being induced by V_s, the voltage across AB; when the noise heard in the telephone is judged to be the same in either position of the switch then :—

$$V_r = \frac{MW}{MN} \times V_s$$

i.e., the near-end cross-talk is $\left(\frac{MW}{MN} \times 10^6\right)$ millionths.

The Western Electric Cross-Talk Meter is based on this principle and is shown diagrammatically in Fig. **38**. The connections show those required for the measurement of near-end cross-talk between (1) AB and CD, (2) the phantom and AB or CD.

The resistances between the stops of this meter can be altered, if required, so that the dial is graduated in decibels instead of millionths.

All measurements can be carried out using actual speech to produce the disturbing voltage V_s instead of a mixed tone generator or oscillator.

Z_r = characteristic impedance of the disturbed circuit CD, and with which it is terminated.

Then the cross-talk between AB and CD is the ratio of the power received (P_r) at CD to the power sent (P_s) at AB. This can be expressed as an attenuation:—

$$\frac{P_r}{P_s} = e^{-2\beta} \qquad \text{(1)}$$

Let Z_t = impedance of the telephone

V_0 = voltage appearing at CD when that branch is open,

Then by *Thevenin's Theorem* (See pp. (*h*) of Notes for Addition to Section I) the current in the branch CD when closed by Z_r is

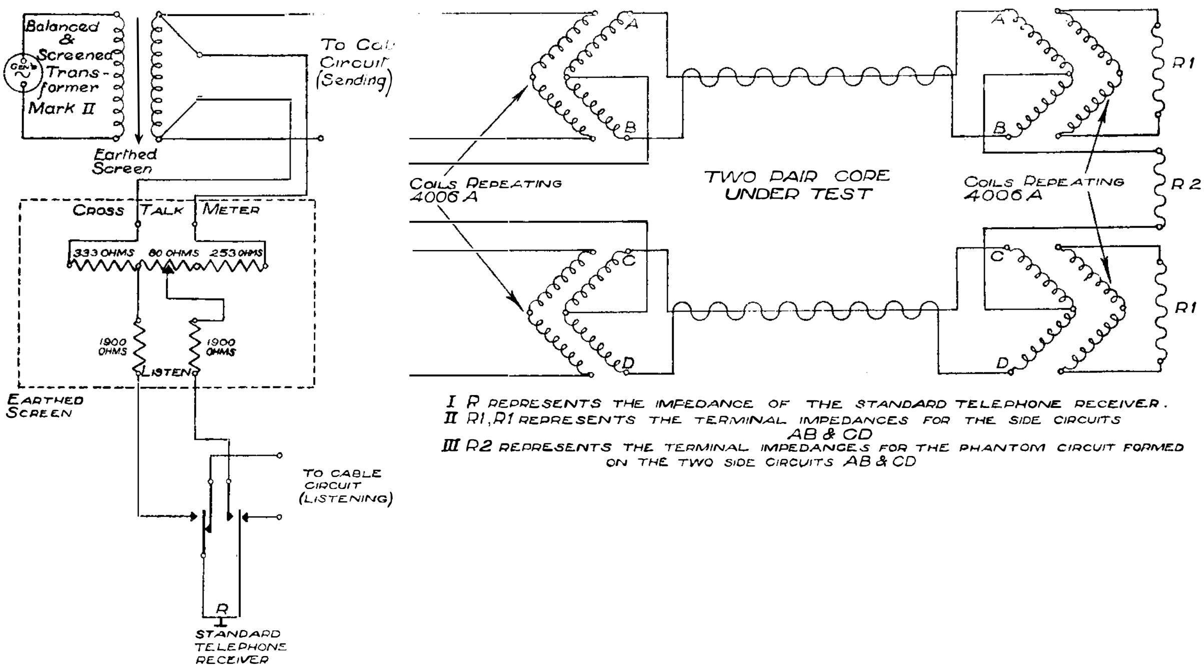


FIG. **38**.—WESTERN ELECTRIC CROSS-TALK METER.

Correction Factors for Cross-Talk Measurements—Meter in Parallel.—In those cases where the disturbed circuit AB has not the same impedance as the disturbed circuit CD, it follows that the ratio $\left(\frac{V_s}{V_r}\right)^2$ does not represent a true power ratio. A correction to the cross-talk meter reading will therefore be necessary.

In Fig. **37**,

Let Z_s = characteristic impedance of the disturbing circuit AB, and with which it is terminated.

$$\frac{V_0}{Z_r + Z_r} = \frac{V_0}{2Z_r} \,. \quad \text{Hence:—}$$

$$P_r = \frac{V_0^2}{4Z_r}$$

$$P_s = \frac{V_s^2}{Z_s}$$

$$\therefore \frac{P_r}{P_s} = \frac{V_0^2}{4V_s^2} \cdot \frac{Z_s}{Z_r} \qquad \text{(2)}$$

From equation (1) and (2)

$$V_0 = 2V_s \cdot \sqrt{\frac{Z_r}{Z_s}} \cdot e^{-\beta} \qquad \text{(3)}$$

The current (I_t) in the branch CD when closed by Z_t is (by Thevenin's Theorem)

$$I_t = \frac{V_0}{Z_r + Z_t} \quad \ldots\ldots\ldots\ldots\ldots(4)$$

By substitution of equation (3) in (4) for V_0

$\therefore$ I_t (the current obtained for comparison when making cross-talk)

$$= \frac{2V_s}{Z_r + Z_t}\sqrt{\frac{Z_r}{Z_s}} \cdot e^{-\beta}$$

Writing $\frac{V_s}{M_s} = I_m$ where I_m is the current in the meter and M the meter impedance

$$\therefore\ e^{\beta} = \frac{I_m}{I_t}\sqrt{\frac{Z_s}{Z_r}} \times \frac{2Z_r}{Z_r+Z_t} \times \frac{M}{Z_s} \quad \ldots\ldots\ldots(5)$$

$$\text{or } \beta = \log_e \frac{I_m}{I_t} + \tfrac{1}{2}\log_e \frac{Z_s}{Z_r} + \log_e \frac{2Z_r}{Z_t + Z_r} + \log_e \frac{M}{Z_s} \quad \ldots\ldots\ldots(5A)$$

If the telephone and meter each have an impedance made equal to that of the listening and sending circuit respectively, *i.e.*, $Z_t = Z_r$; and $M = Z_s$, then :—

$$e^{\beta} = \frac{I_s}{I_t} \times \sqrt{\frac{Z_s}{Z_r}} \quad \ldots\ldots\ldots\ldots(6)$$

Now $\frac{I_t}{I_s} \times 10^6$ is the meter reading; *i.e.*, the correction required to the meter reading is the divisor $\sqrt{\frac{Z_s}{Z_r}} = \sqrt{\frac{\text{Disturbing circuit impedance}}{\text{Disturbed circuit impedance}}}$

Again if $Z_r = Z_s$, as in the case of side-circuit to side-circuit cross-talk measurements :—

$e^{-\beta} = \frac{I_s}{I_t} \equiv$ meter reading; and no correction is required.

Example.—The measured cross-talk between a phantom circuit of impedance 100 ohms and a side-circuit of 400 ohms impedance was 1000 units. Calculate (*a*) the corrected value of the cross-talk and (*b*) the probable meter reading for the side-to-phantom measurement assuming the impedance of the telephone and meter in each case are made equal to that of the listening circuit and sending circuit respectively.

(*a*) Correction factor $= \sqrt{\frac{Z_r}{Z_s}}$ by equation (6).

$$\therefore \text{ True cross-talk} = 1000 \times \sqrt{\frac{400}{100}} = 2000 \text{ units}$$

i.e., the corrected cross-talk is twice the measured value.

(*b*) The correction in this case is

$$\frac{1}{\sqrt{\frac{400}{100}}} = \tfrac{1}{2}.$$

$\therefore$ Meter Reading $\times \frac{1}{2}$ = True Value.
= 2000

i.e., Meter reading = 4000 which gives the *corrected cross-talk as half the measured value.*

The necessity for the correction for impedances when quoting cross-talk values for any given cable is thus of great importance if these values are to be used for comparison purposes.

An alternative to the above correction factors is a complicated testing set which gives the equality of impedances required by means of transformers and resistances.

(4) **Cross-Fire.**

This is the term applied to interference experienced in one telegraph circuit from the working telegraph currents of a neighbouring circuit. Such interference can generally be reduced considerably by suitable terminal devices. The precise measurement for comparison purposes of existing interference is not an easy matter and the question is discussed in detail in papers, references to which are given at the end of Section 10.

(5), (6) and (7). **Noise and Power Circuit Interference.**

The technique of precisely measuring the extent of interferences of this description is not yet fully developed. The method favoured for "noise" measurement is a comparative method wherein, essentially, the induced noise voltage is compared with an inducing voltage of known characteristic wave-form by means of a potentiometer arrangement and the readings obtained on a valve-voltmeter, which can be paralleled alternately with the inducing and induced voltages by the operation of a key. (See references).

Further References for Section 10:—

"Definition and Measurement of Cross-Talk," J. Carvallo, Annales des P.T.T. Sept., 1925. p. 887.

"Telephone Cable Circuit Interference," A. Morris. I.P.O.E.E. Paper No. 126.

"Cable Testing Methods," W. T. Palmer and E. H. Jolly. I.P.O.E.E. Paper read at a London meeting of Institution on 10th Nov., 1931.

"Interference Between Circuits in Continuously Loaded Cables," A. Rosen. J.I.E.E., Vol. 62, 1926. p. 849.

"Neutralization of Telegraph Cross-Fire," R. B. Shanck. Bell System Technical Journal, Vol. V., 1926. p. 418.

"Interference Between Power and Communication Circuits." Summary of Recent Information (1926-29), by W. G. Radley. J.I.E.E., Vol. 69, Sept., 1931. p. 1117.

SECTION 11.

The European Master Reference System.

A Master Reference System is a laboratory transmission circuit used as a fundamental base with which to compare the transmission performance (*i.e.*, any or all of the factors outlined in Section 10) of sub-standard reference systems and actual telephone circuits. It can also be used to compare the performance of sub-standard and actual transmitters and receivers with that of the reference transmitter and receiver.

The reference system itself consists essentially of an artificial line, a condenser transmitter and a moving-coil type of receiver. The performance of the complete system can be stated by comparing the pressure (in dynes per sq. cm.) produced by the receiver with the pressure on the diaphragm of the transmitter and is practically free from distortion, although it can be arranged to imitate any type of distortion desired. Noise effects can also be introduced without otherwise affecting the system.

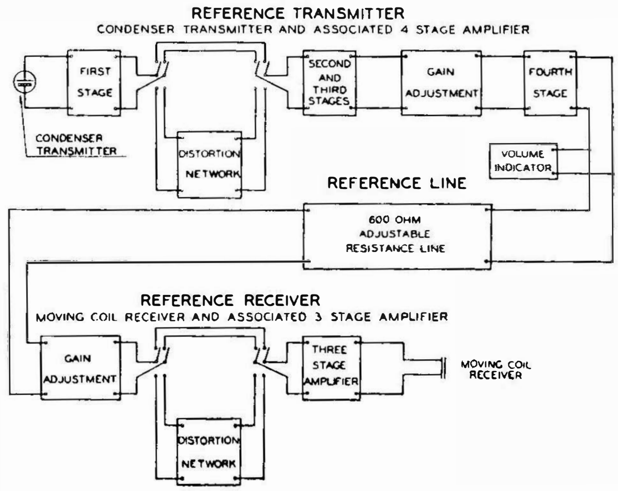


FIG. 39.—SCHEMATIC DIAGRAM OF MASTER REFERENCE SYSTEM.

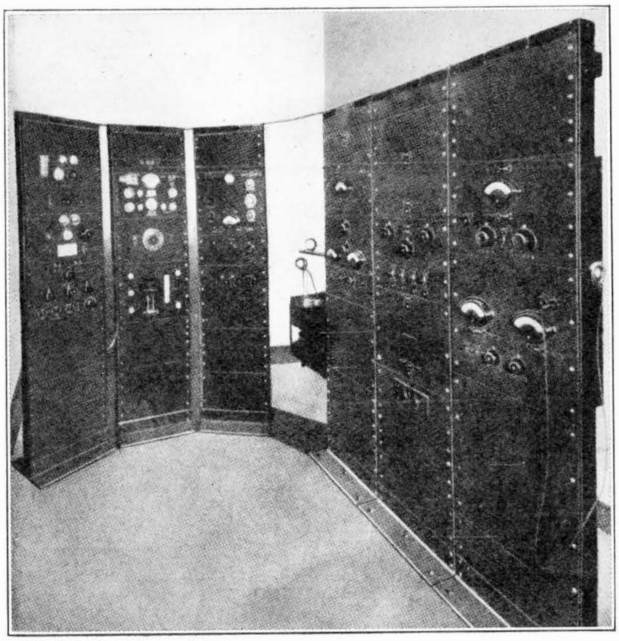


FIG. 40.—MASTER REFERENCE SYSTEM WITH ASSOCIATED CALIBRATION APPARATUS.

Fig. 39 is a schematic diagram of the arrangement and Fig. 40 is a photograph of the European Master Reference System installed in Paris, (a replica of the American Master Reference System).

Reference for Section 11:—

"Master Reference System for Telephone Transmission," W. H. Martin and C. H. G. Gray. Bell Technical Journal, July, 1929. pp. 536-559.

SECTION 12.

Electrical Wave Filters.

Adverting to Section 8, the networks there considered have an interest apart from their use as artificial lines since, as will be seen in this Section, they may be used as electric wave filters. The three principal types are as follows:—

(1) Low Pass Filter.

This is a network which only passes freely frequencies *below* a certain value called the "*cut-off*."

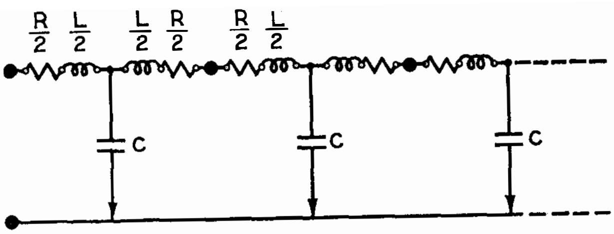


FIG. 41.—LOW PASS FILTER.

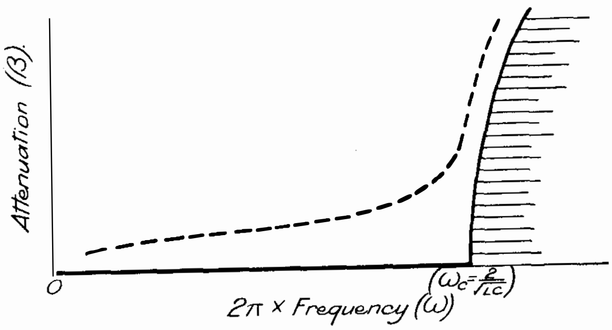


FIG. 42.—LOW PASS FILTER.
The shaded portion represents the non-transmitted range in the resistanceless case.

Consider Fig. 41 which represents a number of T-recurrent networks. By equation (15) of Section 8 we have:—

$$\text{Cosh } P = 1 + \frac{Z_1}{Z_2}$$

where $Z_1 = \frac{1}{2}(R + j\omega L)$

$Z_2 = 1/j\omega C$

P = the propagation constant per section

Let $P = \beta + j\alpha$

$\therefore$ $\text{Cosh } P = \cosh\beta \cdot \cos\alpha + j \sinh\beta \sin\alpha$ (See pps. (*d*) and (*g*), Section 1).

$$\therefore \quad \text{Cosh } \beta \cos\alpha + j \sinh\beta \sin\alpha = 1 + \frac{Z_1}{Z_2}$$

$$= 1 + \frac{\frac{1}{2}(R + j\omega L)}{1/j\omega C}$$

i.e., $\text{Cosh } \beta \cos\alpha + j \sinh\beta \sin\alpha = 1 - \frac{1}{2}\omega^2 LC + \frac{1}{2} j\omega CR$.

To study the effect of frequency on the attenuation, β, neglect R and then equating real and imaginary parts of this last expression we get:—

$$\text{Cosh } \beta \cos\alpha = 1 - \tfrac{1}{2}\omega^2 LC \quad \ldots\ldots\ldots\ldots(1)$$

$$\text{Sinh } \beta \sin\alpha = 0 \quad \ldots\ldots\ldots\ldots(2)$$

By equation (2) we have either $\sinh\beta = 0$ or $\sin\alpha = 0$.

i.e., if $\beta = 0$ (the network passing the electric energy freely with *no attenuation*) then $\cosh\beta = 1$ and hence by equation (1):—

$$\text{Cos } \alpha = 1 - \tfrac{1}{2}\omega^2 LC.$$

This expression is possible from zero up to the value of ω which just makes $\cos\alpha = -1$ and above this value it is inadmissible since *cos* α cannot be more negative than -1.

$\therefore$ the highest permissible value of ω (written as ω_c) is given by:—

$$1 - \tfrac{1}{2}\omega_c^2 LC = -1$$

$$i.e., \quad \omega_c = \frac{2}{\sqrt{LC}} \quad \ldots\ldots\ldots\ldots(3)$$

Equation (3) gives what is termed the **"cut-off" frequency.**

Below this frequency the attenuation is zero, and α changes from 0 to π (*i.e.*, $\cos\alpha$ from $+1$ to -1) as ω goes from zero to ω_c and remains π above ω_c. Above the value ω_c we have ($\alpha = \pi$) $\sin\alpha = 0$ and hence by equation (1):—

$$-\text{Cosh } \beta = 1 - \tfrac{1}{2}\omega^2 LC.$$

In other words β increases rapidly above ω_c. The full curve shows this effect, in Fig. 42, whilst the dotted curve shows the effect of resistance, which is: (1) rounds off the sharp corner at ω_c and (2) gives a finite value to the attenuation throughout the frequency range below "cut-off."

Important Note.—Comparing the dotted curve in Fig. 42 with those for the attenuation of coil-loaded lines in Fig. **27**, Section 9, the similarity will be evident. Equation (5) of Section 9 should also be compared with the above equation (3) and *thus a coil-loaded line can be considered as a low-pass filter* (having each loading section as one section of the network) with distributed resistance in each section.

(2) High Pass Filter.

This is a network which passes freely only frequencies *above* a certain value called the "*cut-off*."

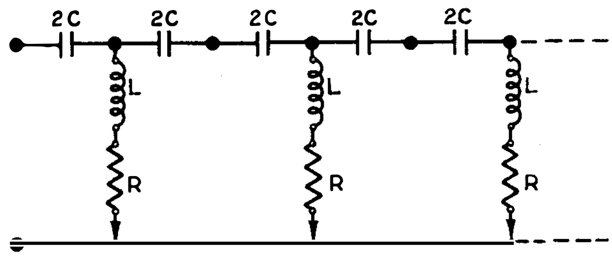


FIG. **43**.—HIGH PASS FILTER.

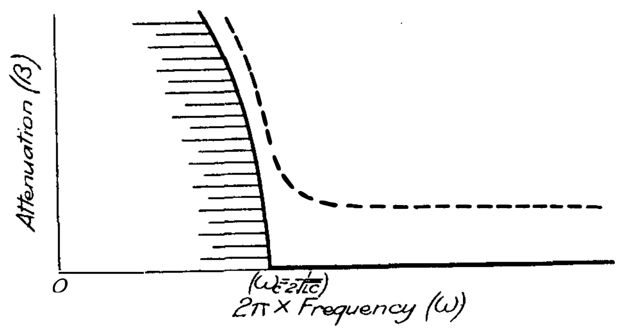


FIG. **44**.—HIGH PASS FILTER.
The shaded portion represents the non-transmitted range in the resistanceless case.

Consider Fig. **43** which represents a number of **T**-recurrent sections. In this case, by equation (15) of Section 8 :—

$$\text{Cosh } P = 1 + \frac{Z_1}{Z_2}$$

$$\therefore \quad \text{Cosh } (\beta + j\alpha) = 1 + \tfrac{1}{2}\left(-\frac{j}{\omega C}\right)\left(\frac{1}{R + j\omega L}\right)$$

As in the previous case, by equating real and imaginary parts and neglecting resistance we get :—

$$\text{Cosh } \beta \cos \alpha = 1 - \frac{1}{2\omega^2 LC} \quad \text{................(4)}$$

$$\text{Sinh } \beta \sin \alpha = 0 \quad \text{................................(5)}$$

Hence by equation (5) if sinh $\beta = 0$, cosh $\beta = 1$, and equation (4) becomes :—

$$\text{Cos } \alpha = 1 - \frac{1}{2\omega^2 LC}$$

Due to the trigonometrical ratio this last equation is only possible for high values of ω and the lowest permissible value of ω, viz., ω_c, is given by :—

$$1 - \frac{1}{2\omega_c^2 LC} = -1$$

$$i.e., \quad \omega_c = \frac{1}{2\sqrt{LC}} \quad \text{.............................(6)}$$

This is termed the **"cut-off" frequency** since the network allows frequencies higher than ω_c to pass readily (see the full curve in Fig. **44**), but greatly attenuates the lower frequencies.

The phase constant, α, changes from 0 to π as ω decreases from a very high value down to ω_c, *i.e.*, cos α changes from $+1$ to -1. The effect of resistance is to round off the corner at ω_c as shown by the dotted curve in Fig. **44**.

(3) Band Pass Filter.

The network considered here is one which will pass freely only a band of frequencies lying between two certain values, the frequencies below and above this band being greatly attenuated.

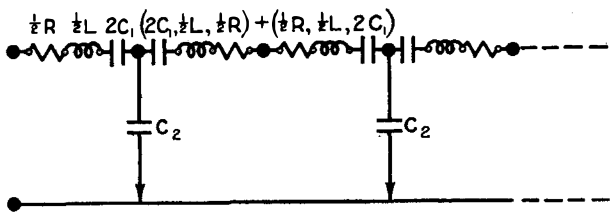


FIG. **45**.—BAND PASS FILTER.

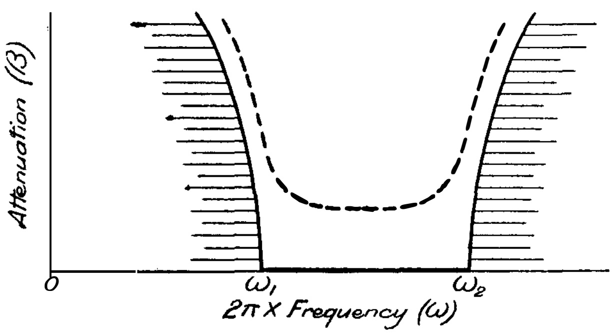


FIG. **46**.—BAND PASS FILTER.
The shaded portions represent the non-transmitted ranges in the resistanceless case.

From Fig. **45** and equation (15) of Section (8) we have :—

$$\text{Cosh P} = \cosh(\beta + j\alpha) = 1 + \tfrac{1}{2}\left(R + j\omega L + \frac{1}{j\omega C_1}\right)(j\omega C_2)$$

$$= 1 - \tfrac{1}{2}\,\omega^2 LC_2 + \frac{C_2}{2C_1} + \tfrac{1}{2}\,j\omega C_2 R$$

As in the foregoing cases the cut-off frequency can be obtained by :—

$$\text{Cosh}\,\beta\cos\alpha = 1 - \tfrac{1}{2}\,\omega^2 LC_2 + \frac{C_2}{2C_1} \quad \text{......(7)}$$

$$\text{Sinh}\,\beta\sin\alpha = 0 \quad \text{..............................(8)}$$

With $\beta = 0$, then :—

$$\text{Cos}\,\alpha = 1 - \tfrac{1}{2}\,\omega^2 LC_2 + \frac{C_2}{2C_1}$$

This equation is obviously impossible for very high values of ω and for very low values due to the trigonometrical ratio, cos α. The limiting values, ω_1 and ω_2, of the band for which the equation holds is obtained from the quadratic :—

$$1 - \tfrac{1}{2}\,\omega^2 LC_2 + \frac{C_2}{2C_1} = \pm 1$$

$$\therefore \quad \omega_1 = \frac{1}{\sqrt{LC_1}} \quad \text{and} \quad \omega_2 = \sqrt{\frac{4}{LC_2} + \frac{1}{LC_1}}$$

From ω_1 to ω_2 the phase constant, α, changes from 0 to π and remains π from ω_2 upwards, being zero for values below ω_1.

Fig. **46** shows the attenuation characteristics for the ideal, or resistanceless, case by the full curve. The dotted curve shows the rounding-off due to resistance and the finite, though small, attenuation throughout the band transmitted.

The Design of Filter circuits is generally concerned, in addition to the cut-off frequency, with the impedance of the circuit in which the filter is to be introduced; and, generally speaking, to avoid reflection losses the filter impedance has to be designed to be equal to the circuit impedance it terminates or subjoins.

The Uses of Filter circuits for transmission purposes are manifold, and the student is strongly advised to consult the references given at the end of this Section for details concerning the important questions of design and application of electrical filters. Amongst the most important applications are :—

(1) For insertion in series with an A.C. supply to eliminate as far as possible unwanted higher harmonics and thus obtain a relatively " pure " fundamental supply frequency.

(2) For separating a number of " mixed " frequencies into the constituent frequencies of the " mixed " wave received, as in carrier-current telephony, voice-frequency telegraphy,

(3) For transmitting efficiently only a certain required " band " of frequencies as in some telephone repeater circuits, etc.

Useful References for Section 12 :—

" Electrical Filters," A. B. Morice. Phil. Mag. (Supplement), April, 1927. pp. 801-843.

" Transmission Characteristics of Electric Wave Filters," O. J. Zobel. Bell System Technical Journal, Oct., 1924. pp. 567-620.

" Impedance Correction of Wave Filters," E. B. Payne. Bell System Technical Journal, Oct., 1930. pp. 794-835.

" The Design of Filters for Audio Frequencies," C. A. Beer and G. J. S. Little. P.O.E.E.J., Jan., 1925. pp. 298-317.

" Electric Wave Filters," O. J. Zobel. Bell System Technical Journal, April, 1931. pp. 284-341.

SECTION 13.—TELEPHONE REPEATERS.

(*Notes to be continued.*)

STAFF CHANGES.

POST OFFICE ENGINEERING DEPARTMENT.

Promotions.

Name.	From	To	Date.
Mercer, C. J.	Assistant Staff Engineer, Radio Section, E.-in-C.O.	Staff Engineer, Telegraph Section, E.-in-C.O.	13-12-31
Timmis, Capt. A. C.	Executive Engineer, Research Section, E.-in-C.O.	Assistant Staff Engineer, Research Section, E.-in-C.O.	1-11-31
Aldridge, A. J.	Executive Engineer, Research Section, E.-in-C.O.	Assistant Staff Engineer, Research Section, E.-in-C.O.	1-2-32
De Wardt, R. G.	Executive Engineer, Radio Section, E.-in-C.O.	Assistant Staff Engineer, Telegraph Section, E.-in-C.O.	9-10-31
Steward, W.	Executive Engineer, Dundee Section, Scot. East District.	Assistant Suptg. Engineer, N.E. District.	25-10-31
Barnes, E. J.	Assistant Engineer, Research Section, E.-in-C.O.	Executive Engineer, Research Section, E.-in-C.O.	1-11-31
Tissington, Capt. H. G.	Assistant Engineer, N. Mid. District.	Executive Engineer, Dundee Section, Scot. E. District.	21-10-31
Beer, C. A.	Assistant Engineer, Research Section, E.-in-C.O.	Executive Engineer, Research Section, E.-in-C.O.	1-2-32
Warren, A. C.	Assistant Engineer, Radio Section, E.-in-C.O.	Executive Engineer, Radio Section, E.-in-C.O.	9-10-31
Arnold, A.	Chief Inspector, Research Section, E.-in-C.O.	Assistant Engineer, Research Section, E.-in-C.O.	1-11-31
Griffiths, W. R.	Executive Officer, Stores Department.	Motor Transport Officer, Class II.	
Bunt, F. H. J.	Draughtsman, Cl. I., E.-in-C.O.	Motor Transport Officer, Class III.	
Chapman, E.	Clerical Officer, Stores Department.	,, ,, ,, ,,	
Collman, E. L.	Inspector, Engineering Department.	,, ,, ,, ,,	
Palser, F. D.	Clerical Officer, Stores Department.	,, ,, ,, ,,	
Ransley, C. C.	Executive Officer, Stores Department.	,, ,, ,, ,,	
Salter, F. J.	Executive Officer, Stores Department.	,, ,, ,, ,,	
Wright, F. V.	Assistant Engineer, E.-in-C.O.	,, ,, ,, ,,	
Malcolm, A. L.	Executive Officer, Stores Department.	Area Transport Officer, London.	
Unitt, A. T. G.	Executive Officer, Stores Department.	,, ,, ,, ,,	
Allen, J. E.	Overseer, Sheffield Post Office.	Area Transport Officer, Provinces.	
Ball, F. T.	Clerical Officer, Stores Department.	,, ,, ,, ,,	
Daft, W. E.	Overseer, Loughborough Post Office.	,, ,, ,, ,,	
Gregson, A.	Inspector, Engineering Department.	,, ,, ,, ,,	
Marks, R.	Executive Officer, Stores Department.	,, ,, ,, ,,	
Townsend, S. B.	Assistant Engineer, E.-in-C.O.	,, ,, ,, ,,	
Withers, C. A.	Clerical Officer, Engineering Dept.	,, ,, ,, ,,	
Wood, E. W.	Executive Officer, Stores Department.	,, ,, ,, ,,	
Dyson, C. E. J. C.	Clerical Officer, Engineering Dept.	Acting Executive Officer.	
Clothier, W.	Inspector, Engineering Department.	Technical Assistants.	
Coventon, A. E.	Skilled Workman, Class I., Engineering Department.	,, ,,	
Dunn, C.	Mechanic-in-Charge, Stores Dept.	,, ,,	
Huxley, R. T.	Inspector, Engineering Department.	,, ,,	
Finlayson, J. W.	Mechanic-in-Charge, Stores Dept.	,, ,,	
Finney, C. W. M. S.	Inspector, Engineering Department.	,, ,,	
Grover, E.	Storekeeper, Stores Department.	,, ,,	
Stokes, F. W....	Mechanic-in-Charge, Stores Dept.	,, ,,	
Webster, H. R. F.	Mechanic-in-Charge, Stores Dept.	,, ,,	
West, P. S.	Mechanic-in-Charge, Stores Dept.	,, ,,	

Area Transport Officers and Motor Transport Officers Class III. will be regarded as of equal status and eligibility for promotion to Class II posts.

Reversion at own Request.

Name.	From	To	Date
White, H. W.	Executive Engineer, London District.	Assistant Engineer, E.-in-C.O.	10-11-31

RETIREMENTS.

Name.	Rank.	District.	Date.
Batchelor, D.S.O., M.C., Major W. M.	Superintending Engineer.	S.W. District.	31-10-31
Pusey, A. E.	Inspector.	London.	31-8-31
Burnside, J.	,,	Scotland East.	28-8-31
Bancroft, R.	,,	S. Mid.	17-9-31
France, G. S.	Executive Engineer.	S. Wales.	30-9-31
Gingell, H.	Inspector.	S. Mid.	31-7-31
Bowie, J.	Chief Inspector.	Scotland West.	31-12-31
Adams, E.	,,	S. Mid.	27-10-31
Cruickshank, W.	Assistant Staff Engineer.	Research Section, E.-in-C.O.	31-10-31
Paterson, J.	Chief Inspector.	Scotland East.	3-11-31
Halton, R.	Assistant Staff Engineer.	Lines Section, E.-in-C.O.	4-11-31
Warner, A.	Executive Engineer.	London.	31-10-31
Beetlestone, M.A.	Assistant Engineer.	London.	4-12-31
West, G. E.	Assistant Engineer.	London.	31-10-31
Booth, Lieut.-Col A. C.	Staff Engineer.	Telegraph Section, E.-in-C.O.	11-12-31

DEATHS.

Name.	Rank.	District.	Date.
De Medewe, J. L.	Inspector.	S. Wales.	24-7-31
Moore, F.	Inspector.	London.	20-8-31
Hardaker, W. H.	Chief Inspector.	N. East.	9-11-31

TRANSFERS.

Name.	Rank.	From	To	Date.
Horn, C. O.	Assistant Engineer.	E.-in-C.O.	N. Mid. District.	15-11-31

CLERICAL ESTABLISHMENT.

PROMOTIONS.

Name.	From	To	Date.
Cramp, T. E.	Clerical Officer, S. Lancs. District.	Higher Clerical Officer, S. Lancs. District.	20-10-31
Bosher, M. E.	Clerical Officer, Eastern District.	Higher Clerical Officer, Eastern District.	25-9-31
Halsall, T. G.	Clerical Officer, S. Lancs. District.	Higher Clerical Officer, N. West District.	4-10-31
Restall, A. T.	Clerical Officer, London District.	Higher Clerical Officer, London District.	1-10-31
Gold, R. J. S.	Staff Officer, E.-in-C.O.	Princ. Clerk, E.-in-C.O.	14-10-31
Laws, W.	Executive Officer, E.-in-C.O.	Staff Officer, E.-in-C.O.	14-10-31
Oliver, S. R.	Clerical Officer, E.-in-C.O.	Acting Executive Officer, E.-in-C.O.	14-10-31
Murray, C. E.	Acting Executive Officer, E.-in-C.O.	Executive Officer, E.-in-C.O.	14-10-31
Bradley, E.	Clerical Officer, London District.	Higher Clerical Officer, London District.	1-11-31
Gibbard, W. E.	Clerical Officer, S. Mid. District.	Higher Clerical Officer, S. Western District.	30-11-31
James, W.	Clerical Officer, S. Eastern District.	Higher Clerical Officer, S. Eastern District.	11-12-31
Hopkinson, J.	Clerical Officer, N. Wales District.	Higher Clerical Officer, Eastern District.	16-11-31

Retirements.

Name.	Rank.	District.	Date.
Green, G. H.	Higher Clerical Officer.	S. Lancs.	19-10-31
Smith, G. R.	Higher Clerical Officer.	Eastern.	24-9-31
Hemming, J. G.	Higher Clerical Officer.	N. Eastern.	2-10-31
Cole, G. G.	Executive Officer.	L.E.D.	30-9-31
Haves, A. H.	Higher Clerical Officer.	L.E.D.	31-10-31
Renshaw, A. S.	Princ. Clerk.	E.-in-C.O.	13-10-31
Grant, J. A.	Higher Clerical Officer.	S. Western.	15-11-31
Gillett, B. F.	Higher Clerical Officer.	S. Eastern.	11-12-31
Cowley, W. H.	Higher Clerical Officer.	Eastern.	16-11-31
McCormack, H. C.	Staff Officer.	S. Mid.	31-12-31
Smith, W. B.	Higher Clerical Officer.	N. Ireland.	27-11-31

Transferred.

Name.	From	To	Date.
Evered, F. M.	Higher Clerical Officer, N. Western District.	Higher Clerical Officer, N. Eastern District.	4-10-31
Ransley, C. C.	Executive Officer, Stores Dept.	Executive Officer, E.-in-C.O. (M/T)	
Griffiths, W. R.	,, ,, ,,	,, ,, ,, ,,	
Salter, F. J.	,, ,, ,,	,, ,, ,, ,,	
Malcolm, A. L.	,, ,, ,,	,, ,, ,, ,,	
Unitt, A. T. G.	,, ,, ,,	,, ,, ,, ,,	14-10-31
Weston, A. S.	,, ,, ,,	,, ,, ,, ,,	
Marks, R.	,, ,, ,,	,, ,, ,, ,,	
Wood, E. W.	,, ,, ,,	,, ,, ,, ,,	
Pursall, S.	Higher Clerical Officer, Stores Dept.	Higher Clerical Officer, E.-in-C.O (M/T)	

Deceased.

Name.	Rank.	District.	Date.
Patrick, J.	Higher Clerical Officer.	Scotland East.	29-10-31

COMMUNICATIONS.

All Remittances and Communications should be addressed to the Managing Editor, P.O.E.E. Journal, Engineer-in-Chief's Office, Alder House, London, E.C.1.

Binding covers and copies of the Contents for Vol. 3 to 23 are available, and may be obtained from the local agents for 1*s.* 6*d.* and 3*d.* respectively. Subscribers can have their copies of Vol. 23 bound, with index included, at a cost of 3*s.*, by sending the Journals to the local agents. Orders for bindings, Vols. 1—19, should indicate whether the original binding with black lettering, or the latter pattern in gold, is required. Covers with gold lettering will be the only type stocked from Vol. 20 onwards.

The price of the Journal is 1*s.* (1*s.* 3*d.* post free) per copy, or 5*s.* per annum, post free. All back numbers 2*s.* each.

POST OFFICE ELECTRICAL ENGINEERS' JOURNAL.

Volume XXIV—April 1931 - March 1932.

INDEX.

PAGE

A.

B.

C.

PAGE

D.

E.

F.

G.

H.