THE
Post Office Electrical Engineers' Journal

START-STOP PRINTING TELEGRAPH SYSTEMS.

(*Continued.*)

A. E. STONE, A.R.C.Sc.

(ii.) THE MORKRUM TELETYPE NO. 2A.

THIS is an improved form of the Morkrum Teletype, using the same 5 unit telegraph code but with type bars instead of a type-wheel. The working speed is 60 words a minute, and the required character is printed on a paper tape by causing the corresponding typebar to strike sharply an inked ribbon as in an ordinary typewriter.

FIG. 1.—MORKRUM TELETYPE NO. 2A.

A general view of the instrument is shown in Fig. 1, while the interior arrangements are shown in Fig. 2. It has a single shunt wound motor of 1/20th H.P. for driving both the Receiving and the Transmitting portions of the instrument.

Transmitter Clutch Mechanism.—The actual transmitting mechanism is the same as that of the No. 1A machine, but the clutch mechanism for driving the Transmitter Cam Spindle is entirely different. In the Teletype No. 1A, when a key is held down, the cam spindle rotates continuously and the relative character is repeated so

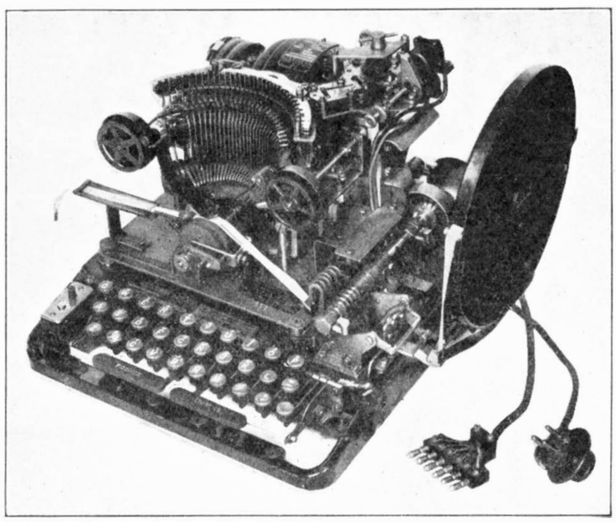


FIG. 2.—TELETYPE NO. 2A. COVER REMOVED.

long as the key is kept depressed. In the No. 2A machine, however, the character is transmitted once only, no matter how long the corresponding key is held down. The Clutch mechanism to effect this is shown in Fig. **3**. The Driving Ratchet is fixed to a shaft which is driven continuously by the motor. The Driven Ratchet engages with the spindle carrying the transmitting contact cams. The Clutch Spring tends to urge the Driven Ratchet into engagement with the Driving Ratchet, but normally is prevented from so doing by the Clutch Lever CL, the upper end of which, under the action of spring S2, bears against the Throw Out Cam forming part of the Driven Ratchet. Each Key Lever, in

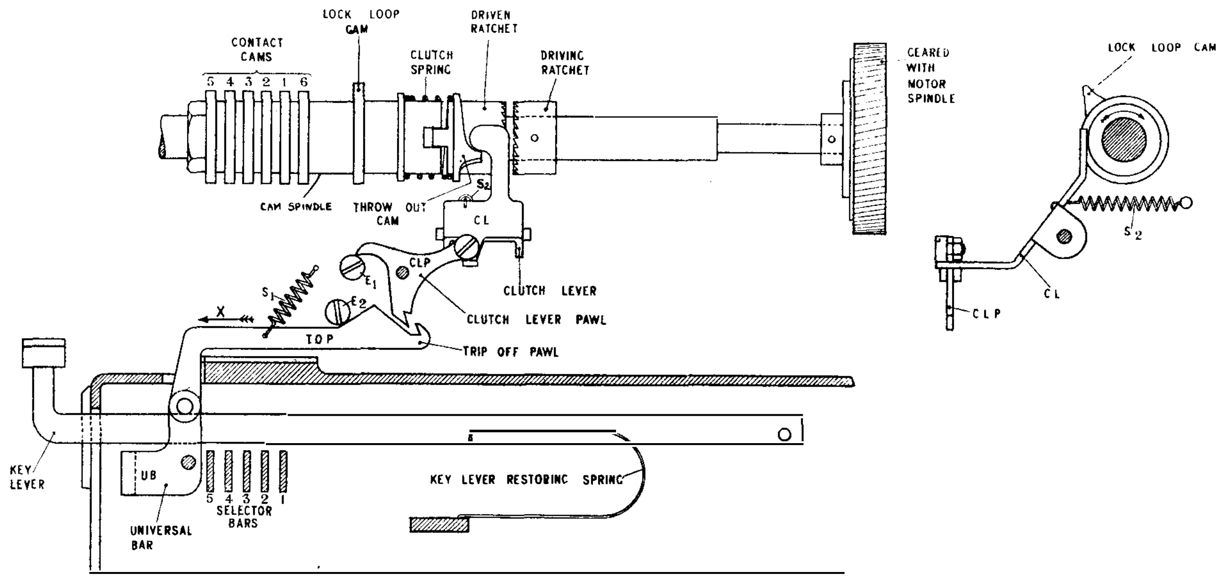


FIG. **3**.—KEY LEVER, SELECTORS AND CLUTCH.

addition to moving the Selector Bars as explained in the case of the 1A Teletype, depresses a Universal Bar UB, which causes the Trip Off Pawl, TOP, to move forward and engage with the Clutch Lever Pawl, CLP. The latter is therefore turned slightly on its axis, causing the upper end of CL to move away from the Throw Out Cam, thereby allowing the Clutch Spring to move the Driven Ratchet into engagement with the Driving Ratchet and the Cam Spindle to be rotated. As TOP moves forward in the direction of the arrow X, it bears against the screw E2 which forces it down, thus disengaging it from CLP, at about the same instant that the Cam Spindle is set in motion. This allows both CLP and CL to return to their normal unoperated positions under the action of spring S2 quite independently of the time that the key is held down. Consequently the upper end of CL in bearing against the Throw Out Cam just before the Driven Ratchet completes one revolution, forces the latter from the Driving Ratchet and brings the Cam Spindle to rest at the end of the revolution.

Printer Selecting Mechanism.—The Main Shaft, Figs. **4** and **5**, rotates continuously and carries on its upper end a Cam Sleeve which it drives by means of a friction Clutch. This consists of two felt washers FW, the upper one of which is held between a Retaining Disc RD, fixed to the main shaft, and the Cam Sleeve Disc CSD. The lower felt washer is held between another Cam Sleeve Disc CSD and the Driving Disc DD, which is keyed to the main shaft but is capable of sliding along it. The Clutch Spring S provides the necessary pressure between the components of the Clutch.

There is a single receiving electromagnet, as in the Teletype No. 1A, having its armature normally attracted when signalling is not taking place. In these circumstances the Cam Sleeve, see Fig. **4**, is held stationary because the Stop Arm SA fixed to it, buts against the Stop Pawl SP which is locked in position by the Stop Pawl Latch SPL. When the " Start " impulse de-energises the electromagnet, the armature is pulled away from the cores, and the plunger P, acting on the lever BCL, trips the Stop Pawl Latch SPL. This releases the Stop Pawl and allows the Cam Sleeve to be driven by the Main shaft. When the " Stop " signal re-energises the electromagnet, the armature is attracted and spring SPLS restores SPL, BCL and P. Spring SPS pulls SP back to its normal position where its projection Y is held by SPL. The Cam Sleeve is therefore stopped at the end of each revolution by SA coming against SP.

The armature of the electromagnet, Figs. **4** and **5**, has an extension AE which carries projections A and B. Mounted on the Cam Sleeve are seven cams, of which five, SC, are for setting

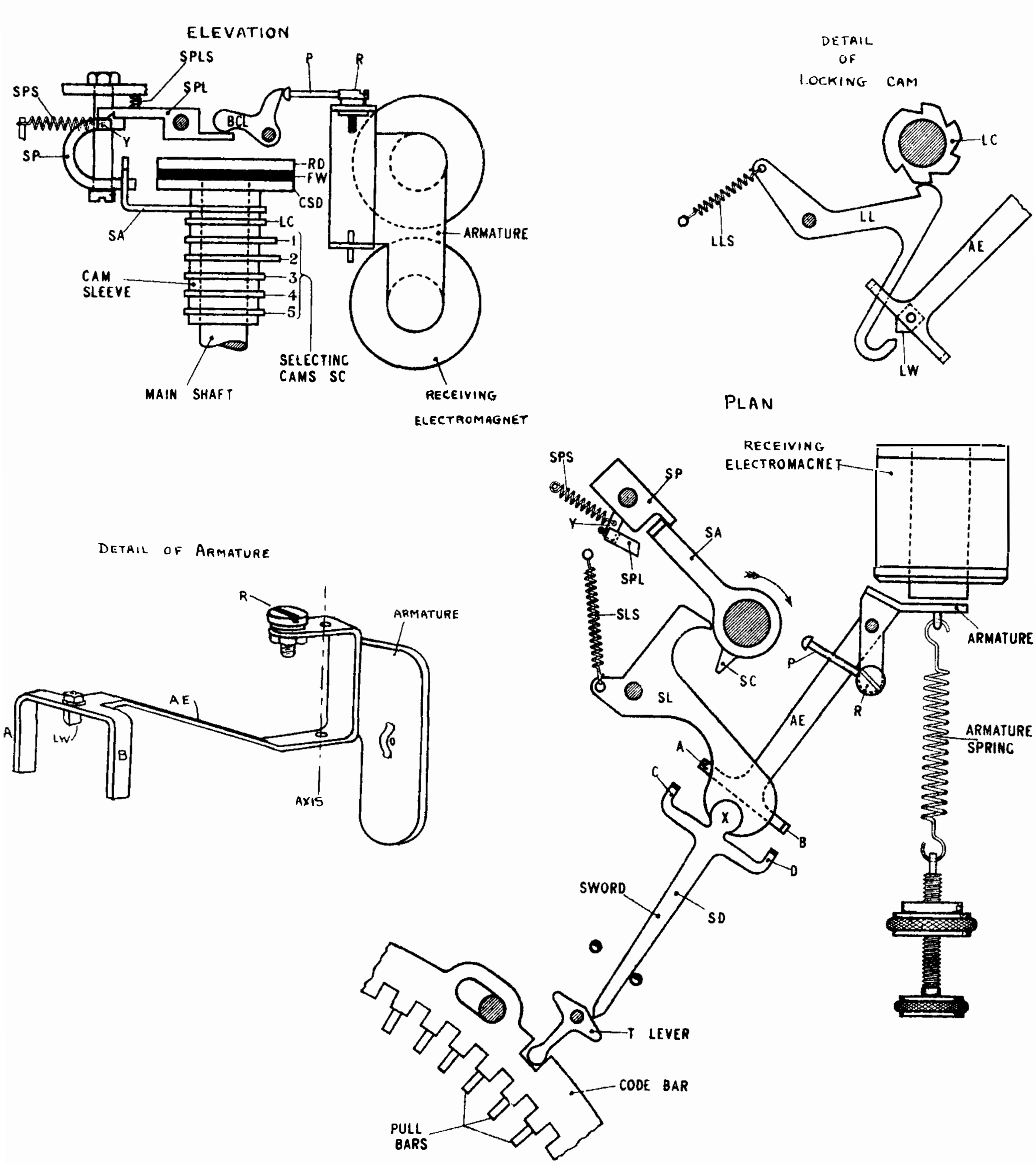


FIG. **4**.—PRINTER SELECTING MECHANISM.

five Code Bars; one, LC, is a locking cam, and the other, No. 6, in Fig. **5**, is for tripping a clutch to set the printing mechanism in motion. Associated with each Selector Cam SC is a Selector Lever SL, a Sword SD and a T Lever, by means of which the corresponding Code Bar is set.

The Cam Sleeve starts to rotate immediately the " Start " impulse arrives; then after a short interval of time the first Selecting Cam SC1 acts on its Selector Lever SL causing it to move in soon as SC1 clears the end of its SL, spring SLS causes SL to return to its normal position, communicating a downward thrust to SD which turns the T lever and moves Code Bar 1 to the right. If the next impulse is a spacing unit, the armature will be pulled away from the cores of the electromagnet by its spring and the resulting displacement of AE will position projection A in the path of lug C of SD. Cam SC2 now acts on its Selector Lever SL and this, in moving the associated Sword forward, causes its lower end

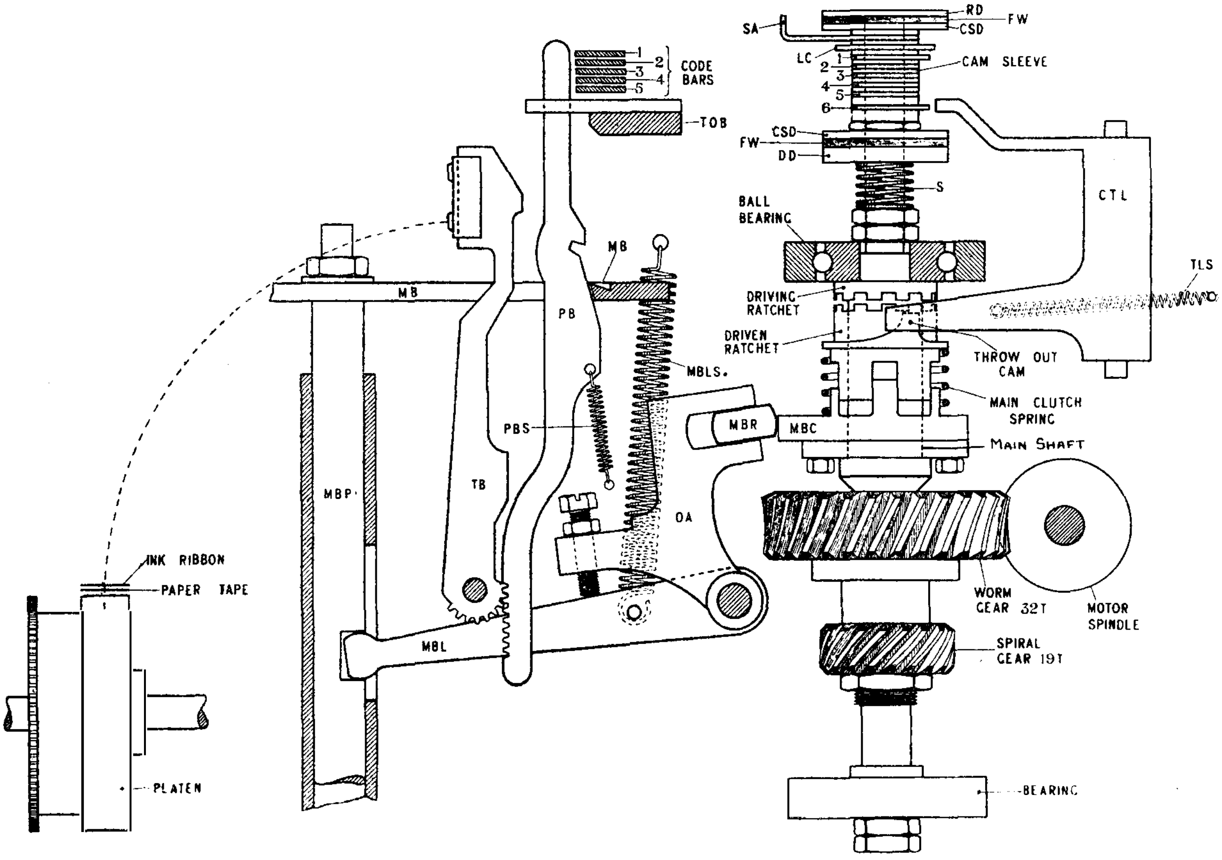


Fig. **5**.—Printing Mechanism.

an anticlockwise direction, carrying with it, its associated Sword SD. If the impulse following the Start signal is a marking unit, the armature of the electromagnet will be attracted and projection B of its extension AE will be moved into the path of the lug D of SD. Accordingly, as SD is carried forward by SL, D will come against B and SD will turn about X as a pivot in a clockwise direction, so that its lower end will move to the left hand side of its T-lever. As to move to the right hand side of the corresponding T-lever. The subsequent restoration of SL causes Code Bar 2 to move to the left, or, if it is already to the left, will allow it to remain there. The other three code bars are positioned similarly, each being controlled by its own sword and levers. It should be noted that the five selector cams are staggered and act on their selector levers in succession.

The Locking Cam LC, Fig. **4**, is provided to hold the armature extension rigid during the period when a sword is striking one of its projections. LC has five notches, the relative positions of which correspond to the highest parts of the five selector cams. The toothed projection of the lever LL presses on the rim of LC and enters the notches consecutively as the cam rotates. At these times the pointed end engages with a Locking Wedge LW fixed to AE, holding AE rigidly either to the right or to the left when a sword is about to strike it.

Printing Mechanism. — Each code bar is notched along its front edge in a definite manner, arranged differently from the others. When the bars are in their normal spacing positions to the left, there is no set of notches in the five bars that is in alignment. This is shown in Fig. 6,

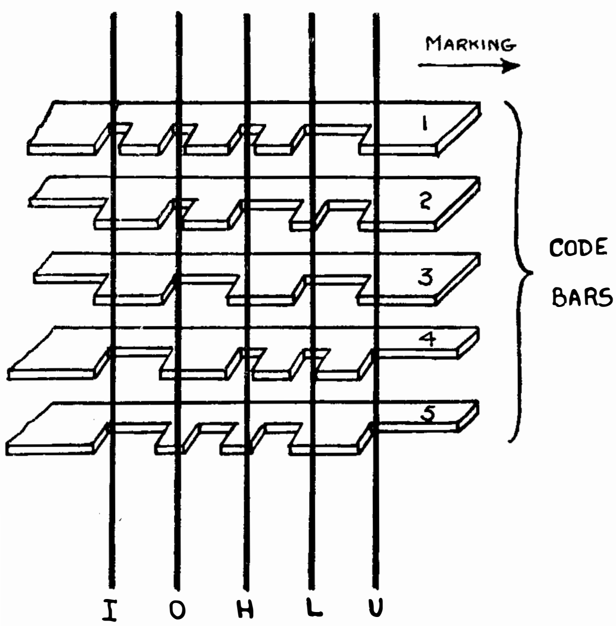


Fig. 6.—Code Bars.

in which it will be seen that for the transverse position indicated by the line U, there are notches only in bars 4 and 5. If, however, bars 1, 2 and 3 are moved slightly to the right (marking position), then a set of notches will be in alignment at this position. Similarly for position H, bars 3 and 5 will have to be moved to the right to produce a set of aligned notches. The code for the letter U is 1, 2, 3 marking units, and 4, 5, spacing units; for the letter H it it 3, 5, marking units, and 1, 2, 4, spacing units.

The lines U, L, H, O, I, etc., actually represent levers which can fall forward into the notches when they are aligned and the arrangement constitutes a device for selecting any particular lever according to the incoming code combination.

The printing mechanism is shown in Fig. 5. The Main Bail Cam MBC and the Driven Ratchet are mounted on a sleeve through which the continuously rotating main shaft passes freely. The Main Clutch Spring tends to move the Driven Ratchet into engagement with the Driving Ratchet fixed to the Main Shaft, but is prevented normally from doing this by the end of the Clutch Throw-out Lever, CTL, which bears against the Throw-out Cam.

Immediately the code bars have been set and just before the Cam Sleeve comes to rest, cam 6 trips CTL allowing the two Ratchet Wheels to engage and to rotate the cam MBC. The shape of this cam allows spring MBLS to act on the lever MBL, tending to raise it and keeping it in contact with MBC, through the Operating Arm OA and the roller MBR. Thus MBL moves according to the contour of the cam MBC. The free end of MBL engages with the Main Bail Plunger MBP which is fixed to the Main Bail MB. In front of the code bars are a number of Pull Bars PB each of which is connected to a particular Typebar TB. MB normally holds these pull bars away from the edges of the code bars. The initial upward motion of MB allows the pull bars which is connected to the typebar of the selected character to be pulled into the aligned notches in the Code Bars by the spring PBS. As MB continues its upward movement it engages with a projection on PB and thus carries it upwards also. Consequently the rack on the lower end of PB causes the typebar to turn about its pivot and its free end carrying the type to move smartly downwards, striking the ink ribbon and printing the desired character on the paper tape. Near the end of its upward stroke PB meets the Trip Off Bail TOB, which throws it out of engagement with MB, allowing it to be returned to its normal position by the spring PBS. MB on returning to its normal position holds the pull bars away from the code bars, which may then be moved for the next selection.

Actual printing occurs after the selection for the next character has been stored up on the swords when the printer is working at its maximum speed. The selection is transferred to the code bars after the previously selected pull bar has been moved out of the notches.

Tape Feed Mechanism. — The paper tape passes from a roll mounted on the side of the instrument and through a Tape Guide TG, Fig. **8**, over a rubber platen. The latter is rotated by the platen shaft which carries a toothed wheel W3 gearing with a pinion on the Tape Feed Roller TFR.

The feed mechanism is shown in Fig. **7**. The Main Bail Plunger MBP in its upward movement acts on the roller attached to lever SOL, thus moving the Feed Pawl SFP downwards. On the return of MBP the spring S, which controls SOL, causes SFP to move upwards and to turn the Ratchet Wheed SRW one tooth in a clockwise direction. SRW is fixed on the spacer shaft which gears with the platen shaft as shown. Accordingly the platen is rotated, and as W3 gears with the Feed Roll the tape is fed forward one space immediately after printing has been effected.

For speed checking purposes, the distant operator depresses a key which sends five spacing impulses and it is not necessary that the tape should be fed forward in these circumstances. It is therefore arranged that the corresponding pull bar in its upward travel shall engage with the Spacer Locking Bail SLB and pull it upwards. This allows spring S3 to move the Locking Pawl SLP into the path of the toe of SOL during the downward travel of MBP, thus preventing SOL from moving and feeding forward SRW and the platen. During the next cycle of operations, if another character is being received, SOL is moved far enough away from SLP to disengage from it as MBP moves upwards. Spring S2 then restores SLB and SLP to normal, and spacing is accomplished in the usual way when MBP descends.

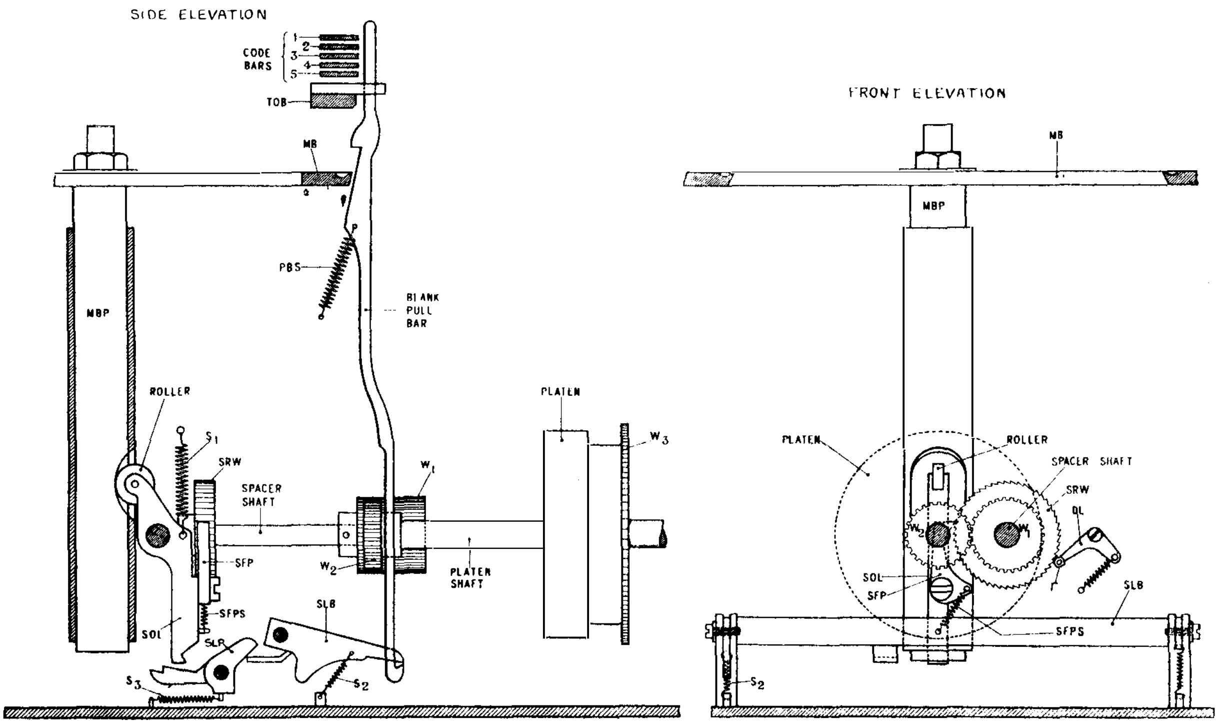


Fig. 7.—Tape Feed Mechanism.

Shift Mechanism (see Fig. **8**).—Each typebar carries two characters, the lower being the Primary, for letters, and the upper the Secondary, for figures, etc. The platen is held in the position shown, for printing letters, by the Carriage Locking Pawl, CLP, which engages

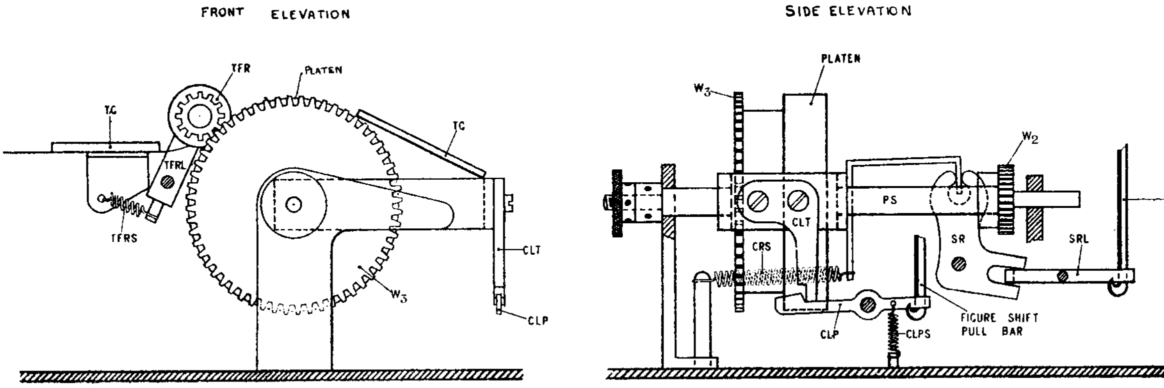


Fig. 8.—Shift Mechanism.

with the Carriage Locking Toe, CLT, fixed to the platen carriage. If it is desired to print Secondary characters, the distant operator sends the " Figure Shift " signal, which selects the Figure Shift pull bar of the Printer. When this pull bar moves upwards it lifts CLP and allows spring CRS to pull the platen to the left in the figure, which is towards the front of the machine. All printing following this operation will be of Secondary characters until the distant operator sends the " Letter Shift " signal. This selects the Letter Shift pull bar which, when it is pulled upwards, turns the Shift Rocker SR, thus moving the Platen to the right, in which position it is locked by CLP engaging with CLT.

Ink Ribbon Feed.—As in the case of a typewriter the ink ribbon is fed from one spool to another as the machine operates.

The Ribbon Feed Shaft, RFS, Figs. **9** and **10**, can be rotated and also be moved endwise to occupy one or other of two positions. It carries the Ratchet Wheel RFR, and in one position gears with the left hand Ribbon Spool Shaft, whilst in the other it gears with the right hand Ribbon Spool Shaft. The lever RFL, Fig. **9**, moves the pawl RFP forward each time the Main Bail Plunger MBP ascends. Spring S, attached to RFL, causes RFP to move backwards and engage with the teeth of RFR as MBP descends, thus turning the Spool Shaft RSS by means of the bevel gearing.

RFS is shown, in Fig. **10**, in gear with the right hand Ribbon Spool Shaft, feeding the ribbon from the left hand spool to the right. When the left hand spool becomes nearly exhausted, a rivet fixed to the ribbon moves lever A downwards, thus causing the lower end of the pawl P1 to be moved to the right into the path of the bail RRB. When MBP moves downwards, RRB engages with P1 and the motion

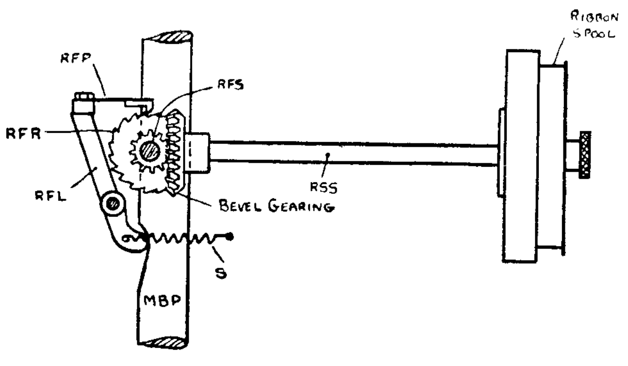


Fig. **9**.

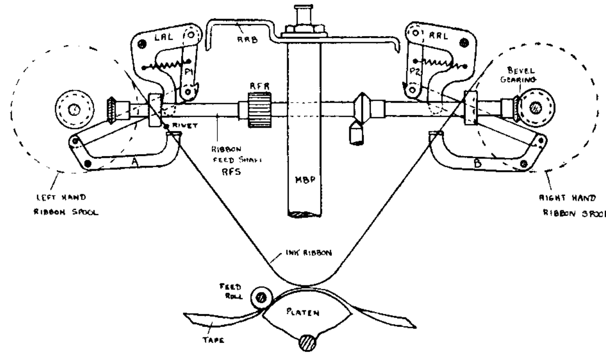


Fig. **10**.

Ink Ribbon Feed.

imparted to the pivoted lever LRL thrusts RFS to the left. This movement disengages the bevel wheels on the right and engages those on the left of RFS, thus driving the left hand Spool Shaft instead of the right hand Spool Shaft. The direction of the feed is reversed again by similar mechanism when the rivet at the right hand end of the ribbon actuates lever B.

The Governor used for maintaining steady and uniform speed, and the circuit connections, are exactly the same as for the Teletype No. 1A.

(To be continued.)

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 31ST MARCH, 1928.

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.
579,919	536	4,059	51,819	164	London.	23,936	66,027	2,182,942	106,785
73,040	2,125	21,536	63,966	1,531	S. Eastern	3,904	45,640	184,712	13,785
77,205	4,344	30,485	53,910	2,655	S. Western	19,352	11,257	139,272	59,018
60,138	6,090	37,649	57,158	4,759	Eastern	22,418	35,476	101,514	74,265
93,826	8,755	44,917	57,317	3,498	N. Mid.	24,637	51,426	237,059	119,626
74,684	4,791	29,416	69,671	4,150	S. Mid.	13,298	22,330	168,532	88,843
57,011	4,671	29,387	51,444	2,771	S. Wales	6,120	25,962	114,617	71,551
100,650	8,024	26,433	48,863	4,182	N. Wales	13,431	41,101	258,464	60,868
153,882	1,528	16,489	42,865	2,502	S. Lancs.	13,422	77,584	459,024	46,327
90,562	6,195	30,784	46,298	3,103	N. East.	11,324	44,590	154,908	67,518
62,466	3,539	23,843	37,052	2,187	N. West.	8,110	32,756	154,908	37,163
46,030	2,511	16,100	24,445	2,547	Northern	4,687	14,776	102,655	51,190
20,932	4.686	8,313	13,703	492	Ireland N.	133	2,306	37,276	1,208
63,652	5,472	25,373	36,584	1,461	Scot. East	3,664	12,212	144,398	47,674
85,840	7,332	24,155	42,695	913	Scot. West	12,116	24,489	217,421	34,857
1,639,837	70,599	368,939	697,790	36,915	Totals	180,552	507,932	4,719,708	880,678
1,605,601	70,769	366,530	690,505	37,957	Figures as 1927. at 31st Dec.	176,404	498,940	4,604,092	876,339

BISHOPSGATE AUTO. EXCHANGE.

BISHOPSGATE Exchange, in Little Pearl Street off Commercial Street, was the second London local automatic exchange to be opened for traffic. 1,300 subscribers were transferred on March 3rd and a further 3,600 on March 10th.

The equipment is similar to that installed at Holborn, but unlike Holborn building, which holds both Tandem and Holborn, there is only one Exchange in the building.

The telephone equipment was manufactured and installed by the Automatic Telephone Manufacturing Co. Ltd., of Liverpool.

The plant is of Strowger type, with equipment for 8,000 lines, and ultimate capacity for 10,000 lines. The plant includes:—

195 directors on 14 boards.
4773 selectors on 32 boards.
56 senders on 7 racks.
960 C.C.I. relay sets on 8 racks.
78 coders on 2 boards.
36 line switch units, ordinary type.
45 ,, ,, ,, P.B.X. ,,
1000 junction relay sets.

The plant is located on two floors; the first floor contains the main frame, test desk, 70 line switch units, power plant, batteries. The second floor contains 11 line switch units and all selector boards, coders, senders, junction relay groups, etc.

The power plant includes two 25-cell (50 volt) 8,000 amperehour batteries (at 9 hr. rate) made by the Chloride Electrical Storage Company: and a 7-cell Counter E.M.F. battery to carry 94 amperes. Messrs. Newton Bros. (Derby), Ltd., supplied the two charging machines, each set comprising a 480v D.C. motor direct coupled to a 1,600 ampere 57 volt D.C. generator. The power board allows for either set to charge either battery or to supply current to the exchange *via* a choke coil in parallel with a battery.

The distribution of power to the various boards and racks is done from three feeder fuse boards. One is located at the power board: one is located on the 2nd floor centrally placed as regards selector boards, and the third is located on the 2nd floor near the junction apparatus.

There is a separate P.B.X. fuse panel, with capacity for 800 fuses, placed near that portion of the main frame where the Prot. H.C. & F. for P.B.X. power leads are located. The manual fuseboard, on which P.B.X. fuses usually are placed, is on the 2nd floor. It was more economical to take the 30v P.B.X. supply lead direct to the fuse panel and have very short switchboard cabling to protectors than to carry the 30v lead upstairs and have long switchboard cabling down to the main frame.

Fig. **1** shows part of the first floor. The meter rack is made in two parallel racks, the nearer one having capacity for 300 meters per bay and the farther one having capacity for 600 meters per bay. The routine test strips for subscribers' meters are clearly shown at right hand of each bay. Beyond the meter racks are line switch units. It will be noticed that the main girders are not totally enclosed in concrete. The height of the building was reduced a few inches by adopting this course, as the depth of the concrete to cover rivet heads was dispensed with.

The manual switchboard on the fourth floor has 3 suites as seen in Fig. **2**.

There are 38 A positions; 18 B positions in the suite by the wall and 7 B positions in the centre of the room. The supervisors desk is seen by the pillar; the meter cabinet contains (*a*) the A operators' position meters worked from a peg count key when required on A positions; (*b*) the B operators' position meters worked automatically from the Pos. apparatus in the auto. room, and (*c*) meters on incoming junctions associated with the key sender positions worked automatically when the release magnet of the selectors on these incoming junctions is energised. Meters are provided at the rate of one per half shelf (*i.e.*, capacity 10 switches) of 20 selectors.

The circuits and apparatus used at Bishopsgate are the same as used at Holborn and the disposition of apparatus on racks is the same.

In order to test the plant continuously, various automatic routiners have been provided. In themselves, these routiners are fairly complicated mechanisms and contain a considerable quantity of apparatus; for instance, the director routiner contains:—

88 relays.
21 rotary line switches.
15 lamp jacks each for 20 lamps.
1 fuse panel capacity 22 fuses.
10 minor switches.
10 strips of lamp jacks (10 per strip).
30 tag blocks.
6 tag strips.
14 mountings each of 6 lever keys.

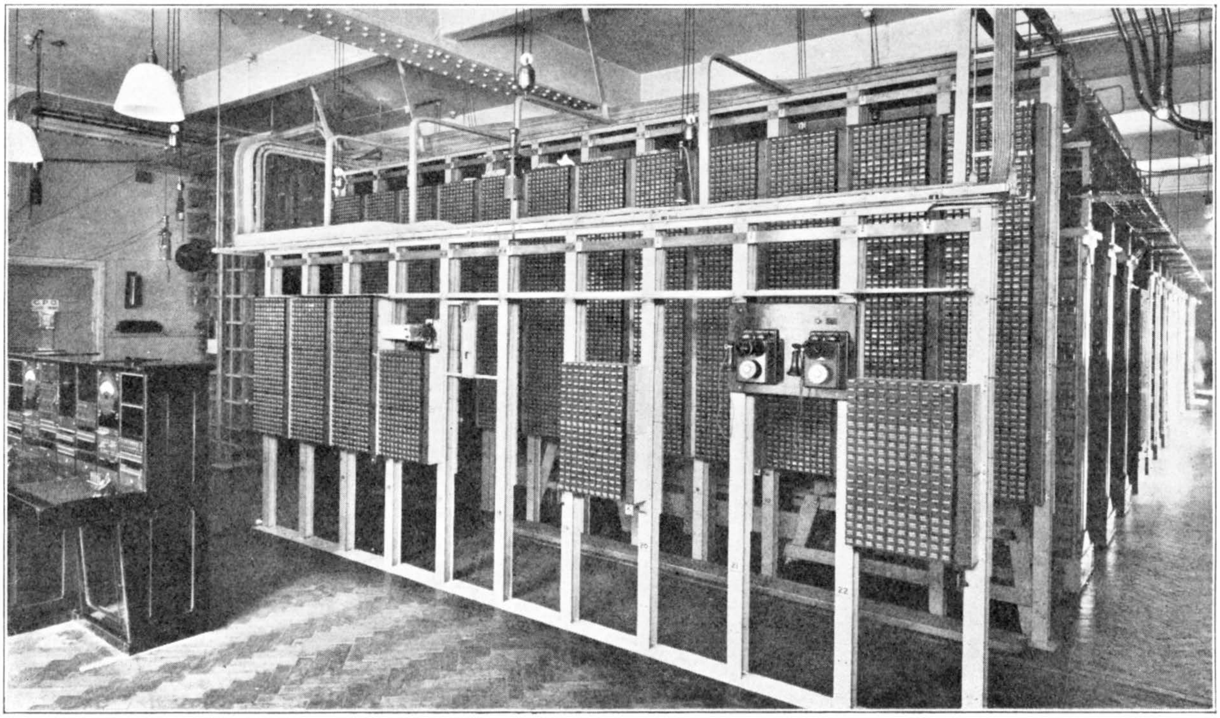


Fig. 1.—Bishopsgate Exchange. Part of First Floor.

Routiners are also provided for testing automatically, Coders, 1st Code Selectors, Senders, C.C.I. repeaters and Junc. Relay Sets. The times taken by these routine testers are approximately as follows:—

Director Routiner takes approximately $1\frac{1}{2}$ mins. for each Director. If the Forced Release test is cancelled, this is reduced to 50 secs. Due to the busying ahead feature, there is no waiting time for the Director to become disengaged.

First Code Selector Routiner takes approximately 2 mins. for each Selector. If the two Forced Release tests are cancelled, the time is decreased to 40 secs. The average waiting time of $1\frac{1}{4}$ mins. in busy period of day is not included in the test times.

Coder Routiner takes approximately 30 secs. for each Coder, plus average waiting time of 9 secs. in busy period of day.

C.C.I. Repeater Routiner takes approximately 20 secs. for each Repeater, plus the average waiting period for the Repeater to become disengaged. This will vary according to the time of day that the test is made and may be 0.60 seconds.

Sender Routiner takes approximately 20 secs. to test each Sender, plus average waiting time of 6 secs. in busy hour.

Keysender "B" Position Apparatus Junc. Relay Set Routiner takes approximately 35 secs. to test each Junction Relay Set. Busy Relay Sets are passed without being tested and without any alarm being given.

The writer is indebted to the Automatic Telephone Company for the photographs.

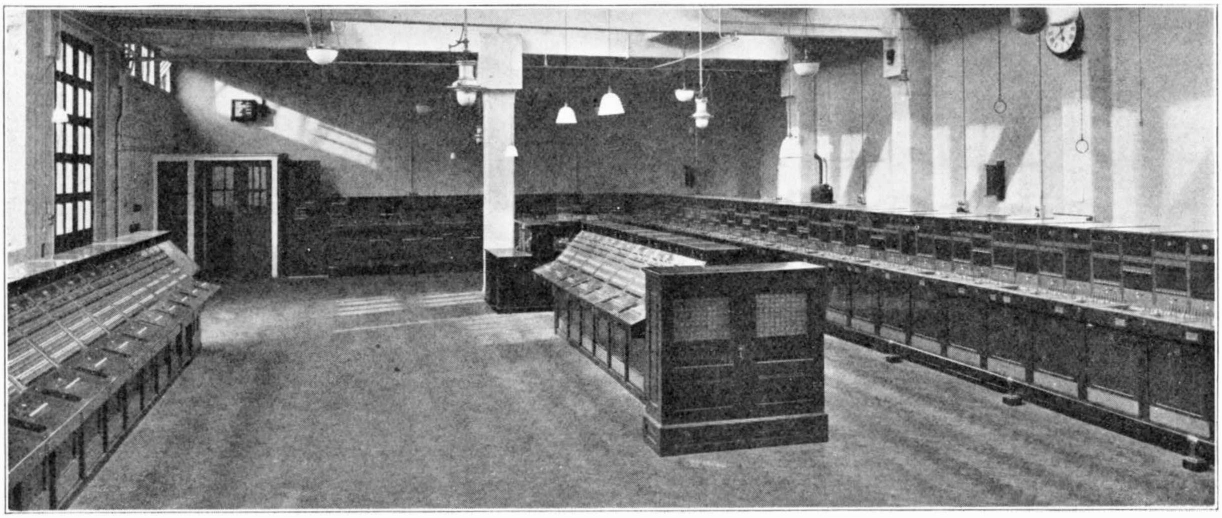


FIG. 2.—BISHOPSGATE EXCHANGE. CORDLESS "B" AND "A" AUTO. MANUAL POSITIONS.

LONDON AUTOMATIC SYSTEM.

MANUAL SERVICES.

H. MORTIMER, E.-in-C.'s Office.

UP to the present an article has not appeared in this Journal in connection with the manual services for Trunks, Toll, Telegrams and Directory Enquiry, which have been adopted as a standard by the British Post Office for Director areas.

It is not proposed to explain the use of these services as they are well-known, but it will be realized that it is necessary for some code or numbers to be dialled by automatic subscribers or operators to gain access to them *via* the automatic switching plant.

Three lettered codes as follows are therefore dialled :—

Trunks	TRU
Toll	TOL
Telegram	TEL
Directory	DIR

It will be noticed that the code corresponds to the first three letters of the service required, so that the subscribers should not experience any difficulty in remembering them.

To route the calls *via* the automatic switching plant, it is necessary to translate the codes dialled into their numerical equivalents of the level of the Code Selector Switch from which they are routed; for example, at Holborn Automatic Exchange and Tandem Exchange, the code translations are as follows:—

Service	Holborn	Tandem
TRU	38	02
TOL	32	04
TEL	312	01
DIR	503	03

It will be realised of course that the routing can take place *via* any level of 1st, 2nd or 3rd code switches, and that they would not necessarily be the same levels in all exchanges.

The traffic facilities to be given on these four services vary somewhat, and the following schedule clearly indicates the service requirements in this respect:—

Service	Circuits to which automatic subscribers have access.	Circuit to which operators have access.
TRU	Non-metering Non-holding	Standard Supervision.
TOL	Non-metering, holding, flashing-in by subscribers.	do.
TEL	Metering, non-holding.	do.
DIR	Non-metering, holding, flashing-in by subscribers.	do.

To obtain the foregoing facilities, it has been necessary to design special circuits for the relay sets inserted in the respective junctions. The diagram number referring to the relay sets will be seen on the routing diagrams reproduced with this article.

Attention is drawn to the fact that where standard supervision is desired, it is not possible to give non-metering conditions, therefore, separate groups of circuits have to be provided.

The following shows the different groups of circuits that have been provided in the London Automatic System to meet all the varying conditions.

Trunks—

(i) Automatic subscribers.

(ii) Automatic manual board.

(iii) Manual exchanges which circulate their traffic *via* Tandem.

(iv) Automatic subscribers *via* Tandem.

Toll—

(i) Automatic subscribers.

(ii) Automatic manual board.

(iii) Manual exchanges which circulate their TOL traffic *via* Tandem.

Telegrams—

(i) Automatic subscribers, Automatic manual board } Common group.

(ii) Automatic subscribers, Automatic manual board, Manual exchanges } Common group for traffic circulated *via* Tandem.

Directory—

(i) Automatic subscribers, Automatic manual board } Common group *via* Tandem.

(ii) Manual exchanges *via* Tandem.

Owing to circuit complexities it was decided that separate groups should be provided for automatic subscribers and auto. manual board to Toll and Trunk respectively. With regard to the direct circuits from the auto-manual boards to Toll and Trunk exchanges, in order to obtain standard supervision it has been necessary to insert a relay set in each circuit, owing to the dry loop condition which exists in the cord circuit (diagram A.T. 812) on the automatic manual boards fitted within the 5 miles area. Outside the 5 miles area, the cord circuit (diagram A.T. 1704) fitted on the manual board provides for standard supervision. It has also been decided, with regard to Toll calls from auto.-manual boards, that the control of the call shall be placed with the A operator at the auto.-manual board; therefore, these circuits terminate on the through clearing positions in the Toll Exchange. The calls originated by an automatic subscriber will be controlled by the Toll operator, and in this case the circuits terminate on a control position at Toll.

It will be seen that it is necessary to provide these different combinations of circuits to cater for the four services in the London Area.

Routing of Calls.

From a perusal of the diagrams showing the routing and circuit diagram numbers referring to the equipment concerned in a through call from any source, it will be seen that for the manual exchange end Diagram C.B. 904 has been quoted. This must be taken as typical only.

The method adopted by the distant manual exchange desiring to obtain Trunks, Toll, Telegram or Directory Enquiry is as follows:—

The distant A operator passes the demand over an order wire to the Tandem B operator for Trunk, Toll, Telegram or Directory as the case may be. The key sender B position operator at Tandem then keys up the three letter code demanded, the call then being routed by the sender *via* the Tandem first and second Code selector switches and relay set (if concerned) to the respective service.

In the case of a subscriber, the desired code is dialled into the Director switch in the automatic exchange. The call is then routed (after the Director has carried out the translation), *via* the first, second or third code selector switches in the originating exchange to the respective service, or *via* the first code switch in the originating exchange, to the incoming first Tandem switches in Tandem exchange, where the call is then routed direct from the second code selector levels.

Should the auto-manual board require any of the four services, the operator can gain access to Toll or Trunk by plugging into the corresponding outgoing junction multiple, or, in the case of Telegrams and Directory, by dialling the code required *via* the first code manual selector switches. This gives access to Telegrams and Directory *via* the same group of circuits to which the subscribers have access. For further particulars of the routing scheme reference should be made to the standard trunking diagrams referring to each exchange.

Circuit Descriptions.

With regard to the circuit diagram numbers quoted, it is not proposed to explain the circuit operations in detail (as this would take too much valuable space), but to indicate only the salient features of the relay sets that are inserted in the junctions, between the Automatic or Tandem exchanges to the four services. The circuits at the originating end follow standard practice; therefore, no circuit description is necessary as these are well known.

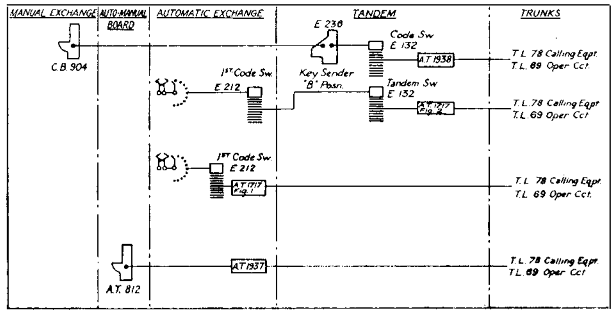


Fig. 1.—Trunks.

Trunks.

Calls routed via Tandem from Manual Exchange.

Relay Set Diagram A.T. 1938 is inserted for the purpose of giving standard supervision to the distant operator. It also provides for guarding the P bank contact after the manual exchange operator has cleared, until the trunk operator clears; this feature is provided to prevent following-on calls from being lost.

Calls routed via Tandem from Automatic Subscribers.

The Relay Set A.T. 1717, Fig. 2, is provided in the circuit between the outgoing level at Tandem exchange, and the Trunk exchange. Its function is to provide holding facilities for the Tandem selector switches until released by the calling subscriber and also to guard the P wire bank contact after the subscriber has cleared until the Trunk operator clears the connection.

Calls routed from Auto-Manual Board.

In this case, the Relay Set A.T. 1937 is inserted to provide standard supervision to the auto-manual board A operator, and also to maintain the visual engaged signal lamp on the auto-manual board after the A operator has cleared, until the connection is cleared by the Trunk operator. It should be noted that a Relay Set A.T. 1937 is only necessary in the junction circuits from the auto-manual board within the five miles area, owing to the "dry loop" condition of the calling cord circuit. Outside the five miles area, the cord circuits are designed to give either wet or dry loop conditions, therefore relay sets are not necessary under these conditions.

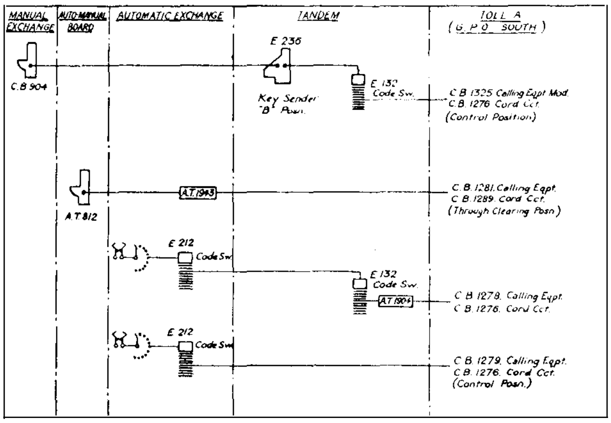


FIG. 2.—TOLL.

TOLL.

Calls routed via Tandem from Manual Exchanges.

No relay set is necessary in these circuits, as the calling equipment and cord circuit at the Toll exchange provide for standard supervision being given to the distant A operator.

Calls routed from Auto-Manual Board.

The conditions quoted under the same heading for Trunks apply to this circuit.

Calls routed via Tandem from Automatic Subscribers.

The Relay Set A.T. 1904 caters for the same conditions as those under the similar heading for Trunks.

Calls routed direct from Automatic Exchanges from Automatic Subscribers.

A relay set is not necessary in this case, as the second or third code selector switches are held by the forward earth from the first code selector switch.

It should be stated that holding conditions are provided in the latter two groups so that the subscribers can flash in the Toll operator without breaking down the train of automatic switches.

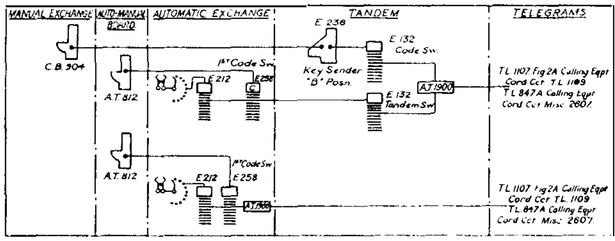


FIG. 3.—TELEGRAMS.

TELEGRAMS.

Calls routed either from an Automatic Exchange or *via* Tandem Exchange use a common group of circuits in each case because registration of the subscriber's meter and also standard supervision is desired on these calls. Both these conditions are obtainable, due to the reversal which is brought about in the relay set when the telegram operator answers. Relay Set A.T. 1900 provides for the reversal, and also guards the "P" bank contact against intrusion after the calling subscriber has cleared, until the telegram operator clears.

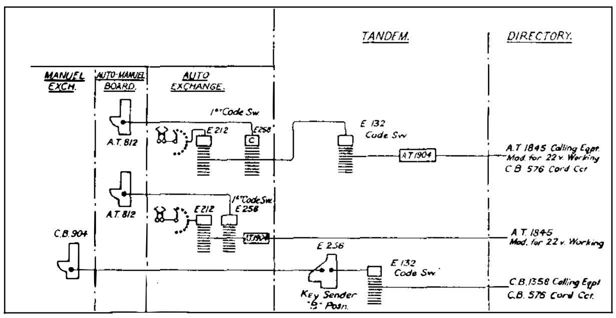


FIG. 4.—DIRECTORY.

DIRECTORY ENQUIRY.

Calls routed from Automatic Subscribers and Auto-Manual Boards direct or via Tandem.

Relay Set A.T. 1904 in this case provides holding facilities which enables the calling subscribers to flash in. It should be stated that full standard supervision is not given on the calls routed from the auto-manual board, owing to the fact that the group of circuits used are the same as those used by the automatic subscribers, and standard supervision and non-registration cannot be given on the same group of circuits. The reason for using the common group is, that the traffic from the auto-manual board will be very small indeed, and would not, therefore, justify a separate group of costly junctions being provided for this purpose.

Calls routed via Tandem from Manual Exchanges.

A relay set is not required in these circuits, as the junction relay group of the key sender B equipment provides the hold forward condition, which enables the Tandem first and second Code selector switches to be held in the operated condition, also, the answering equipment at Directory provides for standard supervision to be given to the originating A operator.

The numbers quoted on the circuit diagrams refer to the particular apparatus concerned, from which full circuit conditions can be obtained.

It is thought that the foregoing remarks, together with the routing diagrams, will enable those interested, to obtain a knowledge of the somewhat complex trunking scheme required for these four services.

MECHANICAL ORDER-WIRE OPERATION.

A METHOD OF HANDLING TRAFFIC FROM MANUAL TO AUTOMATIC EXCHANGES.

D. A. Christian (of Siemens Bros & Co., Ltd.).

Present Methods of Operation.

THE use of an order-wire for handling the traffic between two manual exchanges is well known and has for long proved the most efficient and economical method of manual to manual operation. The outstanding advantages that the order-wire method of operation provides are speed of operation, particularly with respect to the time taken by the " A " operator to handle the call, and simplicity in the junction circuit arrangements necessary. The short time taken by the " A " operator to handle a call is chiefly due to the junction assignment being given from the " B " end, thereby relieving the " A " operator from the necessity of searching for a free junction. The simplicity of the junction circuit arrangement is due to the use of the order-wire for initiating the call, only the clearing signal being controlled over the junction.

When the incoming exchange is converted to automatic working a new set of conditions is obviously met, and at present one of the two following methods of operation is usually adopted. Dials are provided on the " A " positions and the " A " operators have to search for a free junction and dial the necessary trains of impulses to set the automatic switches. This method may be looked on as adopting automatic principles of operation at the manual exchange, in that a search is made followed by transmission of impulses: it is obviously uneconomical in " A " operators' time and is quite unsuitable where the junction traffic is heavy. The alternative method is to retain the services of " B " operators at the automatic exchange and provide cordless " B " positions there. This method may be looked on as adopting manual principles of operation at the automatic exchange and while maintaining the efficiency of the " A " operators, it incurs considerable expense at the " B " end.

Fundamental Considerations Involved in the Problem.

On consideration it will be realised that the completion of a manual to automatic call comprises two operations which are to a great extent distinct, and that several methods of operation are in each case available. These operations and the possible methods of accomplishment are indicated in the following table:—

(1) *The Selection of the Junction.*

(*a*) Click tests made by the " A " operator, with or without group engaged test.

(*b*) Visual engaged signals.

(*c*) Individual jacks for each operator with junctions automatically selected by junction finders.

(*d*) Demand and assignment, as for example, over an order-wire to a " B " operator.

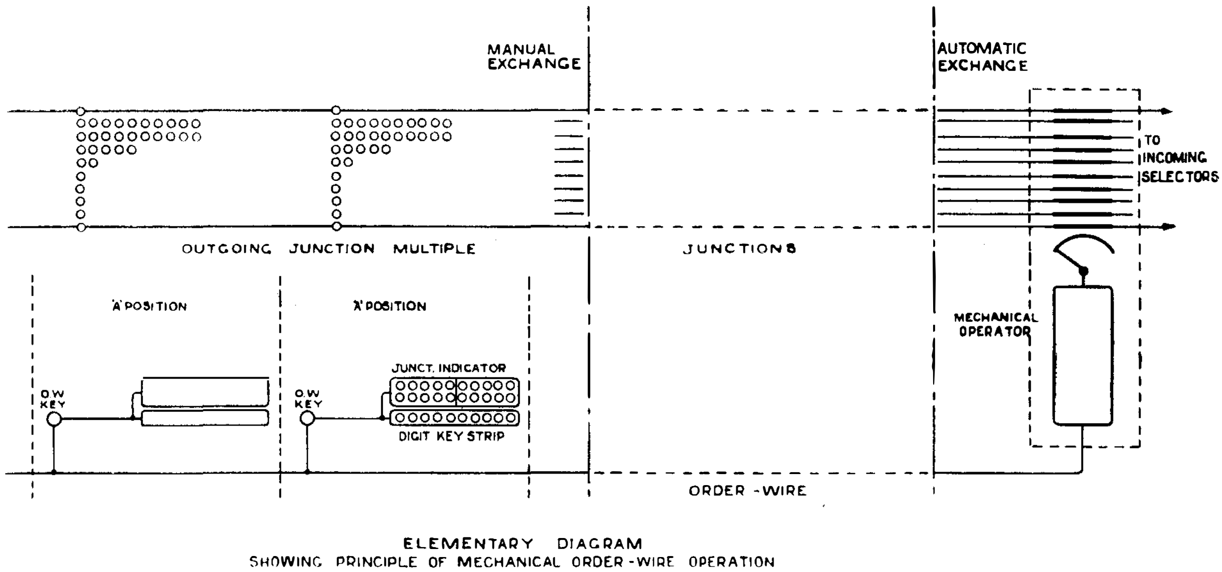
(2) *The Transmission of the Number Required*

(*a*) Dialling.

(*b*) Digit-key Strip.

(*c*) Verbal communications with a " B " operator.

assigned junction. Simultaneously the " B " operator connects the assigned junction to the required number in the multiple. Mechanical Order-wire Operation is based on precisely the same principles but employs what may be termed a mechanical or automatic " B " operator at the automatic exchange. The mechanical-operator, sometimes termed a decoder-sender, consists of a selector type switch and an associated controlling circuit consisting of relays and preselectors. Manifestly, such an apparatus unit cannot respond to a verbal request from the " A " operator, nor can it verbally assign a free junction: the " A " operator is therefore provided with a digit-key strip by which the required number can be signalled and a visual number indicator on which the assignment can be received. A diagrammatic representation of the condition so far considered is shown in Fig. 1.



ELEMENTARY DIAGRAM
SHOWING PRINCIPLE OF MECHANICAL ORDER-WIRE OPERATION

FIG. 1.

The development of any scheme for handling manual to automatic traffic is mainly a matter of combining the particular methods chosen for these two operations. The arrangements about to be described combine methods (*d*) and (*b*).

THE ADAPTION OF ORDER-WIRE WORKING TO AUTOMATIC CONDITIONS.

In manual order-wire operation, the " A " operator depresses the particular order-wire key: passes the required number to the " B " operator verbally: receives a junction assignment also verbally: and connects the calling cord to the

Considering this diagram, it will be seen that conditions exactly similar to manual order-wire working are obtained. The " A " operator, by depressing the order-wire key, can signal to the mechanical-operator the required number by means of the digit-key strip: the mechanical-operator can select a free junction and by signals reverted over the order-wire can indicate the number of the junction on the visual indicator and the mechanical-operator can extend the junction assigned to the required number by sending out the necessary trains of impulses to the automatic equipment.

In the above simple consideration two points have, however, been neglected, and the arrangement requires extension to cover these. In the first place it is clear that while one " A " operator is using the order-wire for signalling, it must be guarded from interference by other " A " operators. This is easily effected by introducing a testing or coupling relay between the order-wire key and the order-wire and arranging the circuit so that when the relay of one position is operated the relays of other positions are unable to operate even if their order-wire keys are depressed. In the second place the mechanical-operator will take much longer to set up the connection through the switches of the automatic equipment than a manual " B " operator will take to plug into the required number in the multiple. To meet this condition it is necessary to provide a number of mechanical-operators to serve the order-wire, these taking duty in rotation. The condition now arrived at is shown in Fig. 2. The necessary junction relay equipment to convert from manual to automatic signalling is indicated in this diagram and the junction indicator is shown in an alternative position in the panel instead of on the keyshelf in front of the digit-key strip.

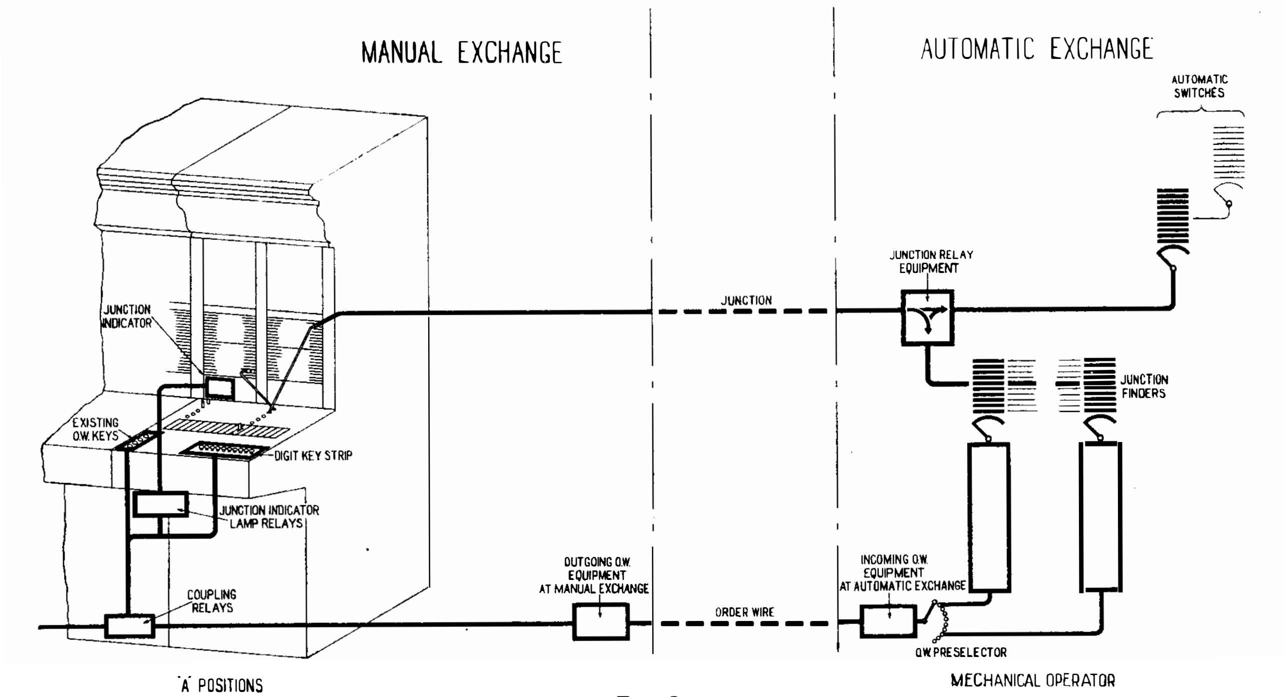


Fig. 2.

The elements of the system having now been explained, a more particularised and detailed description of the method of operation may be given.

Under normal conditions, that is, when no calls are being set up, each mechanical-operator preselects a disengaged junction and couples itself thereto by means of its junction-finder switch. This switch may be of any convenient type according to the number of junctions required: that shown in the diagram is an ordinary two-motion switch provided with the special rotary release magnet used on the Siemens' P.B.X. Final Selector circuit, which enables the wipers to search over all levels successively until a free contact is found. The order-wire preselector also preselects and couples the order-wire to a free mechanical-operator.

On receiving a call for the automatic exchange in question, the " A " operator depresses the corresponding order-wire key. This action tests the order-wire circuit, and if the latter is free, gives the operator the sole use of it as long as the key is depressed.

The operator now keys up the required number on the digit-key strip and each digit is instantaneously transmitted over the order-wire and stored in the selected mechanical-operator.

Immediately on release of the digit-key used for the units digit, the code corresponding to the number of the junction to which the mechanical-operator is coupled is transmitted back over the order-wire and appears on the junction-indicator on the " A " position. The operator having noted the junction number then releases the order-wire key and frees the order-wire for further use. On the release of the order-wire key the junction number is extinguished.

A suitable time is now provided during which the operator can take the junction by plugging into the outgoing junction jack. Should the operator not take the junction, then on the expiry of this period the whole connection is released and the switches return to normal without the called subscriber being rung. Assuming the operator has taken the junction, the mechanical-operator completes the setting up of the connection in the automatic exchange. As soon as this is done it disconnects itself from the junction and its finder again commences to search. The junction is now switched straight through to the automatic switches and the connection is dependent on the presence of the calling plug in the outgoing junction jack.

During conversation full normal supervision is given on the " A " operator's supervisory lamp and on reception of the clearing signals the operator takes down the connection in the ordinary way and the switches in the automatic exchange return to normal.

If, when the operator depresses the order-wire key, the order-wire is already engaged or if there are no free mechanical-operators available, a tone is heard in the operator's receiver. In these circumstances the order-wire key may be held depressed, and as soon as connection with a free mechanical-operator is made, the tone will cease and the call can be set up. Or, if the group of junctions is so large that it requires the use of two or more order-wires, the second or later choices may be tried, just as in manual practice. Should the operator realise that she has operated the digit-keys incorrectly, she can correct the mistake in a quite natural manner, namely, by releasing the order-wire key, re-depressing it and setting up the number again.

For the sake of clarity it has been inferred in the above description that the digit signals are stored in the mechanical-operator until the " A " operator takes the junction. Actually the impulse train corresponding to the first digit is transmitted as soon as the digit is received and each of the remaining trains, except the units train, as quickly as possible after the reception of the corresponding digit. The transmission of the units train is made dependent on the " A " operator taking the junction and, if necessary, is held up until she does so. By this means the call is set up with the minimum delay while at the same time it is ensured that the required line is not rung until the junction is taken.

Since the method of operation follows so closely to existing manual order-wire operation, there is no alteration or modification whatever required to the outgoing junctions or outgoing junction multiple nor to the " A " position cord circuits, nor is it necessary to provide visual engaged lamps or group engaged tests in connection with the outgoing junction multiple. Also the whole outgoing junction multiple remains fully available to all the " A " operators. A further feature is that all the automatic equipment is at the automatic exchange where the battery voltage and other arrangements are most suited to its operation. The equipment at the manual exchange, with the exception of the digit keys and junction indicator, consists entirely of relays, for the operation of which the manual exchange power plant is, of course, quite suitable.

Description of the Equipment Required.

The equipment required at the manual exchange for mechanical order-wire operation is very simple.

Each position is equipped with a digit-key strip and a visual number indicator capable of exhibiting two figures. These may be of any convenient type as found most suitable for the " A " positions to be equipped. Two types of digit keys are shown in Fig. **3**. The longer type will be familiar as the type of strip standardised for use on cordless " B " positions, while the staggered type has been developed for use when the space available on the " A " positions is limited. The junction number indicator is arranged in a form similar to the well-known code call indicator display, except that it shows only two figures. It may be arranged in the panel equipment or on the keyshelf where space permits. The only other item required on the position is the order-wire key itself, which be-

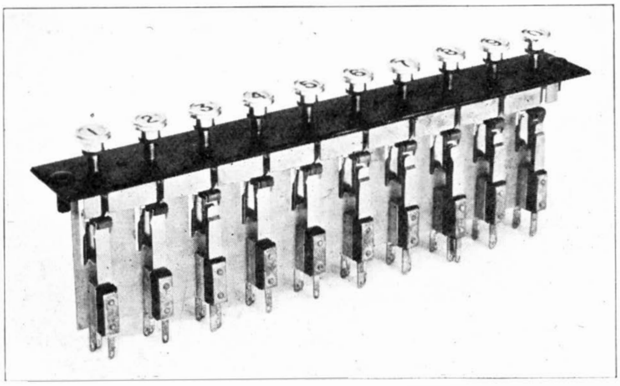


FIG. 3.

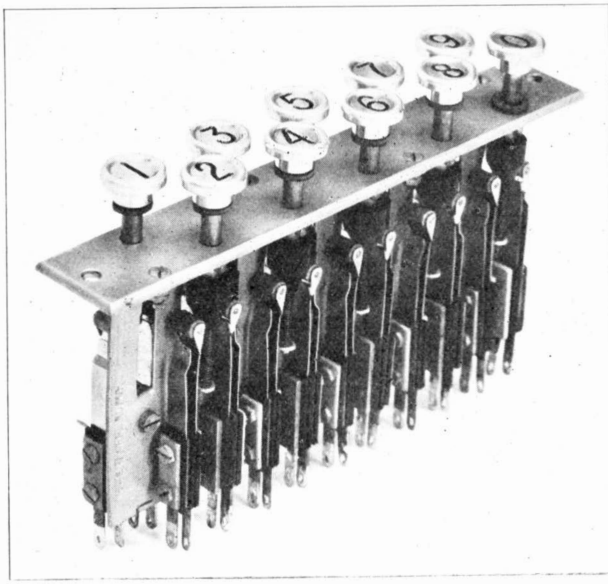


FIG. 3.

ing of the ordinary type with two make contacts, will in almost all cases already exist.

All the other equipment at the manual exchange consists of relay groups, which are provided as follows: One group per "A" position, consisting of thirty relays which control the indicator lamps and the order-wire testing circuit: one relay per position per order-wire for coupling the position apparatus to the particular order-wire required: and one relay per order-wire per exchange associated with the order-wire itself.

It may perhaps be emphasised that the digit-key strip, the junction-indicator and the position relay group are common to any number of order-wires and need no alteration whatever, no matter how many further order-wires may be converted to mechanical operation.

The chief item of equipment at the automatic exchange is, of course, the mechanical-operators and these may vary somewhat in size and appearance according to the size of equipment required. A rack of these circuits is shown in Fig. 4, from which the general appearance of a typical equipment may be obtained.

The junction relay equipments at the automatic exchange are pure relay equipments with circuits very similar to the ordinary incoming junction circuit, the precise circuit required depending, of course, on the type of manual and automatic equipment with which it has to

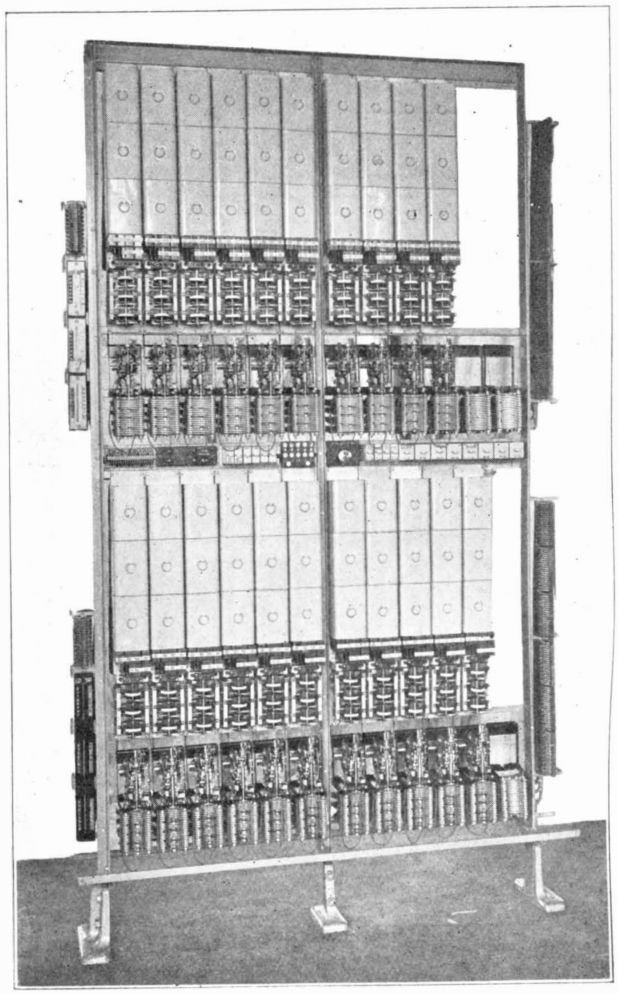


FIG. 4.

operate. This circuit also provides the point at which the mechanical-operator makes connection with the junction.

The order-wire preselector is a simple preselecting circuit and needs no special description.

CIRCUITS.

A full description of the circuits used in this method of operation is considered quite unnecessary to a general understanding of the system and would indeed occupy more space than is

the order-wire proper consists of four wires. At the manual end these, together with two further wires, are multipled to all the " A " positions as in manual practice, although since the position relay equipment is probably most conveniently mounted on special racks, it does not follow that these six wires are actually taken round the manual sections. At the automatic end the order-wire terminates on the order-wire preselector which connects it through to a mechanical-operator.

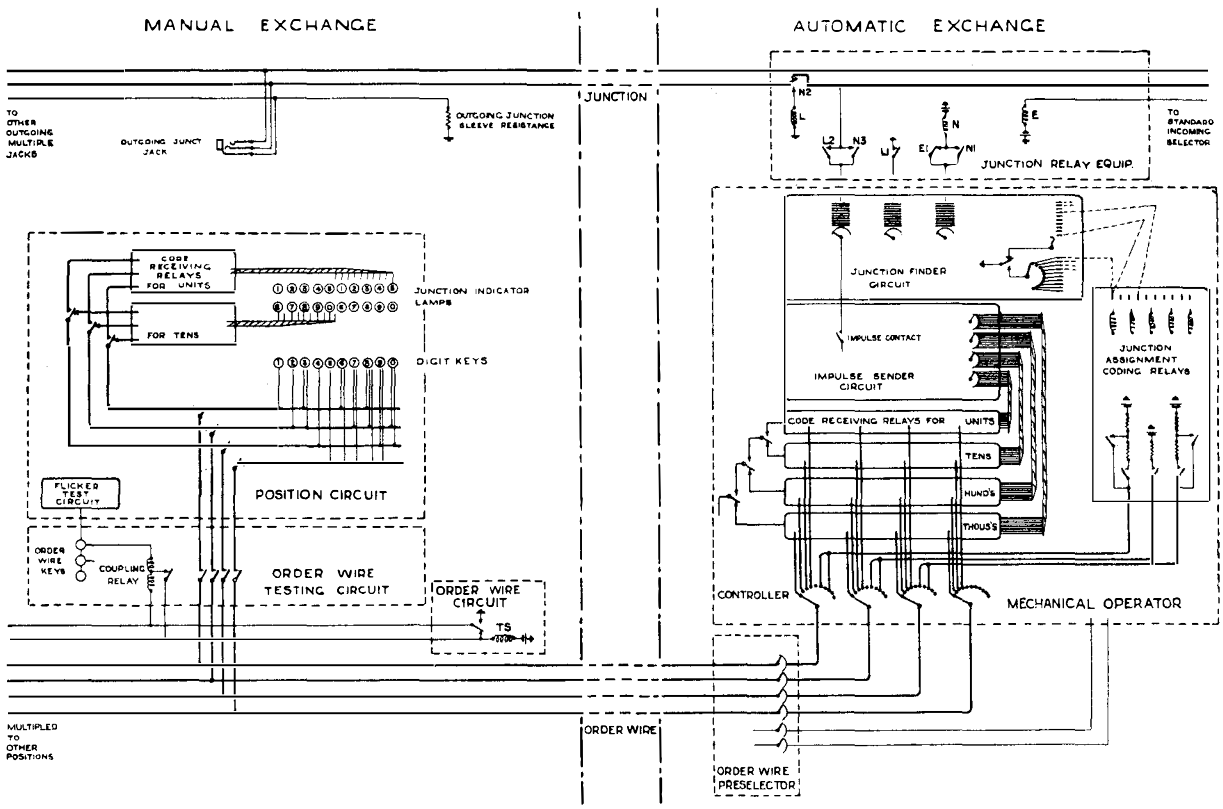


FIG. 5.

available. The following elementary diagrams and description may, however, be appreciated by those interested in circuit design and will at least indicate the principle of operation utilised.

Fig. 5 shows a general circuit outline of the arrangements. In this diagram no attempt is made to show the detailed circuit operation, most of which is quite conventional in character and is of interest only to those operating the equipment.

Referring to the diagram, it will be seen that

When the " A " operator depresses an order-wire key the flicker test circuit is set in operation and under control of this circuit, the precise operation and functions of which are described later, the particular order-wire is tested and the coupling relay connects the four order-wire conductors through to the position if the order-wire is free. The change-over relay contacts are at present in the unoperated position and the order-wire is therefore connected directly through to the digit-keys. Assuming that a free mechanical-operator which has preselected a free junction is available at the automatic end then a relay, not indicated in the diagram, operates and disconnects the busy tone from the " A " operator's receiver. The operator now depresses the required digit-keys one after the other and each key connects earth to one or more of the order-wire conductors in definite combinations.

The controller switch in the mechanical-operator steps on the release of each digit-key, thus distributing the digit codes to the thousands, hundreds, tens and units code receiving relays.

The transmission of impulse trains dependent on the digits received is controlled by the impulse sender circuit. The diagram indicates how each digit is in turn connected up to the banks of the sender-switch. The details of the impulse transmitting circuit are too involved to indicate clearly in the diagram, but contain no point of particular interest to this method of operation. The junction relay equipment shown is suitable for a Siemens No. 16 type automatic exchange and in this case the impulses are transmitted *via* the " A " line to the junction circuit and thence to the automatic switches.

Immediately the units digit has been received by the mechanical-operator the controller steps on to the first code transmitting position, the junction assignment circuit is now brought into operation and a certain combination of the coding relays is operated dependent on the vertical position of the junction-finder switch and the contacts of the operated relays connect definite potentials to the order-wire conductors. The change-over relay circuit at the manual position also changes over at the release of the units digit-key and the code thus transmitted is received on the tens set of code receiving relays at the manual end. These relays lock up and the associated lamp in the junction indicator lights. The controller now steps to the second transmitting position and the action is repeated except that the assignment coding relays are now dependent on the rotary position of the finder switch. The number of the junction assigned is thus shown on the junction-indicator and the " A " operator now releases the order-wire key and plugs into the assigned junction. Although this operation takes some time to describe, it should be realised that the action takes place so quickly that the assignment is shown almost instantaneously after the release of the units digit key.

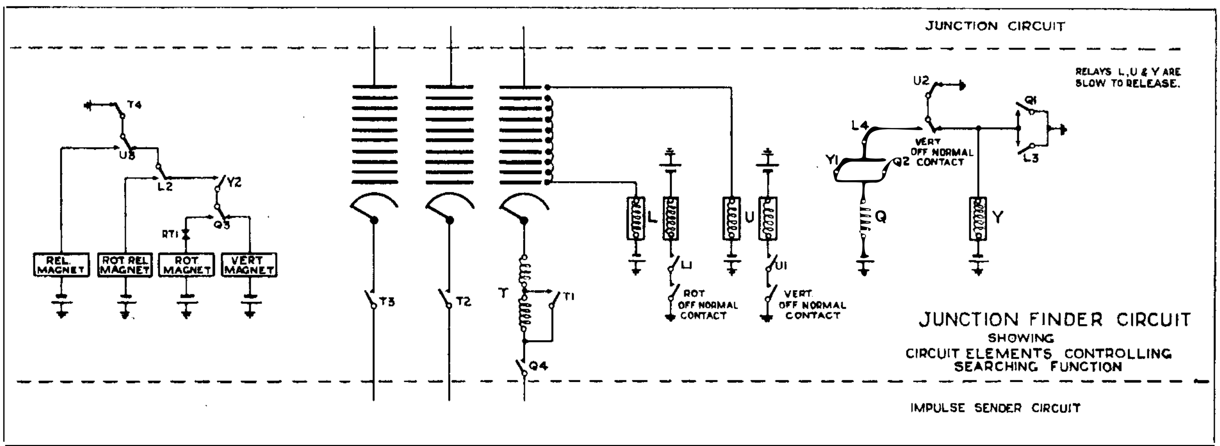


Fig. 6.

Meanwhile impulses are being transmitted by the mechanical-operator to the junction and thence to the switches in the automatic exchange from the impulse contact *via* the first wiper of the junction finder switch and contact N3 in the junction circuit.

On plugging into the junction the " A " operator operates relay L in the junction relay equipment. Contact L1 signals the fact to the mechanical-operator and thus permits the units impulse train to be sent and the required line to be rung. On the completion of the units train the mechanical-operator releases itself from the junction by opening the circuit of its third wiper, thus releasing relay N and connecting the junction through and leaving the connection entirely dependent on the presence of the plug in the outgoing junction jack. In the circuit arrangements indicated, which are suitable for use with an automatic exchange of the Siemens' No. 16 type, the connection is actually held by the battery on the " B " wire holding the line relay in the transmission bridge which is situated in the incoming selector: the incoming selector in turn holding relay E in the junction relay equipment and thus at E1 marking the junction engaged to other searching junction-finder switches. With automatic equipments using circuits based on other prnciples the junction auxiliary equipment circuit will differ from that shown and may require a transmission bridge to convert the manual signals to the type used in the automatic exchange.

After the mechanical-operator is released the junction finder proceeds to search, if necessary, level after level, for another free junction and having found one stops thereon and waits until it is again taken into use by the order-wire. The circuit control for effecting this searching action is shown in Fig. **6** and the action is as follows:—

On reaching the last (eleventh) contact in a level relays T and L operate in series: T4 cuts the drive circuit to the rotary magnet: L locks through L1 and the rotary off-normal contact: L2 connects up the rotary release magnet and L3 operates relay Y. Relay Q is released by L4: Q4 releases relay T: T4 closes the circuit of the rotary release magnet and the selector wipers are returned to rotary normal (without, however, the selector shaft being dropped to vertical normal). The rotary off-normal contact opens on rotary normal being reached and relay L releases: L2 closes the circuit of the vertical magnet and the wipers are stepped up to the next level. Relay Y now releases and at Y1 operates relay Q: Q3 prepares the circuit of the rotary magnet: Q1 again operates relay Y which at Y2 closes the circuit of the rotary magnet and the search again proceeds. On reaching the last contact of the " O " level, relay U is operated instead of relay L and by a similar action which will be readily traced from the diagram the wipers are completely released to vertical normal and then stepped up to the first level and the search again proceeds.

The order-wire testing circuit, including the flicker test circuit, is shown in Fig. **7**. By means of the flicker test circuit double connections on the order-wire are made a practical impossibility. The principle of action is that the testing relays are designed so that two cannot operate in parallel: the result of this, without the flicker test circuit, would be that the operators would lock each other off the order-wire if more than one operator was waiting with her order-wire key depressed for the order-wire to go free. The

ORDER-WIRE TESTING CIRCUIT
SHOWING FLICKER TEST

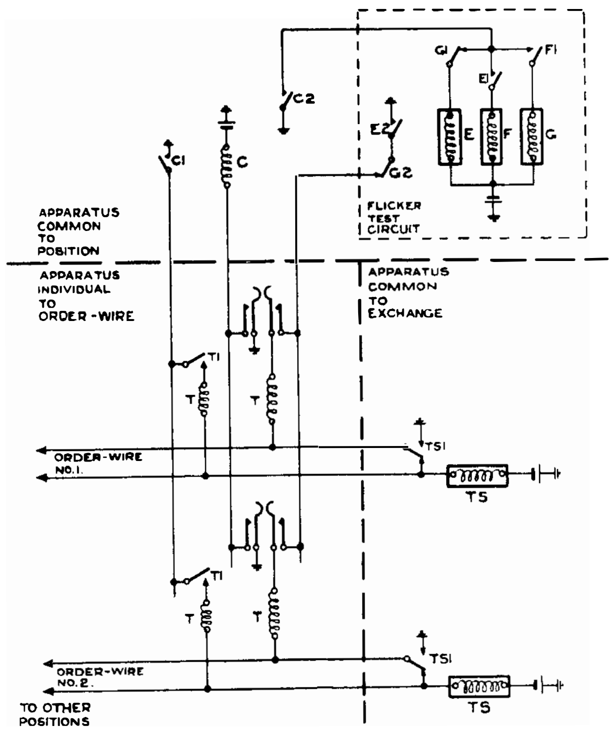


Fig. 7.

flicker test prevents this state of affairs occurring as will be seen from the following description:—

When the order-wire key is depressed the circuit of relay T is not directly closed as it is still open at E2. Relay C, however, operates and C2 operates relay E, which at E2 closes the testing circuit. Assume the order-wire is engaged: T will not operate: relay F operates through E1: relay G operates through F1: the testing circuit is now opened at G2. Relay E is now released by G1 and in turn releases F and G. Relay E again operates and the testing circuit is again closed. Relays E, F and G are slow releasing so that it will be seen that the testing circuit is closed only for the short part of the cycle taken for F and G to operate while it is held open for the long part of the cycle during which E, F and G release and E operates. Due to the inevitable difference in the timing of the E, F and G relays the periodicity of this cycle will be different for every A position, so that when the order-wire goes free it is extremely unlikely that the circuit of two testing relays will be closed at the same time and that first closed will, of course, obtain access to the order-wire. Further, even if two testing circuits are actually closed when the order-wire goes free, neither relay will operate on that cycle of the flicker circuit, but since on the next cycle the phase of the two flicker circuits will have altered, one of the testing relays will get in.

The only other circuit arrangement of interest is that of the junction assignment coding relays which is shown in Fig. **8.**

This circuit could be arranged in many ways; that shown is reasonably economical in relays while at the same time being straightforward and simple. The coding relays A, B, D and E have high and low resistance windings as shown, while C is a marginal relay which operates through the low resistance windings but does not operate when a high resistance winding is in circuit. An earth applied through either the vertical or rotary wipers to the first contact will therefore operate relays D and A but not C and by connecting battery through high resistances to the B and D wires of the order-wire, will operate relays TA and TD at the manual end and so light lamp No. 1 in the assignment indicator. The following table gives the coding and receiving relays operated and the conditions on the order-wire for the various digits:—

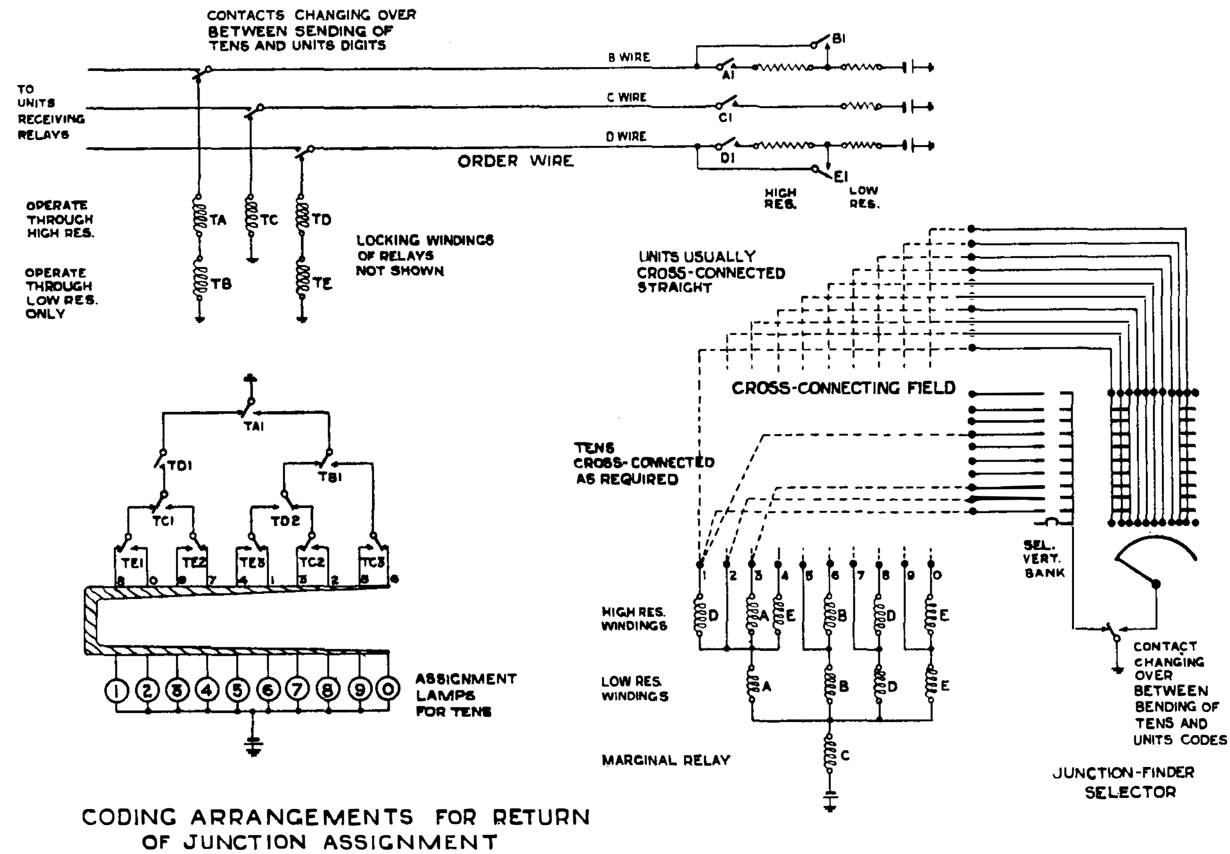


FIG. **8.**

Digit.	Coding Relays Operated.	Condition on Order Wire. B Wire.	C Wire.	D Wire.	Receiving Relays Operated.
1	AD	HR–		HR–	TA TD
2	AC	HR–	LR–		TA TC
3	A	HR–			TA
4	AE	HR–		LR–	TA TD TE
5	BC	LR–	LR–		TA TB TC
6	B	LR–			TA TB
7	DC		LR–	HR–	TC TD
8	D			HR–	TD
9	EC		LR–	LR–	TC TD TE
0	E			LR–	TD TE

TRAFFIC CARRYING ABILITY OF THE SCHEME.

Since mechanical order-wire operation is in principle very similar to manual order-wire operation, it follows that the traffic considerations involved are also of a similar nature. There are, however, two important distinctions between manual and mechanical operation which should be appreciated.

In the first place, the order-wire gives access to a gang of mechanical-operators instead of to only one operator as in the manual case. Now since the natural manual condition of one operator to one order-wire is departed from, it follows that a sufficient number of mechanical-operators can be provided to ensure that the order-wire itself is fully loaded. This means that the load on the order-wire is limited only by its own capacity to transmit numbers and return assignments and not, as is the case in manual operation, by the " B " operators' capacity to set up connections.

In the second place, since the mechanical-operators do not suffer from fatigue, the order-wire can be kept loaded up to its full capacity for an indefinite period.

The load on the order-wire being thus freed from any restriction due to the capacity of the " B " operator the number of calls which the order-wire can carry may now be considered, and this capacity is now dependent purely on the time taken to handle each call and the average time which can be permitted in waiting for the order-wire to go free.

Observations show that the average time taken to make a call over the order-wire, that is to key up the four digits on the key-strip and to read the number of the junction assigned is 2.0 seconds or 0.5 seconds less than the corresponding time in manual practice: 2.25 seconds may be taken as a safe figure.

The waiting time is, of course, of great importance and should not be allowed to exceed that provided in manual practice. We may, therefore, take as the load for one order-wire the normal load for one order-wire under the best manual conditions. This load is taken to be 460 calls per hour and calculations based on Erlang's formulæ for waiting times show that this will give an average waiting time per call of 0.5 seconds for the mechanical order-wire compared with 0.6 seconds in the manual case.

So far no advantage has been taken of the removal of the restriction due to the manual " B " operator, but when a group of order-wires to the same exchange is considered, this feature of mechanical operation becomes really important. It is, of course, well known that the separate circuits of a group can be worked at much greater efficiency than a single circuit, so that the load on an order-wire forming one of a group can be much greater than that on a single order-wire while still maintaining the same average waiting time on the group. With the restriction due to the manual " B " operator removed this advantage can be fully utilised by merely ensuring that the number of mechanical-operators provided is sufficient to handle the increased load and the following figures give an indication of the advantage thus obtained :—

	MANUAL	MECHANICAL		
	One O.W.	One O.W.	Two O.Ws.	Three O.Ws.
Calls per hour per group	460	460	1520	2560
Calls per hour per O.W.	460	460	760	853
Average waiting time in secs.	0.6	0.5	0.3	0.2
Connections with no delay	68%	71%	74%	75%

It will be noticed that the loads per order-wire for groups of 2 and 3 order-wires are 760 and 853 calls per hour respectively. These are far in excess of anything accomplished in manual practice and yet the waiting times are less and the quality of service is therefore higher. As has been explained this is due to the removal of the limitation imposed by the physical capacity of the " B " operator.

The number of mechanical-operators required also depends on the average call duration and the waiting time permissible. The time taken for the mechanical operator to handle a call depends on the number of impulses in the trains constituting the required number, and from observation the average time from the depression of the order-wire key until the release of the mechanical-operator is found to be 8 seconds: 9 seconds may be taken as a safe figure and will allow for the few cases where delay occurs due to the " A " operator delaying in taking the junction. As previously explained, the waiting time on the mechanical-operators should be so short that it

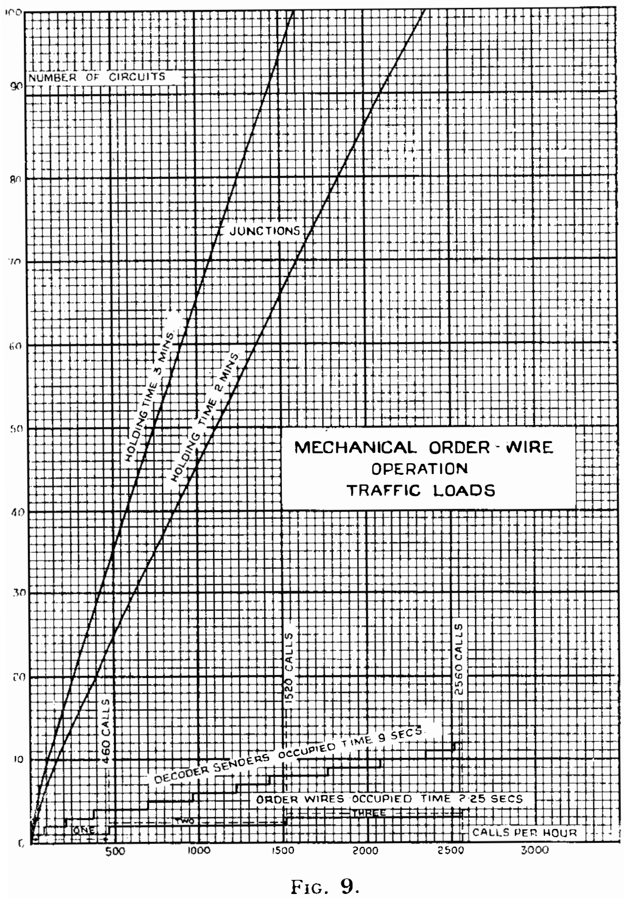


FIG. 9.

can never appreciably affect the service given by the order-wire. The provision of mechanical-operators on this basis is shown by the curves in Fig. **9**, which curves also show the necessary provision of order-wires and junctions for loads from zero up to 2,500 calls per hour.

SIZE OF JUNCTION GROUPS.

The arrangements which have been described are particularly suitable for the operation of groups approaching a hundred junctions. Where a smaller junction group is concerned the type of switch used for the junction-finder may be varied and the preselector type employed if suitable. On the other hand, where a number of small groups of junctions from different manual exchanges converge on an automatic exchange it may be convenient to retain the selector type of junction-finder and connect the various junction groups to different levels of the finder multiple. In this case it is necessary to definitely associate certain mechanical-operators with each particular group, in order to avoid the mechanical-operators by chance segregating themselves on certain junction groups and leaving others unattended: the condition is easily catered for by arranging each of the finder switches to restrict its search to the level or levels corresponding with the junction group with which it is associated. This arrangement renders it easy to transfer an operator from one group to another as may be required by variations of traffic.

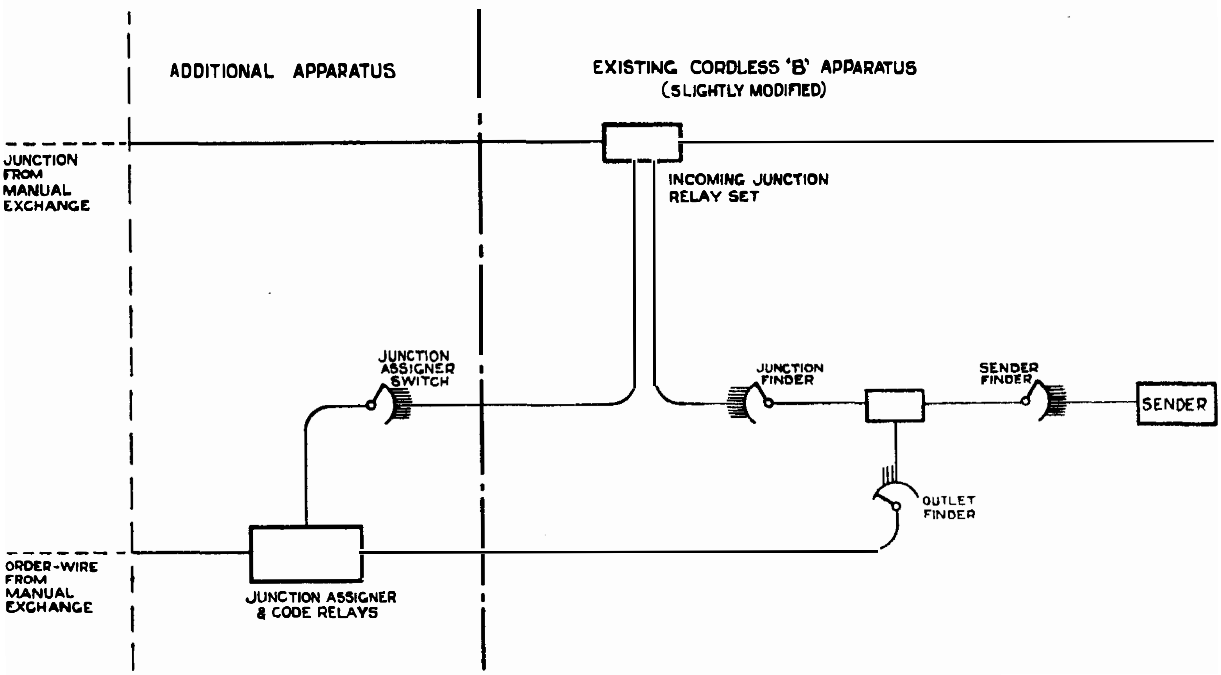
Another condition is where the junction group exceeds one hundred junctions. This condition may be met by operating the junctions as two entirely separate groups, each of not more than one hundred junctions and having separate order-wires for each group. The " A " operators would recognise which order-wire had been used and would take the assigned junction in the corresponding group. If desired, two extra lamps may be fitted on the junction-indicator to indicate the hundred and these can readily be controlled direct from the order-wire key depressed without in any way affecting the order-wire circuits themselves.

ADAPTION OF THE SCHEME TO AN AREA IN WHICH CORDLESS " B " WORKING IS ALREADY IN OPERATION.

The principle of mechanical order-wire operation is not restricted to the precise arrangements already described, and a case which justifies special consideration is that in which cordless " B " operation is already in use.

In this case the possibility of using the existing cordless " B " apparatus at the automatic exchange arises, and in the case of the Department's standard cordless " B " arrangements it is possible to make use of all the existing apparatus, except, of course, the cordless " B " sections themselves, with only the most trifling alterations to the wiring.

The general principle of this adaption is to provide a switch at the automatic end which will perform automatically the functions of assigning a free junction and of transmitting the number of the junction so assigned back to the junction-indicator at the manual exchange. A diagrammatic representation of these arrangements is shown in Fig. **10**, in which the existing apparatus is shown on the right hand and the extra apparatus required is shown on the left hand of the diagram.



ADAPTION OF MECHANICAL ORDER-WIRE OPERATION TO MAKE USE OF EXISTING CORDLESS 'B' APPARATUS

Fig. **10**.

With this arrangement what has previously been termed the mechanical-operator has been split up into several distinct parts and the functions divided as follows:—The selection of the junction is performed by the " assigner switch "; the " outlet finder," " junction finder " and " sender finder " switches perform the previously unnecessary function of coupling the order-wire to a free sender and connecting that sender to the assigned junction; the codes keyed up by the " A " operator are received and retransmitted as impulses by the sender; and the assignment is reverted to the " A " position by the " assigner switch."

Consequent on the above differences a slightly greater time will elapse before the " A " operator can key up the number required, since search for a free sender has to be made before this may be done. Further, it will be noted that when more than one order-wire is required between two exchanges each order-wire has access only to a particular group of junctions instead of any junction being available to any order-wire.

Ecomomic Aspect.

Space does not permit of an exhaustive analysis of the economic aspect of mechanical order-wire operation and it would indeed be difficult to give complete data on this subject, chiefly because the additional apparatus required at the " A " positions is practically all common to the position and therefore becomes increasingly efficient as the number of order-wires operated on a mechanical basis increases.

A comparison with cordless " B " operation in the case of a typical instance will, however, be indicative of the economies to be expected. The instance selected is that of an area having six automatic and three manual exchanges with order-wires and junction groups as follows :—

	A1 Jts.	A1 O.Ws.	A2 Jts.	A2 O.Ws.	A3 Jts.	A3 O.Ws.	A4 Jts.	A4 O.Ws.	A5 Jts.	A5 O.Ws.	A6 Jts.	A6 O.Ws.
M1 (60 'A' posns)	30	1	10	1	20	1	25	1	12	1	30	1
M2 (40 ,,)	20	1	8	1	15	1	20	1	8	1	15	1
M3 (50 ,,)	30	1	10	1	15	1	20	1	20	1	20	1
Total	80	3	28	3	50	3	65	3	40	3	65	3

The relative number of mechanical-operators and cordless " B " positions for such a case would be approximately as under :—

	A1	A2	A3	A4	A5	A6
Mechanical-Operators ...	11	6	9	10	7	10
Cordless " B " Positions...	3	1	2	3	2	3

Comparative costs based on the above figures show that the total capital cost of the mechanical order-wire equipment is only about £3,800 more than the cost of the cordless " B " equipment, while both the operators' quarters and the services of at least twenty operators are rendered unnecessary at the automatic exchange.

EQUIVALENT T's FOR TELEPHONE TRANSFORMERS.

H. J. Gregory, B.Sc., Whit.Ex., A.M.I.E.E.

It is convenient when making calculations concerning the transmission efficiency of subscribers' instruments and cord circuits to consider the induction coil or repeating coil as represented by a network of impedances forming a T. The derivation of the equivalent T for a telephone transformer may be considered as follows :—

These transformers have an iron core, consequently the impedance of the windings will be affected by the hysteresis and eddy current losses in the core. The conditions obtaining in an iron-cored transformer may be represented by Fig. 1, in which the third winding with its circuit closed imitates the iron core losses.

x, y and z are the currents in the primary, secondary and tertiary windings respectively.

The equations for this network are :—

$$E = x(r_1 + j\omega l_1) + y(j\omega m_1) + z(j\omega m_3) \quad \ldots\ldots(1)$$

$$O = x(j\omega m_1) + y(r_2 + j\omega l_2) + z(j\omega m_2) \quad \ldots\ldots(2)$$

$$O = x(j\omega m_3) + y(j\omega m_2) + z(r_3 + j\omega l_3) \quad \ldots\ldots(3)$$

from which it follows that

$$y = -x \frac{j\omega m_1 + \dfrac{\omega^2 m_2 m_3 (r_3 - j\omega l_3)}{r_3^2 + \omega^2 l_3^2}}{r_2 + j\omega l_2 + \dfrac{\omega^2 m_2^2 (r_3 - j\omega l_3)}{r_3^2 + \omega^2 l_3^2}} \quad \ldots\ldots(4)$$

$$E = x \left[\left(r_1 + j\omega l_1 + \frac{\omega^2 m_3^2 (r_3 - j\omega l_3)}{r_3^2 + \omega^2 l_3^3} \right) - \frac{\left(j\omega m_1 + \dfrac{\omega^2 m_2 m_3 (r_3 - j\omega l_3)}{r_3^2 + \omega^2 l_3^2} \right)^2}{r_2 + j\omega l_2 + \dfrac{\omega^2 m_3^2 (r_3 - j\omega l_3)}{r_3^2 + \omega^2 l_3^2}} \right] \quad \ldots\ldots(5)$$

If there had been no iron losses, the conditions would be represented by Fig. 1 with the tertiary winding removed and equations (4) and (5) would be reduced to

$$y = -x \frac{j\omega m_1}{r_2 + j\omega l_2} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

$$E = x\left[r_1 + j\omega l_1 - \frac{(j\omega m_1)^2}{r_2 + j\omega l_2} \right] \ldots\ldots\ldots\ldots\ldots (7)$$

Comparing equations (4) with (6) and (5) with (7) it will be seen that the effect of the losses in the iron core is apparently to make the effective resistance of the primary winding.

$$r_1 + \frac{\omega^2 m_3^2 r_3}{r_3^2 + \omega^2 l_3^2}$$

(r_1 is the D.C. resistance).

and its inductance is reduced to

$$l_1 - \frac{\omega^2 m_3^2 l_3}{r_3^2 + \omega^2 l_3^2} \qquad (8)$$

Similarly the effective resistance of the secondary circuit is increased to

$$r_2 + \frac{\omega^2 m_2^2 r_3}{r_3^2 + \omega^2 l_3^2}$$

and its inductance reduced to

$$l_2 - \frac{\omega^2 m_2^2 l_3}{r_3^2 + \omega^2 l_3^2} \qquad (9)$$

The mutual impedance beween the primary and secondary circuits, according to (4) and (5), has a resistance component

$$\frac{\omega^2 m_2 m_3 r_3}{r_3^2 + \omega^2 l_3^2}$$

and the mutual inductance is reduced to

$$m_1 - \frac{\omega^2 m_2 m_3 l_3}{r_3^2 + \omega^2 l_3^2} \qquad (10)$$

If the impedance of the primary winding is measured with the secondary winding on open circuit the result would be

$$r_1 + \frac{\omega^2 m_3^2 r_3}{r_3^2 + \omega^2 l_3^2} + j\omega\left(l_1 - \frac{\omega^2 m_3^2 l_3}{r_3^2 + \omega^2 l_3^2} \right) \ldots (11)$$

The same applies to the impedance of the secondary winding and the mutual impedance.

Suppose we have two coils AC and BC of inductance L_1 and L_2 respectively, with a mutual inductance M between them as shown in Fig. **2.** If these two coils are joined together at C so that the coils in series are assisting, then this arrangement can be represented by the equivalent T shown in Fig. **3.*** This will be evident if the inductance between corresponding letters on the two diagrams are considered. If the coils are joined in series opposing as in Fig. **4,** the

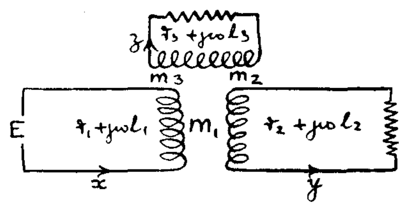


FIG. 1

FIG. 2.

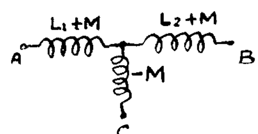


FIG. 3

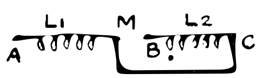


FIG. 4.

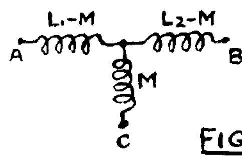


FIG. 5

equivalent T will be as shown in Fig. **5.** Similarly if the two coils are separate as in Fig. **6,** they can be represented mathematically by the equivalent T of Fig. **7** or Fig. **8.** This also applies if the impedances have resistance components.

SUBSCRIBERS' INSTRUMENT CIRCUITS.

The transmitter may be considered to be a generator of alternating current and if its variation of resistance is $r_o \sin \omega t$ and the feeding current is I then its E.M.F. will be $E = Ir_o \sin \omega t$,

* *See Bibliography 1.*

neglecting harmonics. Also if the D.C. resistance of the transmitter is r and is taken to be the internal impedance of the generator, the conditions for a L.B. instrument may be represented by Fig. **9**, and its equivalent Fig. **10**.

Similarly the C.B. instrument shown in Fig. **11** may be represented by Fig. **12** for Sending and Fig. **13** for Receiving. The induction coil is connected as an autotransformer.

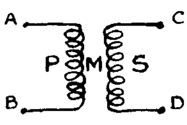


FIG. 6

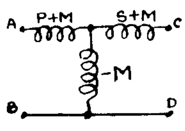


FIG. 7

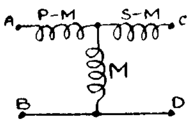


FIG. 8.

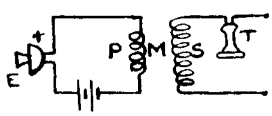


FIG. 9.

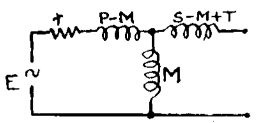


FIG. 10

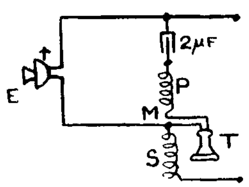


FIG. 11.

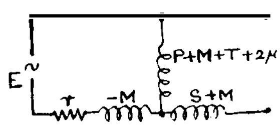


FIG. 12.

The information required for the construction of the equivalent T's can be obtained from the results of impedance tests. In making these tests it is necessary to keep the flux in the core in approximately the same condition as regards A.C. and D.C. as obtains in practice. In the case of L.B. induction coils the following tests are made :—

1. Impedance with 0.3 volt A.C. of the primary winding with 30 mA D.C. fed to the secondary winding through high impedance retards.

2. Test repeated with 200 ohm non-inductive resistance in place of the retards.

3. Impedance with 1 volt A.C. of the secondary winding with 100 mA D.C. fed to the primary winding through high impedance retards.

4. Test 3 repeated with 20 ohm non-inductive resistance in place of the retards.

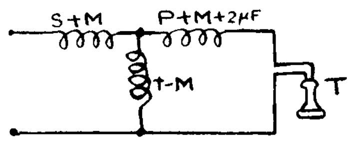


FIG. 13.

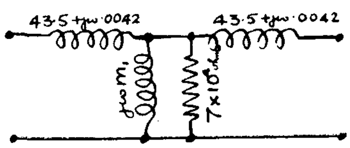


FIG. 16.

Equivalent T for Repeating Coil 4003A

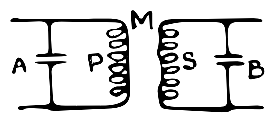


FIG 18

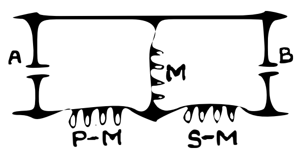


FIG. 19.

The values of A.C. and D.C. are intended to give approximately the same ampere turns for all the tests. In tests 1 and 3 the impedance of the retards is so high compared with that of the induction coil windings that the coil may be considered to be on open circuit as regards A.C. If Z_p is the impedance of the winding as measured by Test 2 and R is the non-inductive resistance across the other winding, then from a consideration of the equivalent T in Fig. **8** it will be readily seen that

$$Z_p = P - M + \frac{M\,(S - M + R)}{M + S - M + R}$$

$$\therefore \quad M = \sqrt{(P - Z_p)\,(S + R)} \quad \ldots\ldots\ldots\ldots\ldots\ldots (12)$$

Similarly if Z_s is the result obtained by Test 4

$$M = \sqrt{(S - Z_s)\,(P + R)}$$

The value of M can therefore be calculated twice from the results of the four tests. These two calculated values should be equal.

The impedances of an average L.B. induction coil 1ω/25ω are at 5,000 radians per second.

$$P = 2.0 + j\,27.8$$
$$S = 36.2 + j271.5$$
$$M = 3.8 + j\,79.5$$

The tests on C.B. induction coils are made with 1 volt A.C. across each winding and with 50 mA D.C. The impedances of an average coil at 5,000 radians per second are

$P = 48 + j381$ (26 ohm winding)

$S = 45 + j534$ (17 ohm winding)

$M = 25 + j439$

The impedances of induction coils are affected very little by direct current.

4003A Repeating Coils.

These coils are 1 : 1 ratio transformers, and as they are toroidal coils wound on a core of iron wire they have very little magnetic leakage. The inductance of the windings, however, is considerably affected by direct current. In order to obtain the equivalent T for a repeating coil at speech frequencies and with the values of direct current obtaining in practice some were tested in the following manner :—

Test 1. Impedance with a P.D. of 1 volt at the stated frequency, of winding 2—1—6—5 with six 5L retards in series connected across the winding 4—3—8—7 and with a battery of the necessary voltage to give the value of direct current desired in the latter winding.

Test 2. Impedance with a P.D. of 1 volt at the stated frequency of winding 2—1—6—5 with 300 ohms connected across the winding 4—3—8—7 and with a battery in series with this resistance to give the same value of direct current as in Test 1.

Test 3. Same as Test 1, but with windings 4—3—8—7 and 2—1—6—5 interchanged.

Test 4. Same as Test 2, but with windings interchanged.

In order to obtain the results given below these four tests were repeated for several frequencies and with several values of direct current at each frequency. In Tests 1 and 3 the impedance obtained will be lower than the real value for the winding as this impedance is not negligible compared with that of the six retards in series. The impedance of these retards, however, was known under the various conditions of the tests and their effect on the observed values of the impedances of the repeating coil windings were allowed for in the following manner.

From a consideration of the equivalent T, given in Fig. **8**, it follows that if **Z** is the impedance of the six retards in series and P_1 is the observed impedance of the primary winding,

$$\text{then } P_1 = P - M + \frac{M(S - M + Z)}{S - M + Z + M}$$

$$= P - \frac{M^2}{S + Z}$$

$$\therefore\ P = P_1 + \frac{M^2}{S + Z}$$

But $\frac{M^2}{S+Z}$ is the correcting factor which, in this case, is small compared with P and the error in P will be quite small if $\frac{M^2}{S+Z}$ be assumed to be equal to $\frac{P_1^2}{P_1 + Z}$

We then have the real value for the impedance of the winding

$$P = P_1\left(1 - \frac{P_1}{P_1 + Z}\right) \quad\text{.........................(13)}$$

The following Table 1 contains the mean results of impedance tests made on a number of repeating coils 4003A, made with a P.D. of 1 volt at several frequencies and with different values of direct current flowing through one half of the coil. The impedances of the two windings were found to be equal and the mutual impedance has been calculated in the same manner as described for induction coils.

TABLE I.

IMPEDANCE OF REPEATING COILS 4003 A.

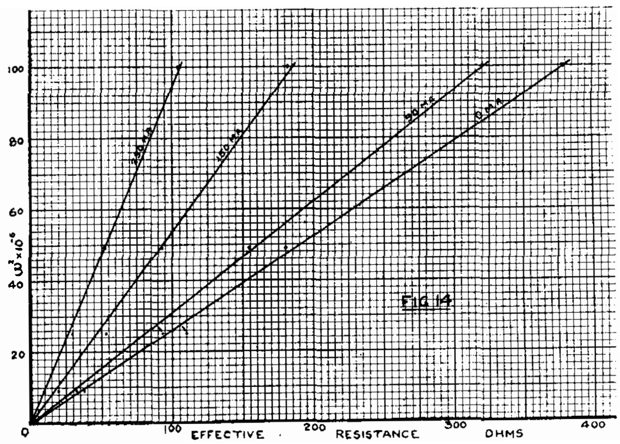
Frequency Radians per sec.	Direct Current M.A.							
	0		50		150		250	
	R	L	R	L	R	L	R	L
Half Coil.	ohms	Henry	ohms	Henry	ohms	Henry	ohms	Henry
3000	81·5	·536	77	·4873	64.2	·3746	55·2	.2776
5000	154	·550	138	·5048	98	·3740	75	.2784
7000	223	·534	197·5	·4919	136.6	·3797	96	.2822
10000	421	·5385	360	·4932	224	·3758	147	.2838
Mean		·5396		·4944		·3750		.2805
Mutual.								
3000	38	·5313	32·3	·4833	19·4	·3704	9·8	·2733
5000	110	·5460	94	·5012	53	·3700	30	·2746
7000	180	·5294	154	·4871	93.6	·3759	52·6	·2786
10000	379	·5340	320	·4890	182	·3718	104·5	·2793
Mean		·5352		·4901		·3720		·2767
Difference between the impedance of Half-Coil and the Mutual Impedance.								
3000	43·5		44·7		44·8		45·4	
5000	44		44		45		45	
7000	43		43·5		43		43·4	
10000	42		40		42		42·5	
Mean	43·1	.0044	43·0	.0043	43·7	.0040	44·1	.0038

Average difference $= 43{\cdot}5$ ohms $+ j\omega .0042 = P - M = S - M$.

Average D.C. resistance of Windings 41·5 ohms.

The following points may be noted from these results :—

1. The inductances of the windings (P and S) and the Mutual inductance are affected very little by the frequency of the testing current. A very slight increase with frequency was obtained, which is practically negligible.
2. The difference between the inductance of the windings and the mutual inductance is due to magnetic leakage and decreases slightly as the inductances decrease, but may be taken as .0042 henry on the average.
3. The difference between the effective resistance of the windings and the resistance component of the mutual impedance is the same for all frequencies and values of direct current, allowing for experimental error. This difference on the average is 43.5 ohms and is near to the average D.C. resistance of the windings, 41.5 ohms.
4. Plotting the effective resistance of the mutual impedance against the frequency squared in Fig. **14** shows that proportionality holds between these quantities.



5. Plotting the resistance component of the mutual impedance against the mutual inductance squared in Fig. **15** shows that proportionality holds also between these quantities.

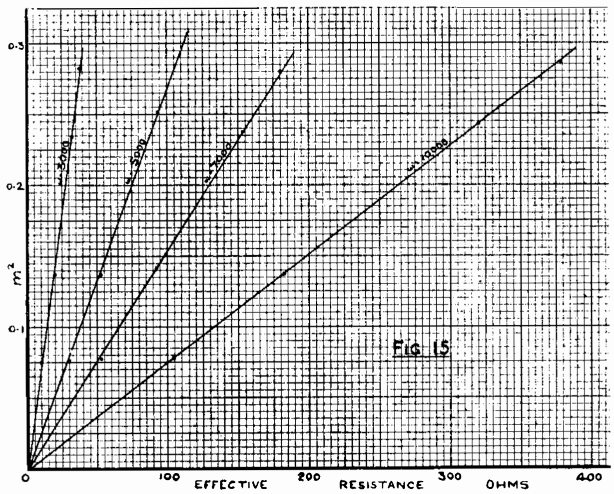


FIG 15

6. Dividing these same resistance figures by the corresponding values of $\omega^2 m_1^2$ gives the following results :—

TABLE 2.

Frequency Radians per sec.	Direct Current M.A.			
	0	50	150	250
3000	.149 × 10⁻⁴	.153 × 10⁻⁴	.157 × 10⁻⁴	.146 × 10⁻⁴
5000	.147 × 10⁻⁴	.150 × 10⁻⁴	.154 × 10⁻⁴	.159 × 10⁻⁴
7000	.131 × 10⁻⁴	.133 × 10⁻⁴	.135 × 10⁻⁴	.138 × 10⁻⁴
10000	.133 × 10⁻⁴	.134 × 10⁻⁴	.132 × 10⁻⁴	.134 × 10⁻⁴
Mean	.140 × 10⁻⁴	.1425 × 10⁻⁴	.1445 × 10⁻⁴	.144 × 10⁻⁴

Average = .143 × 10^{-4}.

It may be of interest to see how the theory given at the beginning is borne out by the results obtained from these repeating coils.

As these coils are 1 : 1 ratio transformers and have very little magnetic leakage, we may write when neglecting magnetic leakage

$$l_1 = l_2 = m_1$$

also $m_3 = \sqrt{l_1 l_3} = \sqrt{l_2 l_3} = m_2$

The impedance of each winding from (11) is therefore

$$r_1 + \frac{\omega^2 l_1 l_3 r_3}{r_3^2 + \omega^2 l_3^2} + j\omega\left(l_1 - \frac{\omega^2 l_1 l_3^2}{r_3^2 + \omega^2 l_3^2}\right) \dots (14)$$

and the mutual impedance from (10) is

$$\frac{\omega^2 l_1 l_3 r_3}{r_3^2 + \omega^2 l_3^2} + j\omega\left(m_1 - \frac{\omega^2 l_1 l_3^2}{r_3^2 + \omega^2 l_3^2}\right) \dots (15)$$

So that the difference between the effective resistance of the winding and the resistance component of the mutual impedance is r_1 the D.C. resistance of the winding. (See 3 above).

The eddy currents produced in the iron core will be proportional to the rate of change of flux and consequently proportional to the frequency as well as the magnitude of the flux variations. In the case under consideration, the reduction in the inductance of the windings as the direct current increases is due to the reduction in the permeability of the core and this inductance will be proportional to the permeability. The eddy currents are therefore proportional to the frequency and the inductance of the windings. The watts lost due to eddy currents will therefore be proportional to the square of both the frequency and inductance. Figs. **14** and **15** therefore indicate that the core losses are due to eddy currents. This appears reasonable since the variation of flux due to the alternating current is very small and would not be expected to cause appreciable hysteresis loss.

Reverting to equation (15) given above, it follows that the mutual impedance is

$$\frac{\omega^2 m_1 r_3 l_3}{r_3^2 + \omega^2 l_3^2} + j\omega m_1\left(1 - \frac{\omega^2 l_3^2}{r_3^2 + \omega^2 l_3^2}\right)$$

$$= \omega m_1 r_3 \times \frac{\omega l_3 + j r_3}{r_3^2 + \omega^2 l_3^2}$$

$$= \frac{m_1}{l_3}\left(\frac{1}{\frac{1}{r_3} + \frac{1}{j\omega l_3}}\right)$$

This latter expression means that the mutual impedance is equal to the two impedances $j\omega m_1$ and $\frac{r_3 m_1}{l_3}$ in parallel.

It therefore appears that the tertiary winding containing $r_3 + j\omega l_3$ of Fig. **1** represents the paths of the eddy currents and that these losses are represented by a resistance $\frac{r_3 m_1}{l_3} = G$ in parallel with the mutual inductance. Further, as m_1 and l_3 are both proportional to the permeability of the core, the resistance G will be a constant quantity for all frequencies and conditions of magnetisation of the core and is determined only by the specific resistance of the core material and the dimensions of the magnetic circuit.

This resistance G is shown by Steinmetz (see Chap. XIV., Alternating Current Phenomena) to be equal to $\frac{\cdot 507\,\epsilon\lambda l}{\mathrm{A}n^2}$

where l = length of the magnetic circuit
A = cross section of the magnetic circuit
n = number of turns in the windings
λ = electric conductivity of the iron core.
ϵ is the coefficient of eddy currents
and for an iron wire core
$\epsilon = 0.617\, d^2 \times 10^{-9}$
where d = diam of the iron wire;
and for laminated cores
$\epsilon = 1.645 a^2 \times 10^{-9}$
where a = thickness of the stampings.

The figures for the mutual impedance in Table 1 are in the form R + jX and the value of m_1 and G may be obtained as follows. The mutual admittance will be equal to the sum of the admittances $\frac{1}{j\omega m_1}$ and $\frac{1}{G}$

$$\frac{1}{R + jX} = \frac{1}{j\omega m_1} + \frac{1}{G}$$

$$\therefore \frac{R - jX}{R^2 + X^2} = -\frac{j}{\omega m_1} + \frac{1}{G}$$

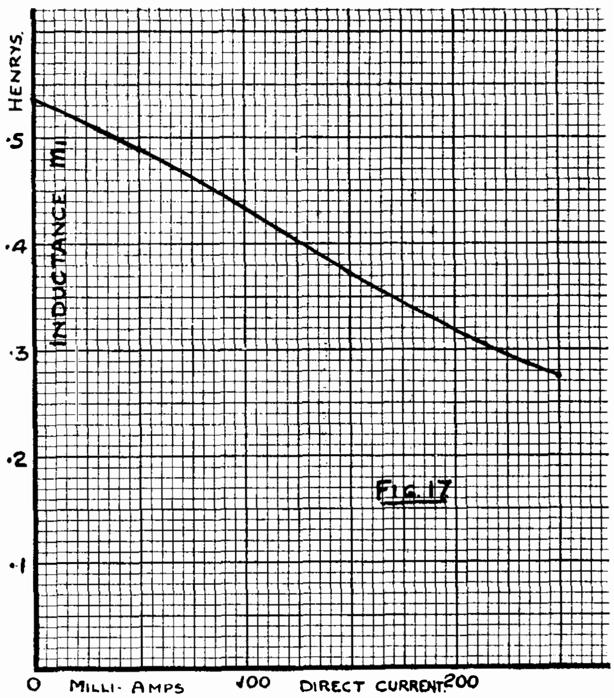
$$\therefore G = \frac{R^2 + X^2}{R} \text{ and } \omega m_1 = \frac{R^2 + X^2}{X} \quad \ldots\ldots (16)$$

From the results given in Table 1 it is evident that for practical purposes R² is sufficiently small compared with X² to write

$$G = \frac{X^2}{R} \text{ and } \omega m_1 = X$$

This means that the inductance figures given for m_1 stand unaltered and that G is the reciprocal of the figures given in Table 2.

The mean value for G is therefore 7.0×10^4 ohms. The very slight increase of the mutual inductance with frequency as indicated in Table 1, is probably due to a very small self-capacity in the windings. The reduction of the figures in Table 2 with frequency may be due to hysteresis losses. Both of these effects are negligible for practical purposes and a repeating coils 4003A may be represented by the equivalent T of Fig. **16** under any condition of frequency, and direct current in the windings where the mutual inductance m_1 for the required value of direct current is given in Fig. **17.**



REPEATING COILS 4006A.

In repeating coils 4003A the self-capacity of the windings is so small that it can be neglected. Repeating coils 4006A, however, are differentially wound, consequently there is appreciable capacity between windings 2—1 and 6—5 and also between 4—3 and 8—7. If it be assumed that the self-capacity of a winding of a transformer may be represented by an equivalent capacity shunted across the terminals of the winding, the conditions are represented by Fig. **18.** A and B are the impedances of these equivalent capacities. P, S and M would be the primary, secondary and mutual impedances respectively, if the transformer windings had no self-capacity. Applying the principle of the equivalent T the network of Fig. **19** will represent the transformer.

The π network of impedances consisting of A, P − M and M may be replaced by an equivalent T consisting of X, Y and Z as shown in Fig. **20**.

$$\text{where } X = \frac{AM}{A+P}\,;\; Y = \frac{A(P-M)}{A+P}\,;\; Z = \frac{M(P-M)}{A+P}$$

Similarly the π network consisting of X, Z + S − M and B may be replaced by an equivalent T consisting of X¹, Y¹ and Z¹ as shown in Fig. **21**.

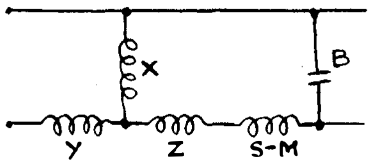


FIG. 20

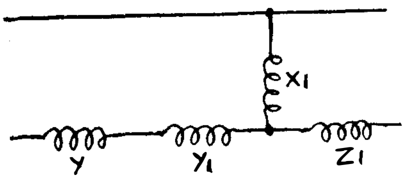


FIG. 21.

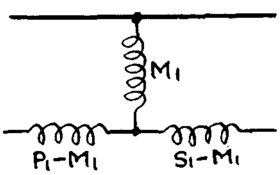


FIG. 22.

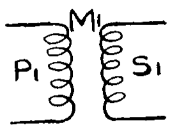


FIG. 23

$$\text{where } X^1 = \frac{ABM}{D} : Y + Y^1 = \frac{AB}{D}(P-M) + \frac{A}{D}(PS-M^2)$$

$$Z^1 = \frac{AB}{D}(S-M) + \frac{B}{D}(PS-M^2)$$

$$\text{where } D = (A+D)(B+S) - M^2 \quad \ldots\ldots\ldots\ldots(17)$$

The transformer can therefore still be represented by an equivalent T as shown in Fig. **22**.

$$\left.\begin{aligned} \text{where } M_1 &= \frac{ABM}{D} : P_1 = \frac{ABP}{D} + \frac{A}{D}(PS-M^2) \\ S^1 &= \frac{ABS}{D} + \frac{B}{D}(PS-M^2) \end{aligned}\right\} \quad \ldots\ldots\ldots(18)$$

The impedances of the windings as measured in the usual manner will be P¹ and S¹. The self-capacity of the windings of a transformer therefore does not introduce any difficulty in obtaining the equivalent T. If the impedances of the windings are measured in the usual manner and the equivalent T derived from the results as previously described, the self-capacity of the windings will be automatically accounted for.

Table 3 contains the results obtained from some 4006A repeating coils and some transformers Nos. 15A and 16A with a P.D. of 1 volt at several frequencies.

The measurements made were:—

1. Impedance of winding 2—1—6—5 with winding 4—3—8—7 on open circuit. This is P.
2. Impedance of winding 2—1—6—5 with 500 ohms non-inductive resistance across 4—3—8—7.
3. Impedance of winding 4—3—8—7 with winding 2—1—6—5 on open circuit. This is S.
4. Impedance of winding 4—3—8—7 with 500 ohms across 2—1—6—5.

The above are 1 : 1 ratio transformers and if the mutual impedance is obtained from these impedance test results by means of formula (12) and P − M and S − M obtained by subtraction, it will be evident that as this is a difference between two large quantities, inaccuracy is likely to occur. It was found preferable, therefore, to obtain P − M directly from the impedance measurements from the formula

$$P_1 - M = \frac{Z(P_1 + R)}{2P_1} - \frac{R}{2} \quad \ldots\ldots\ldots\ldots(19)$$

which is an approximation derived from a consideration of the equivalent T and (12). The results for $P_1 - M$ and M, given in Table 3, were calculated from the mean of the impedance tests obtained on the two windings, *i.e.*, P_1 is the mean of tests 1 and 3 and Z is the mean of tests 2 and 4. R = 500 ohms. $P_1 - M$ therefore is the mean of P − M and S − M. The average value of P − M and S − M for all frequencies given in Table 3 have been arranged so that their mean is equal to $P_1 - M$ and the difference between their resistance components is the same as the difference between the D.C. resistances of the windings.

On comparing these results for P − M and S − M thus obtained with those for 4003A repeating coils it will be noticed that they are very similar. This leads one to suggest that a 4006A repeating coil may be represented by a network similar to that of Fig. **16** for 4003A coils, but with capacities added to represent the self-capacity of the windings as in Fig. **24.**

It will be seen later that the impedance of the self-capacities C_A and C_B at speech frequencies will be large compared with that of P − M and S − M, so that the network may be modified to Fig. **25** where $C = C_A + C_B$.

TABLE 3.

EQUIVALENT T's. FOR REPEATING COILS 4006A AND TRANSFORMERS Nos. 15A AND 16A.

Frequency Radians per second	$P^1 - M$ R	$P^1 - M$ X	$P^1 - M$ L	M R	M X	
Repeating Coils a 4006A.						
3000	69.1	15.1	.00503	800	5625	
5000	69.5	24.2	.00484	3200	11520	For all frequencies.
7000	70.7	32.4	.00463	16700	19800	P − M = 74.6 + jω.0048
7500				24620	22960	S − M = 66.0 + jω.0048
8000				33800	22670	
8500				42310	6586	D.C. Resistance of P = 60.9 ohms
9000				34220	−11040	D.C. Resistance of S = 69.5 ohms
10000	71.8	46.5	.00465	19750	−18715	
Mean	70.3		.0048			
Transformers 15A.						
3000	67.0	14.5	.00482	769	8570	
5000	67.5	23.5	.00469	2385	18020	For all frequencies.
7000	68.2	32.4	.00463	13844	44910	P − M = 74.0 + jω.00467
7500				27460	60380	S − M = 62.0 + jω.00467
8000				72800	79700	
8500				148630	5850	D.C. Resistance of P = 70.6 ohms
9000				93830	−67250	D.C. Resistance of S = 58.5 ohms
10000	69.2	45.5	.00455	19800	−50400	
Mean	68.0		.00467			
Transformers 16A.						
3000	44.8	16.56	.00552	454	8160	For all frequencies.
5000	45.0	27.0	.0054	1257	15650	P − M = 43.2 + jω.0054
7000	45.0	37.64	.00538	4355	30220	S − M = 47.2 + jω.0054
8000				10615	47730	
9000				37800	83250	D.C. Resistance of P = 42.7 ohms
10000	45.8	53.6	.00536	144200	102200	D.C. Resistance of S = 46.7 ohms
Mean	45.2		.0054			

This is the equivalent T in which the mutual impedance consists of an inductance, resistance and capacity in parallel and is confirmed by the results given in Table 3, where for 4006A repeating coils M shows a resonance between 8,500 and 9,000 radians per second. It may be of interest now to consider a method of obtaining these three components of M. (See Bibliography No. 4).

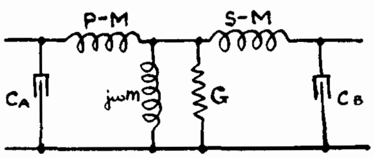


FIG. 24

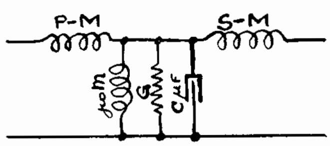


FIG. 25

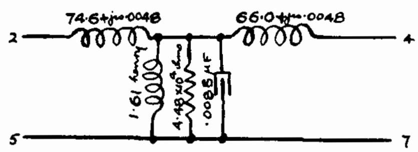


FIG. 27. Equivalent T for 4006A Repeating Coil.

The results for M are given in the form $R+jX$ and, from Fig. **25**, its admittance is:—

$$\frac{1}{M} = \frac{1}{R+jX} = \frac{1}{j\omega m} + \frac{1}{G} + j\omega C$$

$$\therefore \frac{R-jX}{R^2+X^2} = -\frac{j}{\omega m} + \frac{1}{G} + j\omega C$$

$$\therefore \frac{R}{R^2+X^2} = \frac{1}{G} \quad \text{.................................(20)}$$

$$\text{and } \frac{X}{R^2+X^2} = \frac{1}{\omega m} - \omega C$$

$$\therefore \frac{\omega X}{R^2+X^2} = -\omega^2 C + \frac{1}{m} \quad \text{................(21)}$$

G may therefore be calculated from $\frac{R^2+X^2}{R}$ and if $\frac{\omega X}{R^2+X^2}$ is plotted against ω^2 a straight line should be obtained and from the intercept of ω^2, *i.e.*, when $\omega^2 = O$, $\frac{\omega X}{R^2+X^2} = \frac{1}{L}$

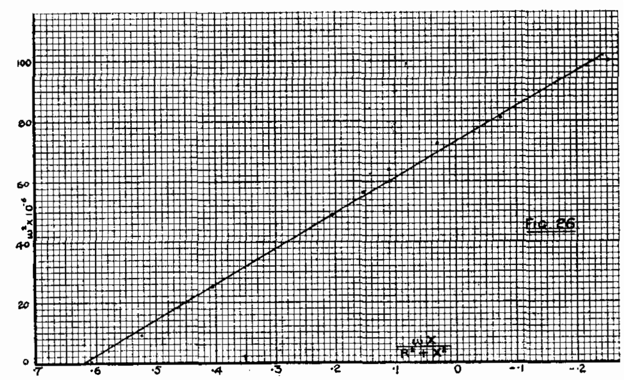
Further, the slope of this line will be equal to C. From the results from 4006A coils, given in Table 3, the calculated figures in Table 4 have been derived.

TABLE 4.

ω	ω^2	R^2+X^2	$\frac{R^2+X^2}{R} = G$	$\frac{\omega X}{R^2+X^2}$
3000	9×10^6	32.3×10^6	40.4×10^3	.522
5000	25 ,,	143.2 ,,	44.8 ,,	.4025
7000	49 ,,	672 ,,	39.6 ,,	.206
7500	56.25	1137 ,,	46.2 ,,	.151
8000	64 ,,	1654 ,,	49.0 ,,	.110
8500	72.3 ,,	1833 ,,	43.4 ,,	.0305
9000	81 ,,	1292 ,,	37.8 ,,	−.077
10000	100 ,,	740 ,,	37.5 ,,	−.253

Mean for G = 4.48×10^4.

ω^2 is plotted against $\frac{\omega X}{R^2+X^2}$ in Fig. **26** and the points lie fairly well along a straight line. The deduced results from Fig. **26** are $m = 1.61$ henry and $C = .0085\ \mu F$.



A 4006A repeating coil can therefore be represented at any frequency between 3,000 and 10,000 radians per second by Fig. **27**.

Treating the results obtained from the Transformers 15A and 16A in the same way the values for G, m, and C were:—

For Transformer 15A.
$G = 14.4 \times 10^4$ ohms. $m = 2.5$ henrys.
$C = .00554\ \mu F$.

For Transformer 16A.
$G = 20.2 \times 10^4$ ohms. $m = 2.5$ henrys.
$C = 00374\ \mu F$.

The equivalent T's are consequently as shown in Figs. **28** and **29**.

TRANSFORMERS 15B, 15C, 16B and 16C.

These transformers are similar to repeating coils 4006A in that their windings have appreciable self-capacity, but their ratio of transformation is 1 : 1.263 for 15B and 16B and 1 : 1.61 for 15C and 16C. They can, however, be represented by Fig. **18** and the effect of the self-capacity on the impedance of the windings is shown in (18). The magnetic leakage of these coils is small, and if it be neglected we can write $PS - M^2 = O$. It then follows from (18) that the effect of self-capacity is to multiply all the three impedances P, S and M by the same factor $\frac{AB}{D}$

If the permeability of the core remains the same r_3 and l_3 in (14) will be constant with respect to frequency. The effective resistance and the reactance of each winding are therefore from (14) proportional to the inductance of the respective winding. Neglecting the D.C. resistance and magnetic leakage of the windings, it follows that the impedances of the windings should have the same angle and their ratio $\frac{\text{Secondary}}{\text{Primary}}$ should be equal to N^2 where N is the ratio of transformation, seeing that the inductance of a coil winding is proportional to the square of the number of turns it contains. Evidently, therefore, the impedance of the windings P and S of these transformers now being considered will have equal angles and their ratio will still be N^2 at any frequency notwithstanding their self-capacity. It is consequently convenient in the case of these transformers to consider their equivalent unity ratio transformer.* If the ratio of the secondary winding impedance to the primary is N^2 then the equivalent T for the unity ratio transformer will consist of $P - \frac{M}{N}$ $\frac{S}{N^2} - \frac{M}{N}$ and $\frac{M}{N}$ as shown in Fig. **30** and the impedance connected to the secondary winding must be divided by N^2.

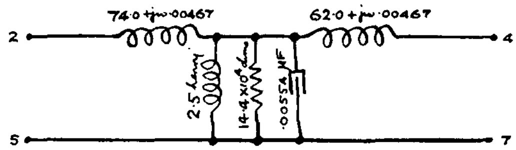


FIG 28. Equivalent T for Transformer 15A.

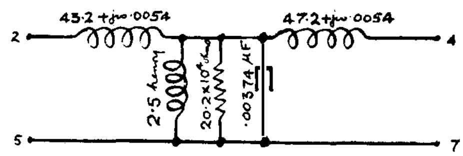


FIG. 29. Equivalent T for Transformer 16A.

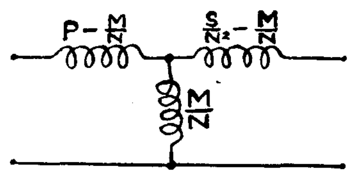


FIG. 30.

This equipalent ratio will be correct only if the D.C. resistance of the windings is small compared with their impedance and the magnetic leakage is small.

In obtaining the equivalent T for these transformers the same four tests were made as for 4006A repeating coils. These measurements are :—

P = impedance of winding 2—1—6—5

S = ,, ,, ,, 4—3—8—7

Z_1 = ,, ,, ,, 2—1—6—5 with 500 ohms across 4—3—8—7.

Z_2 = impedance of winding 4—3—8—7 with 500 ohms across 2—1—6—5.

The mean of the results obtained on some

* *See Bibligraphy No. 2.*

transformers 16B are given in Table 5, with the ratio N^2 calculated from the effective resistance and reactance figures. The values obtained from the reactance figures are probably the more nearly correct as the effective resistance is usually much the smaller figure, excepting at frequencies near the resonance point.

For the same reason that $P-M$ was obtained direct from the impedance test results in the case of 4006A coils, it is desirable to obtain $P-\frac{M}{N}$ and $\frac{S}{N^2}-\frac{M}{N}$ in a similar manner, and the corresponding formulæ are:—

$$\left.\begin{aligned} P-\frac{M}{N} &= \frac{Z_1\,(S+R)}{2S}-\frac{R}{2N^2} \\ \frac{S}{N^2}-\frac{M}{N} &= \frac{Z_2\,(P+R)}{2PN^2}-\frac{R}{2} \end{aligned}\right\}\quad\ldots\ldots\ldots(22)$$

where $R = 500$ ohms in this case.

The values of $P-\frac{M}{N}$ and $\frac{S}{N^2}-\frac{M}{N}$ thus

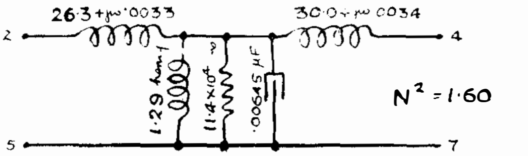
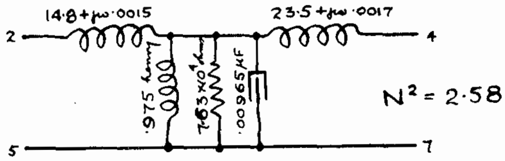


Fig 31.

Equivalent unity ratio T for Transformer 16B.



Equivalent unity ratio T for Transformer 16C

obtained from the impedance test results together with the corresponding values of $\frac{M}{N}$ are shown in Table 6.

TABLE 5.

IMPEDANCE TESTS OF TRANSFORMERS 16B.

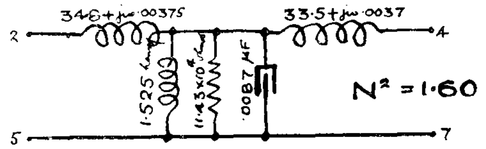
ω	P		S		N^2	
	R	X	R	X	From R	Form X
3000	327	4550	485	7155	1·49	1·57
5000	733	8045	1120	13100	1·535	1·63
7000	2120	15100	3250	23800	1·54	1·58
8000	3950	20900	6150	33300	1·56	1·59
9000	9300	32000	14830	51400	1·595	1·60
10000	40200	53900	63000	87400	1·57	1·62
					Mean	1·60

TABLE 6.

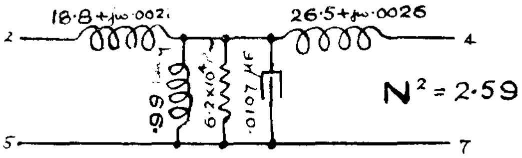
ω	$P-\frac{M}{N}$	$\frac{S}{N^2}-\frac{M}{N}$	$\frac{M}{N}$ R	$\frac{M}{N}$ X
3000	26.2+jω.0033	29.5+jω.0037	300	4540
5000	26.2+jω.0033	29.5+jω.0034	705	8030
7000	26.2+jω.0033	29.5+jω.00325	2094	15080
10000	26.5+jω.0033	31.0+jω.00322	40200	53870
Mean	26.3+jω.0033	30.0+jω.0034		

After obtaining $\frac{M}{N}$ by subtracting the results for $P - \frac{M}{N}$ from those for P and applying the method described for 4006A repeating coils, the three components making up $\frac{M}{N}$ have been calculated. The results are L = 1.29 henry, C = .00645 μF and G = 11.4 × 10[4] ohms. The equivalent unity ratio T for transformers 16B and 16C is therefore shown n Fig. **31**.

Treating the results obtained from the other types of transformer in the same way the following equivalent T's have been obtained :—



Equivalent unity ratio T for Transformer 15B.



Equivalent unity ratio T for Transformer 15C.

FIG. **32**.

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5. *B. S. Cohen, A. J. Aldridge and W. West. "The Frequency Characteristics of Telephone Systems and Audio Frequency Apparatus and their Measurement." I.E.E. Journal, 1926, Vol. 64, p. 1023.*
6. *K. S. Johnson. "Transmission Circuits for Telephone Communication."*
7. *C. P. Steinmetz. "Alternating Current Phenomena."*

THE NEW TOLL EXCHANGE, LONDON.

SINCE the opening of the first Toll Exchange in Norwich Street, London, E.C.4, in 1921, the development of Toll traffic has shown a continuous increase. The facility provided by a plant capable of handling, on a non-waiting basis, telephone calls to and from subscribers within a radius of fifty miles of London, soon came into favour with the telephoning public. The growth of traffic through the Norwich Street Exchange has more recently been of the order of twenty per cent. per annum, and the consequent steady addition of lines brought into this exchange to meet traffic requirements has absorbed the whole of the accommodation available. During the summer of 1925, an extension of 25 positions was installed, but this was merely to meet immediate demands.

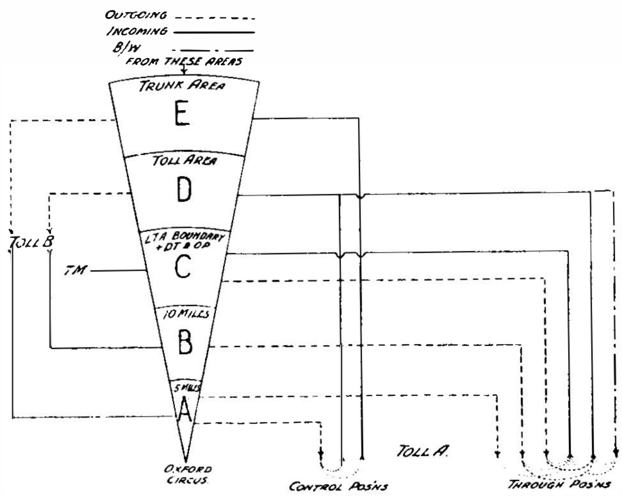


Fig. 1.—Toll Traffic Scheme, London.

Meanwhile, consideration had been given to increasing the capacity of the Toll handling equipment and it was decided that the most effective means of achieving this would be by building a new exchange to deal with outward Toll traffic from London, reserving the Norwich Street plant for inward Toll business.

Such an exchange has now been completed and was opened for service at 2 p.m. on Saturday, the 3rd December, 1927, with 796 junctions from and to London local exchanges and 743 lines to the Toll area, the latter number being mainly circuits transferred from Norwich Street.

The new exchange, known as "Toll A," is situated in the General Post Office (South) building in Carter Lane, E.C.4, and is a distance of half a mile from the Norwich Street premises now known as "Toll B."

Method of Routing of Toll Traffic.

A brief description of the method of routing traffic through the new Toll Exchange may now prove of interest. It will be recognised from what has already been said that the Norwich Street Exchange is interdependent in this consideration of the routing adopted.

The present incidence of Toll traffic in the London zone is defined in annular areas centred around Oxford Circus, and the diagram, Fig. 1, indicates the routing of the various classes of such traffic.

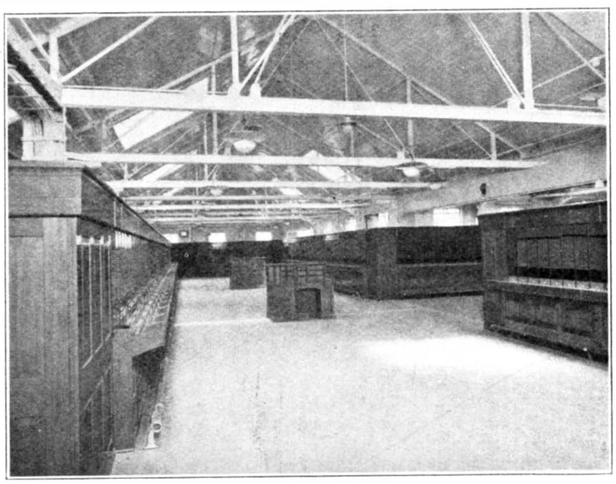


Fig. 2.—Main Switchroom.

The new exchange, Toll A, receives on "Control" positions, where the telephonists prepare the tickets and control the connections, all calls from within the five mile circle to exchanges in the D area and to certain centres in the E area.

The traffic from the A area to the C area, from the B to the C and D areas and from the C to C and the D areas is handled on "Through" positions, the ticketing of the calls being done at the originating exchange. Calls between D

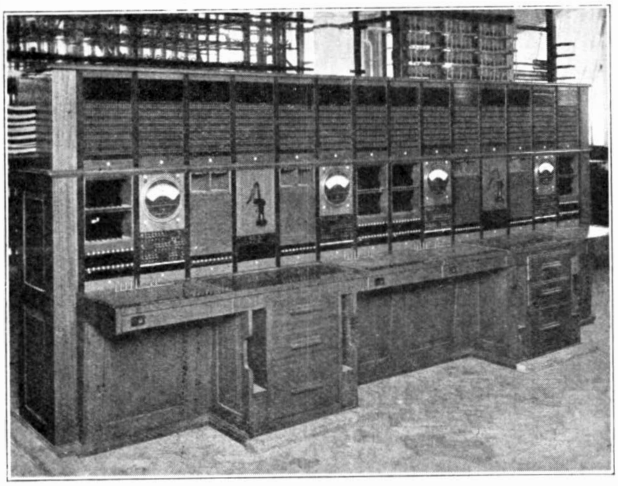


FIG. 3.—TEST DESK.

area exchanges where direct lines are not provided are also dealt with on the Through positions, bothway circuits being available in these cases.

Conversely calls from the D area to exchanges within the ten mile circle are passed through Norwich Street (Toll B), while calls from the C area to these same exchanges are routed through Tandem.

A number of groups of Provincial circuits hitherto terminated in the Trunk Exchange has been transferred to Toll A, thus virtually extending the Toll area. The exchanges concerned are Aldershot, Camberley, Chatham, Horsham, Leigh-on-Sea and Southend.

There is also connected to the new Toll Exchange a circuit to each of certain Trunk centres in the Home Counties where there is sufficient Toll to Trunk traffic to justify direct lines. Such places are Cambridge, Canterbury, Hastings, Ipswich, etc.

When through any abnormal circumstances, such as pressure of traffic, breakdown, etc., delay arises in completing connections on a Toll route, the calls are passed by order wire from the regular position to a Delay position where the telephonist tickets the calls and completes them seriatim as reverted calls, as is done in Trunk procedure.

DESCRIPTION OF THE EQUIPMENT.

The switchrooms in the new exchange occupy the whole of the fifth floor of G.P.O. (South), a space of 8,250 square feet. Fig. **2** is a view of a part of the main switchroom.

The I.D.F., apparatus racks, power distribution and fuse board are accommodated in a room on the fourth floor, while the test desk of four positions, Fig. **3**, and M.D.F. are on the ground floor.

Power is obtained from the Central Exchange main 24-volt batteries, which have been increased in capacity, and from smaller subsidiary cells (1000 A.H.) to provide a voltage of 30 for line signalling purposes on the Toll cord circuits. The City Exchange main battery in the same building has also been increased in capacity and is available in case of emergency for Toll use.

It may here be mentioned that the old charging plant in the City power room has been replaced by a motor-generator of modern type fed from the 440-volt., 3-phase supply, and giving an output of 1200 amperes at 37 volts. A small motor-generator worked off the same supply has also been provided to charge the subsidiary 6-volt. batteries already referred to. In the Central power room the existing 1000-ampere generator has been retained, but the motor has been replaced by one similar to that provided in the new motor-generator in the City plant.

The switchroom equipment comprises 158 Control positions, 29 Through positions, 2 Delay positions, 1 Service and 1 Fault position. All sections are of the standard C.B. No. 1 type of framework.

There are also a 14-position Information Desk, Fig. **4**, a service observation desk, five supervi-

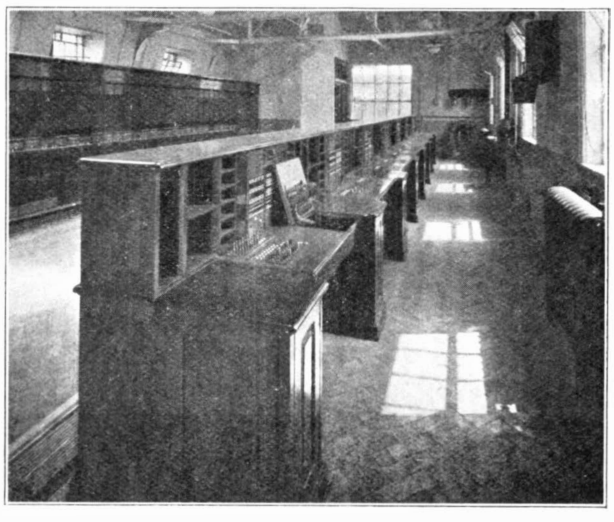


FIG. 4.—INFORMATION DESK.

sors' desks and a meter cabinet for registering effective and ineffective calls.

CONTROL POSITIONS.

The Control positions, a section of which is shown in Fig. 5, and a rear view in Fig. 6, have an equipped capacity for 1,580 jack-ended junctions from London exchanges in the A area, a six-panel multiple of 2,800 jacks covering lines to the C, D and E areas, service circuits and miscellaneous lines to the Information Desk. Each position is provided with ten cord circuits, each cord circuit being fitted with speaking and ringing key, time check key, supervisory lamps and a time check lamp. There are 40 order wire keys for Toll and C area groups and service lines and two keys for effective and ineffctive metering. Each position is fitted with a Veeder clock immediately behind the register keys.

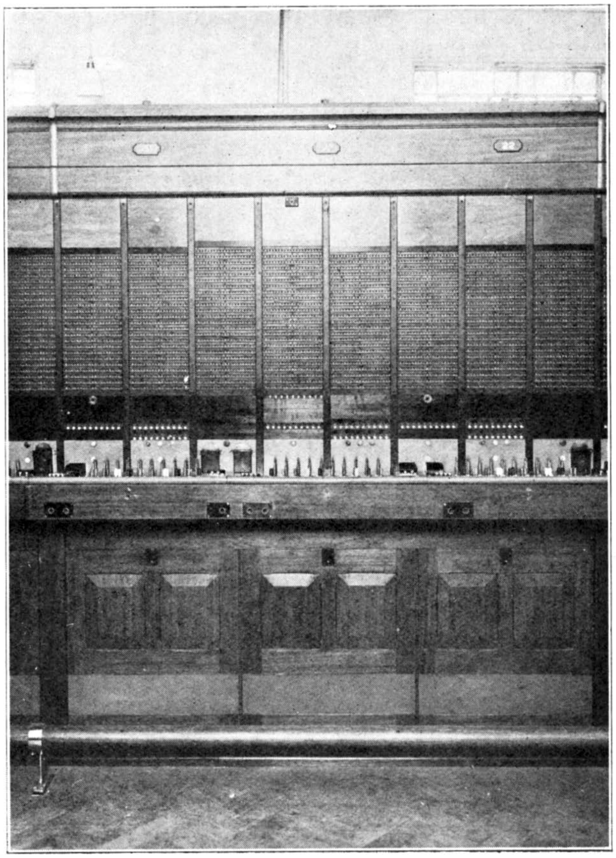


FIG. 5.—TYPICAL SECTION, "CONTROL" POSITIONS.

These clocks are of compact construction and project through the keyboard displaying the time in figures through a small rectangular aperture, similar to that of the ordinary exchange meter. The clocks are electrically driven from a master clock with six-second propulsion through groups of relays.

It may here be mentioned that ordinary electrical display clocks are fitted in the switch-rooms, but are driven from the main master clock for the building, thus providing an alternative time service in the event of failure of the Veeder clocks.

The time check circuit is given in Fig. 7. The time checks, of which 1,600 are equipped, consist of two relays ST and D, the former operating contact springs and the latter a driving pawl somewhat similar to that in the ordinary subscriber's meter. The time checks are of a very compact type and are mounted on racks in the apparatus room with the L and K relays referred to in the diagram.

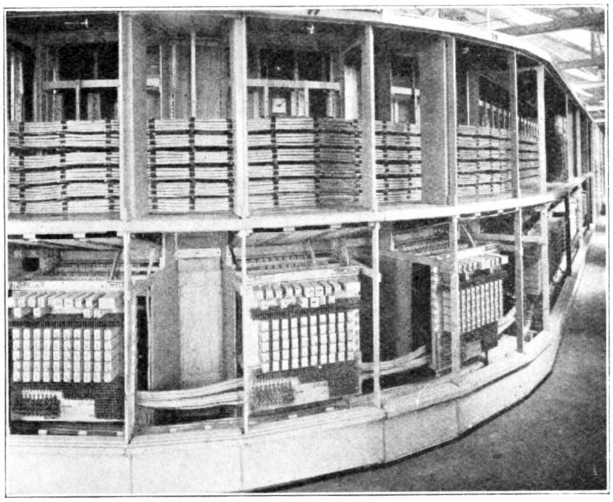


FIG. 6.—REAR VIEW OF CONTROL POSITIONS.

To operate the time check the telephonist pushes forward the time check key of the cord circuit associated. This key, which is of the lever type, provides the battery for energising the ST coil and also completes the seconds impulse circuit from the master clock referred to in the description of the Veeder clocks. The ST coil, through the movement of its armature, closes the springs above that coil and at the same time operates the pivoted lever, which disconnects the lamp circuit and closes the driving circuit through the other set of springs

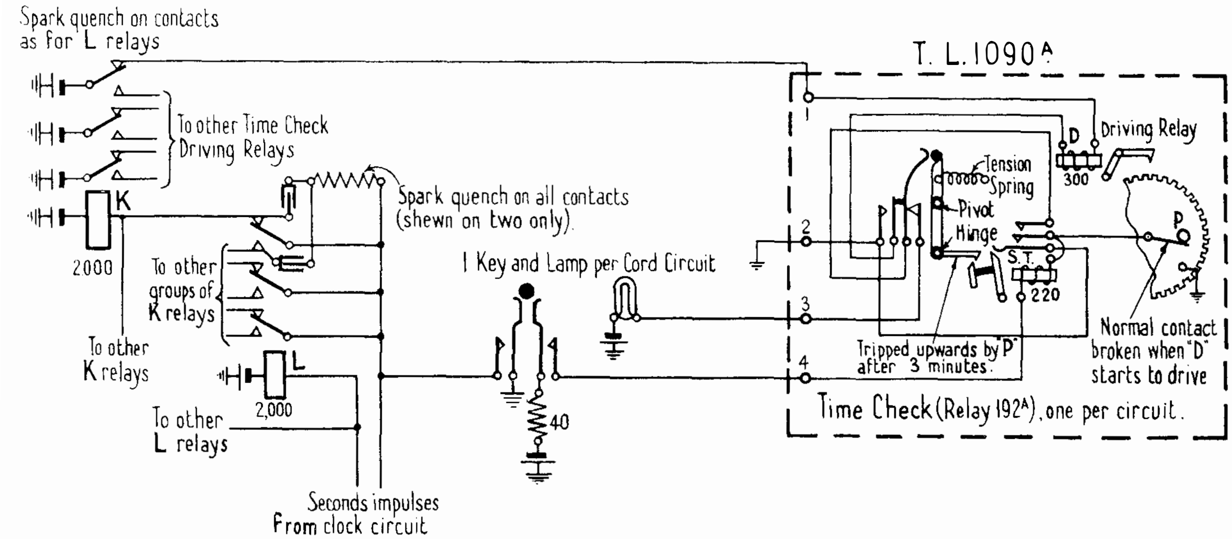


FIG. 7.—TIME CHECK CIRCUIT.

shown in the diagram. D is then energised by means of the seconds impulses received from the contacts of the K relay associated and the toothed wheel steps in unison. At the first step the original earth connection is broken at the P spring on the wheel train, but ST remains energised through the earth provided on its own springs. At the end of the 180 impulses (3 minutes) the projection on the wheel trips the hinged lever upwards and knocks the bottom pawl away from the toothed wheel. The springs associated with the lever and the toothed wheel restore to normal. The armature of ST, however, is still operated and the time check lamp lights. To operate the time check for a further three minutes period, the key is momentarily restored to normal to allow the armature of ST to fall back and thus reset the time check. The earth on the P spring is to ensure that the time check will only operate when the driving wheel is in its normal position.

Besides the usual panel pilot lamp, there are on the Control positons an Instruction circuit pilot and a Register pilot. Accessories such as a ticket holder and tray for each position and a spring ticket clip in front of every cord circuit complete the key and cord shelf equipment.

Each of the incoming junctions is provided with an ancillary answering equipment, the primaries being in the 2nd, 5th and 7th panels of each section and the secondaries in the 1st, 4th and 6th panels. To avoid congestion only five jacks in each strip of ten primaries are used, the remaining five being in another strip below with diagonal displacement. The panel arrangement is clearly shown in the photograph, Fig. 5.

Night concentration equipments for 330 of the incoming circuits are also provided on a suite of 45 control positions. The night concentration jacks are on the 1st and 4th panels of these sections. The black keys seen in Fig. 5 above the incoming primary jacks are the concentration keys and are of the usual plunger type.

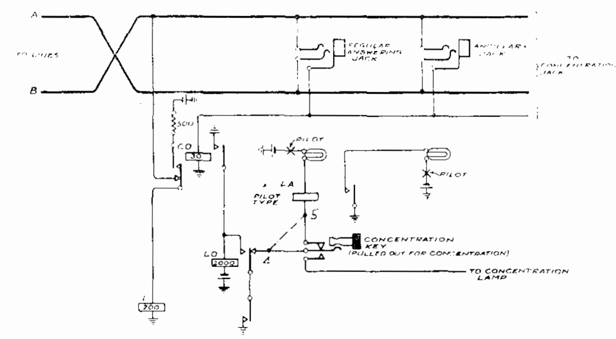


FIG. 8.—CONTROL POSITIONS—INCOMING CIRCUITS FROM C.B. AND AUTO-MANUAL POSITIONS. (C.B. 1278).

Fig. 8 gives the calling equipment for a junction incoming from a C.B. exchange or automatic exchange manual board, and Fig. 9 the circuit for an incoming junction dialled out from an automatic exchange. In both cases the ancillary and concentration facilities are shown and in Fig. 9 provision is made for giving ringing tone back to the calling subscriber.

The object of the 20000 ohms resistance across the 4 m.f. condenser in the latter circuit is to maintain a "wet" condition at the contacts of the CO relay during conversation.

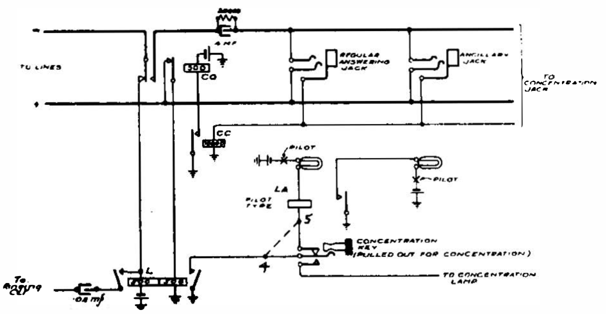


FIG. F.—CONTROL POSITIONS—INCOMING CIRCUITS DIALLED OUT FROM AUTO EXS. (C.B. 1279).

When regular answering circuits are terminated on positions which are also used for concentration the key shown in Figs. **8** and **9** is omitted, together with the concentration jack, and terminals numbered 4 and 5 are strapped together. This remark applies to the other jack-ended junction terminations to be described.

The regular, ancillary, concentration and auxiliary calling equipments have been separately wired as units to the I.D.F. to facilitate rearrangement arising from constantly changing conditions at distant exchanges.

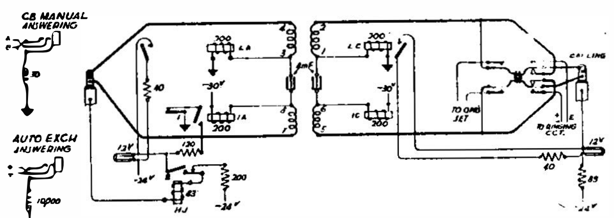


FIG. **10**.—CONTROL POSITIONS—CORD CIRCUIT. (C.B. 1276).
Answering C.B. Manual—Toll Ex. Control.
Answering Auto dialled out—Toll Ex. Control and Operator hold.

The cord circuit used on the Control positions is given in Fig. **10**. It shows the relays operating the supervisories, HJ and LA, when the cord circuit is used to answer a C.B. manual exchange and IA when the subscriber at an automatic exchange to which the cord is connected has cleared, HJ and LA not being actuated. In the latter case the 4 μF. condenser shown in Fig. **9** prevents the operation of LA and the metering relay at the automatic exchange.

The current flowing through relay IA when the subscriber hangs up operates the holding relay at the automatic end.

30-volt. line signalling with condensered repeating coils and balanced impedance coils and relays is used.

THROUGH POSITIONS.

The Through positions (Fig. **11** shows a section) have equipments for the accommodation of 870 jack-ended junctions, and are not provided with ancillary terminations. These will carry circuits incoming from the A, B, C and D areas. As in the case of the Control positions the jacks and calling lamps occupy only the alternate positions in each strip, two strips of 10 jacks and lamps being provided on most panels and on certain panels, three.

Night concentration equipments, 600 in all, are fitted for that number of incoming circuits on ten of the Through positions.

The outgoing Toll and service multiple is a continuation of that on the Control positions.

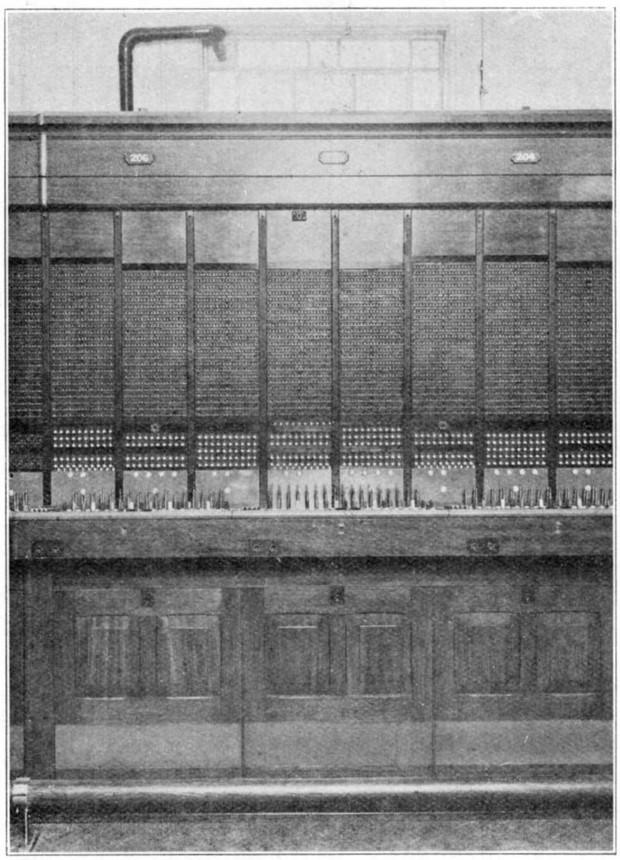


FIG. **11**.—TYPICAL SECTION, "THROUGH" POSITIONS.

The keyboard equipment consists of 17 pairs of cords with speaking and ringing keys, and register keys. No provision is necessary for Veeder clocks, time check keys and lamps and ticket trays.

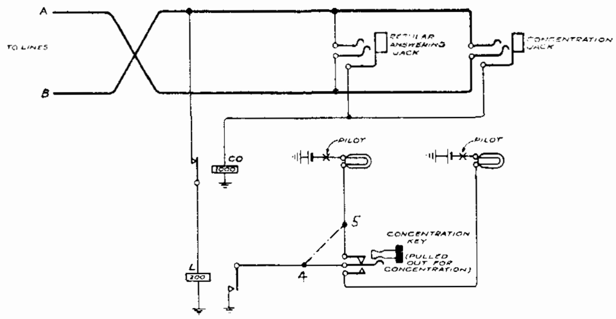


FIG. 12.—THROUGH POSITIONS—INCOMING CIRCUITS FROM C.B. EXCHANGES. (C.B. 1281).

Fig. 12 gives the calling equipment for the incoming circuits terminated on the Through positions and Fig. 13 the circuit for the termination on these positions of the bothway lines. 300 bothway auxiliary equipments have been provided.

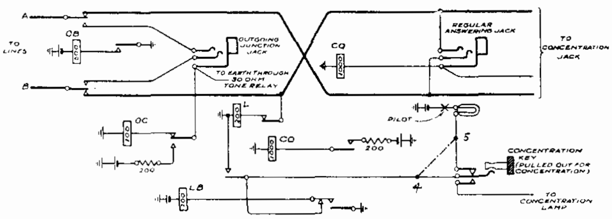


FIG. 13.—THROUGH POSITIONS—BOTHWAY CIRCUITS TO C.B. EXCHANGES. (C.B. 1280).

It will be seen in both Figs. 12 and 13 that an incoming call is indicated through the medium of relay L, but in the case of the bothway circuit the sleeve connection of the cord circuit plug energises CQ, then LB which connects the battery for the engaged test on the bushes of the outgoing junction multiple jacks. On the other hand if the circuit be taken for an outgoing call, relays OC and OB switch away the line from the incoming equipment.

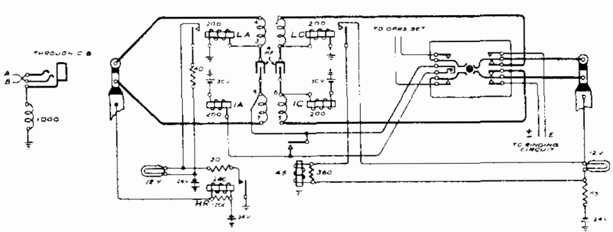


FIG. 14.—THROUGH POSITIONS—CORD CIRCUIT. (C.B. 1289). ANSWERING J.E. JUNCTIONS, THROUGH SIGNALLING, DISTANT CONTROL.

The cord circuit used on the Through positions is that shown in Fig. 14. The arrangement provides for through operation of the supervisory signals from the distant Toll Exchange by means of relays LC and T.

Fig. 15 gives the cord circuit provided on the Service and adjacent position and on the Fault position. It is of a universal type and combines the facilities available in the Control and Through position cord circuits.

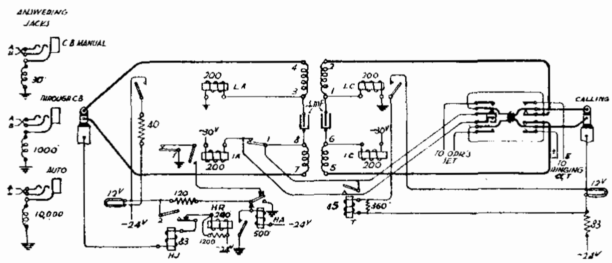


FIG. 15.—UNIVERSAL CORD CIRCUIT—SERVICE AND CIRCUITS. (C.B. 1259).

PLUG-ENDED ORDER WIRE JUNCTION POSITIONS.

A suite of eleven positions will be equipped very shortly with 30 plug-ended junctions per position for use in connection with incoming order wire circuits. These lines will be from London and Toll area exchanges where the groups of lines are sufficiently large to justify order wire working. Fig. 16 indicates the circuit termination to be provided. The manual ringing key is provided for emergency purposes.

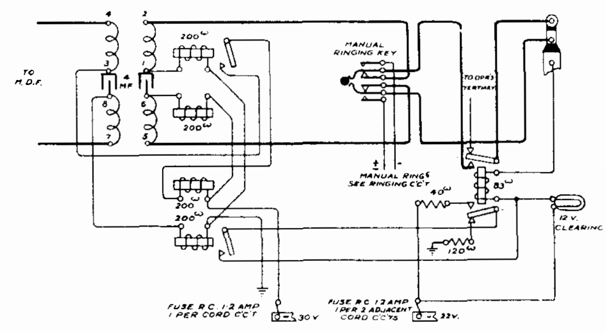


FIG. 16.—INCOMING PLUG-ENDED ORDER WIRE FAULT POSITIONS. (C.B. 1277)

OUTGOING TOLL MULTIPLE; GROUP ENGAGED TONE.

Fig. 17 shows the arrangement provided in connection with the outgoing Toll multiple to give group engaged tone. In previous installations having this facility special jacks, one to each group of five multiple jacks, have been necessary to supply the engaged tone. This was to prevent interference between the engaged tone and plugging-up tone. In the new Toll Exchange, however, the whole of the actual multiple jacks are utilised in the arrangement illustrated, the bush of the first jack in the group of five being the one to have tone connected to it when all the five circuits are engaged. Interference between the tones has been avoided by providing special plugging-up cords for use in the first jack of a group.

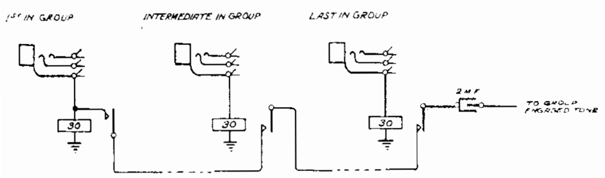


FIG. **17**.—GROUP ENGAGED TONE CIRCUIT.

ROUTE INFORMATION CIRCUITS.

In order that the telephonists on both the Control and Through positions may rapidly obtain information as to the routing of calls two route information enquiry circuits have been provided from all positions to the Information Desk. The circuits are terminated on two operator's instrument jacks at the rear of the desk and are also multipled on a lamp and jack equipment on each of the 14 positions of the Desk.

To deal with route enquiries expeditiously the circuit arrangement provides to meet three conditions of traffic: (*a*) Both circuits may be used on a ring-down basis, any operator on the desk taking the calls. This is usually during the slacker periods of the day and at night. (*b*) One operator, at the rear of the desk dealing with route enquiries only, is able to take both circuits by plugging her telephone set into the instrument at the rear of the Desk. (*c*) Two such operators at the rear of the Desk may take one circuit each at periods of pressure.

Fig. **18** gives the circuit arrangement of the route information equipment. Each main switchboard position has two keys in the order wire group, one black and the other white, marked Inf. The depression of either key operates relay G through contact G3, and if the circuit is not already occupied at another position, that is, there is no earth on the test wire, the earth connection shunting relay B is removed at G3 and B operates in series with G. The operator's telephone circuit is now connected through B1 and 2 to contacts 1 and 2 of relay O, which is energised when the telephone plug is in the instrument jack already referred to at the rear of the Information Desk, conditions (*b*) and (*c*).

It will be noticed that the depression of the Inf. key also puts an earth through contact B3 on to the test wire, which serves to prevent a second operator entering the same circuit.

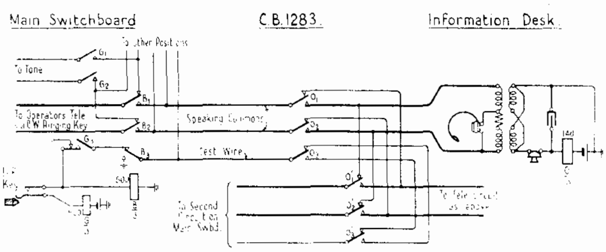


FIG. **18**.—ROUTE INFORMATION CIRCUIT.

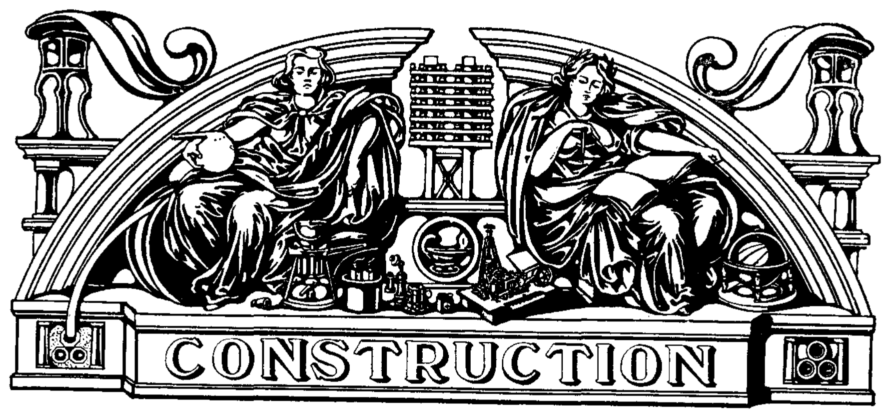
Had the route information circuit been engaged, however, an earth connection would have already been on the test wire and the B relay would not energise. In such circumstance, tone *via* the springs of relays B and G would be received by the calling operator.

If one telephonist only is in attendance at the rear of the desk and, therefore, the relay O in circuit No. 1 only is actuated, it will be evident from the diagram that enquiries on circuit No. 2 will come through to the first operator, the two circuits being connected in parallel by the contacts of O in line No. 1.

When the second route enquiry operator inserts her instrument plug the second O relay is energised and separates the two circuits and their test wires.

The whole of the circuit arrangements and lay-out of equipment was designed by the Post Office Engineering Staff. The installation, together with the enlargement of the charging plant, was carried out by Messrs. The Standard Telephones and Cables, Limited, who have kindly provided the photographs illustrating this description.

WM. D.



THE POST OFFICE (LONDON) RAILWAY.

SOME years ago, when traffic conditions were nothing like so bad as they are at present, the British Post Office came to the conclusion that it would be desirable to replace the road-van service it was then using by a more up-to-date method of transporting the letter and parcel mails between the principal post offices and railway stations in London, with a view both to accelerating the service and contributing to the reduction of the street congestion. A committee was therefore appointed in 1909, to consider the question in all its bearings; it decided that the best results would be obtained by employing an automatic system with electrically-operated trains without drivers, control being effected from special cabins at the various stations along the line. A scheme embodying these ideas was accordingly prepared in detail, the first contracts were let, and the tunnelling work was started just after war broke out. This world catastrophe naturally necessitated a change in policy. It was decided, however, to complete the tunnelling. No further progress was, however, made until after the Armistice, the tunnels being meanwhile employed for storing works of art.

Soon after the end of the war, tenders were invited for the electrical equipment of the railway, the specifications laying down a complete scheme but permitting alternative proposals to be put forward. The prices ruling at that time were, however, such to render it probable that, if the tenders received were accepted, the cost would adversely affect the economic soundness of the scheme; and it was not until 1924, therefore, when costs had fallen considerably, that contracts were placed for the electrical equipment, rolling-stock, conveyors, lifts and other necessary apparatus.

It may be mentioned here that the consulting engineer for the civil engineering work and the track construction of the railway was Mr. Harley H. Dalrymple-Hay, M. Inst., C.E., of Regent Street, London, a similar function for the equipment being exercised, first by Sir John Snell, G.B.E., until his appointment as Electricity Commissioner, and then by Mr. A. M. Sillar, M. Inst., C.E., of Victoria Street, Westminster. Major H. C. Gunton, M.B.E., Principal Power Engineer of the Post Office, representing Col. T. F. Purves, O.B.E., Engineer-in-Chief, has, in conjunction with Mr. Sillar, been responsible for the electrical equipment, rolling-stock, conveyors and lifts. To these gentlemen, and to Messrs. W. H. Powell and J. R. Kingston, we wish to express our thanks for their assistance in the preparation of this article.

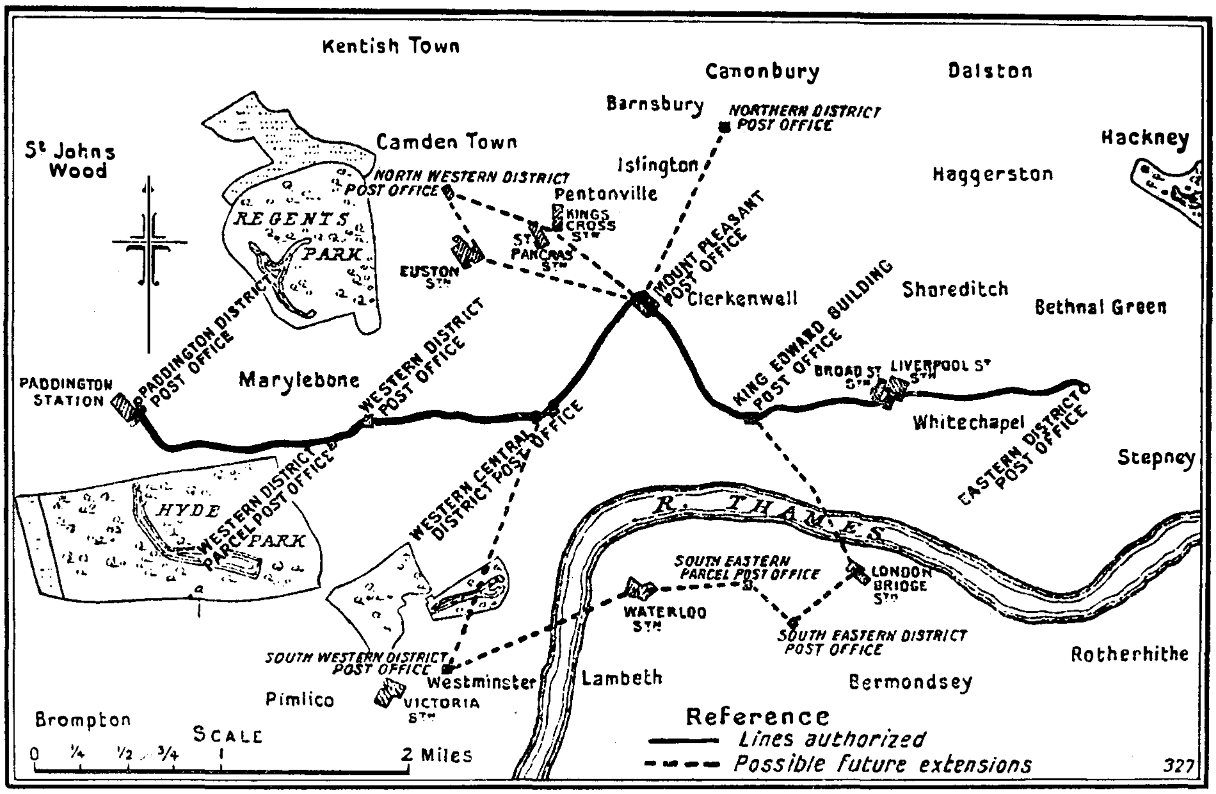
Mr. Evan Evans, whose services were temporarily placed at the disposal of the Postmaster-General for the purpose by the London Underground Railways, occupies the position of Manager of the railway, and amongst other improvements, which were incorporated at his suggestion, was the employment of the containers, described later. Major W. G. Carter, M.C., of the Post Office Engineering Department, is the Executive Engineer, and is responsible for the maintenance of the Railway.

The extent of the railway, which is now running, is shown on the accompanying map (Fig. 1); the total length, as at present constructed, is 6½ miles.

Tenders for the necessary civil engineering work were invited in 1912, the contract for the tunnelling being let to Messrs. John Mowlem and Company, Limited, and for the station platform construction and permanent way to Messrs.

The gauge that would most conveniently carry rolling-stock of sufficient capacity to handle the required traffic is 2 ft.; this is the first permanent 2-ft. gauge railway in this country. The minimum size of the tunnel between the stations, which would accommodate a single track of this gauge and give the necessary clearances, was one of 7-ft. internal diameter. In order, however, to economise expenditure, it was decided to run both tracks in one tunnel between the stations. The minimum size tunnel requisite

Fig. 1. **ROUTE OF THE POST OFFICE TUBE.**



Charles Brand and Son, both of London. Tunnelling was actually commenced on October 16th, 1914, and finished, except for certain works at Mount Pleasant car sheds, and at Paddington and Liverpool Street, in 1917. The station platform and permanent way contract was commenced in December, 1925. Before going into details, it may be as well to make a general statement on certain factors which determined the civil engineering construction of the railway.

for this purpose on straight runs, and assuming that no curves would have a less radius than 400 ft., was one of 9-ft. internal diameter. This gave the necessary clearances, and was therefore the size finally chosen. As, however, at the stations the platforms are of the "island" type, like those of the tube railways, two tunnels were necessary, and 7-ft. tunnels were, therefore, constructed for a short distance from the end of each station tunnel to the commencement of the 9-ft. tunnel, the connection between the two diameters being made by step-plate junctions. In the stations themselves, accommodation had to be provided, not only for the platform line, but for a through line, and at the West Central District Office, Mount Pleasant and King Edward Building for a running round loop line as well, making three tracks in all. At these three-track stations, the internal diameter of the station tunnel is, therefore, 25 ft., while at the other stations it is 21-ft. 2½ in. To provide for sliding and loop connections it was also necessary in some cases to construct tunnels varying from the standard diameter of 9 ft. up to 19 ft., and even from 10 ft. to 25 ft.

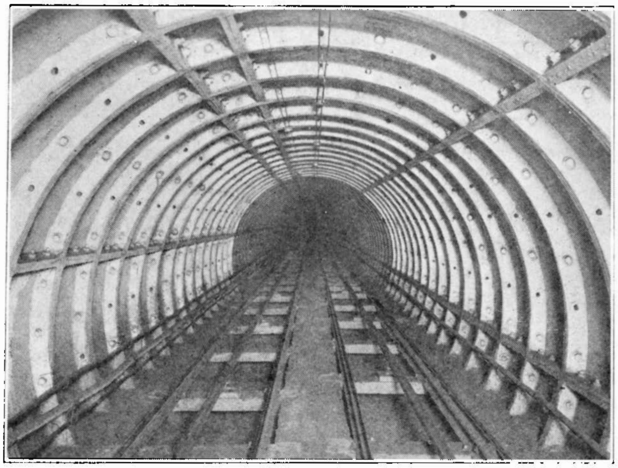


FIG. 2.—DOUBLE TRACK IN 9 FEET TUNNEL.

Generally speaking, the running tunnels, of which an illustration is given in Fig. 2, between the various stations were driven by the ordinary method of the Greathead shield. The short lengths of tunnels forming the station were excavated by hand mining, a method which presented no difficulty in the London clay. After excavation, the whole of the work was grouted with pure Portland cement.

In addition to the tunnel proper, permanent shafts were provided at all stations for giving access to the platforms, by means of conveyors, lifts and staircases, from the basement level of the various Post Office buildings and main line railway stations. These shafts generally have an internal diameter of 12 ft. They are of the usual construction, and were sunk by underpinning and lined with cast-iron segments. At Mount Pleasant and King Edward Building, which are two of the busiest stations on the railway, some of the shafts are 14 ft. in diameter.

Intercommunication between the island platforms is obtained by cross-passages of 10ft. internal diameter, while other works include the lay-by sidings at each end of the stations at Paddington, King Edward Building, and the Eastern District Office, as well as at the eastern end of Mount Pleasant station.

Coming to the track, the running rails are of British standard section No. 35, weighing 35 lbs. per yard, and are secured to oak sleepers by ¾ in. coach screws. This heavy design has been adopted, in order to reduce the maintenance work. The sleepers themselves are embedded in the concrete of the tunnel invert and are 3 ft. 6 in. long, their section being 7 in. by 3½ in. Great attention was paid to the question of curvature. On the running round loops the minimum radius of curvature is as low as 60 ft.

Dealing now with the electrical equipment, it may first be mentioned that the main contract for this important portion of the railway was let to the English Electric Company, of London. The E.H.T. and L.T. cables, other than those incorporated in the Control System, were supplied by the British Insulated Cables, Ltd., as sub-contractors. The track equipment proper, for which Messrs. Robert W. Blackwell and Company, Limited, of London, were sub-contractors, includes a mild-steel conductor rail of channel section, weighing 15 lb. per yard, which was supplied in 30 ft. lengths. Its conductivity is 1.8 microhm per yard. The conductor rails are supported on insulators, placed about 8 ft. apart, so that the upper surface of the rail is 3 in. higher than the face of the track rails, and the contiguous lengths are secured to each other by tapering steel fish plates 12in. long, by ¾ inch thick, by ⅞ inch wide at the top and 1¾ inch wide at the bottom. Ramps are provided at all places where the conductor rails are discontinuous, these being formed by bending down the conductor rail 1½ in. in a length of 1 ft. 6 in. In the platform sections the conductor rails have a lead of 2 ft. 6 ins. over the track sections, so as to allow sufficient braking distance and to ensure that the train comes to rest in the centre of the platform berth.

At places where the conductor rail is interrupted continuity is ensured by the use of 0.1 sq. in. jumper cables, which are fixed so that all live metal is kept clear of the track foundation and track rails. Two sizes of solid head bonds are used. Those for the track rails have a span of $7\frac{1}{8}$ in. between the bond hole centres and those for the conductor rails one of 14 in. In both cases the bonds are of the standard flexible type. Two bonds are used for each conductor rail joint. The track rail, in addition to being bonded at the joints, are cross-bonded at intervals of about 100 yards by means of special bonds, which are connected to the cast-iron tunnel.

The conductor rails are divided into sections and one of the track rails is track-circuited throughout to form a control section. In order to increase the capacity of the earth return, with a view to keeping within the drop of pressure recognised by the Board of Trade, bare copper cables are laid throughout.

Supplies of electricity for operating the traction and other equipment on the Railway are drawn from the mains of the City of London Electric Lighting and the Charing Cross and City Electric Companies, the point of entry in both cases being a sub-station adjoining the Post Office sub-station at King Edward Building. These supplies form part of the electricity taken from the undertakings by the Department for general power and lighting purposes, and are given on the three-phase system at a pressure of 11,000 volts. and a frequency of 50. This pressure is stepped down to 6,600 volts by a bank of three 1,000 kV.-A. single-phase transformers with a total capacity of 3,000 kV.-A. which are installed in the sub-station we have just mentioned. The 6,600 volt. side of these transformers is connected to duplicate 'bus-bars, change-over switchgear being provided, so that the supply may be taken from one or other of the two undertakings in alternate months. The duplicate 'bus-bars in King Edward Building are connected to the Post Office sub-station at Mount Pleasant, where the 'bus-bars are in duplicate, by 0.1 sq. in. feeders, which are in triplicate. A supply is also given from the King Edward Building sub-station through two 0.0225 sq. in. three-core cables to the railway sub-station at Liverpool Street and from Mount Pleasant, through two 0.06 sq. in. three-core cable, to the railway sub-station at the Western Parcels Office. At Mount Pleasant the converting plant is accommodated in an existing sub-station. In other cases the traction equipment is placed in the invert of the large tube which forms the railway station. The feeders are protected by an overload circuit breaker at each end.

In each traction sub-station the 6,600 volt three-phase supply is first converted to direct current at 440 volts. For this purpose two sets of the 133-kW. single-phase transformers are used, making a 400-kW. bank, which is connected in delta on the E.H.T. side and in six-phase star on the low-tension side. This bank is connected to a 400-kW. rotary converter. The rotaries are shunt-wound and are fitted with commutating poles and damping windings. They are self-synchronising, and a pony motor is used for starting. There are sixteen of these sets in all, and they were all manufactured by Messrs. Newton Brothers (Derby), Limited.

A supply to the motors for operating the lifts, conveyors, and ventilating plant and the lighting circuits is also given from the 440-volt 'bus-bars, either direct, in the case of the stations where there are sub-stations, or through 0.5 sq. in. mains and distribution switchboards. Finally these two sets of 'bus-bars are connected through a 0.5 sq. in. and 0.1 sq. in. cable respectively to the 440-volt and 150-volt sections of a contractor rack, from which 0.1 sq. in. and 0.04 sq. in. cables supply the different sections of the conductor rail in that railway station zone.

The rolling stock consists of steel motor wagons, which are made up into trains of two or three wagons. Each wagon is capable of carrying a load of 1,120 lb. The electrical equipment of these wagons is simple, consisting principally of two 22-h.p. 440-volt, direct-current series motors, which are connected permanently in parallel. It also includes a resistance in series with each motor, which is permanently in circuit, and a set of electrically-operated braking equipment and reverser. The whole of the operation of the trains is automatic, control of the starting and stopping being effected from switch cabins at each station. No drivers are required.

The wagon motors are energised in the ordinary way from the conductor rail, which is divided into sections, each section being controlled either by automatic track circuits on the sections between the stations or by levers working under track circuit control in the station areas. These levers are concentrated in the various switch cabins. To start the train, its proper route is set up, as described hereafter, and the conductor rail is energised at 440 volts, so that it runs off down a falling gradient. The same pressure is employed on the conductor rails through the tunnel, the maximum speed reached being about 35 m.p.h. When the station is approached, the train enters a section on a rising gradient in which the conductor rail is dead, and is brought to rest by the automatic

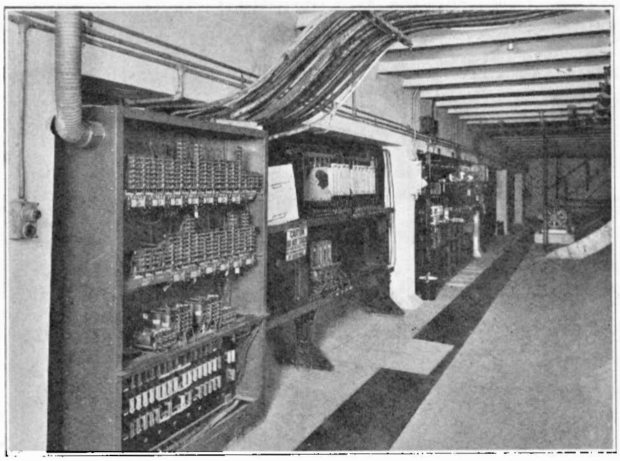


FIG. 3.—RELAY CABINET CONTACTOR RACK AND DISTRIBUTOR BOARD.

operation of the brakes. After a short interval the conductor rail in this section is energised at 440 volts and remains energised at that voltage for a predetermined time, which is sufficiently long to give the train a good start. At the end of this period the voltage is reduced to 150 volts, and the train runs into the station under this pressure. Here it either enters a dead berth section and is brought to rest by the brakes alongside the appropriate platform, or passes on to a through section, if it is not to stop at the station.

Operation in and out of the sidings is effected at a pressure of 440, 250 or 150 volts, this depending upon the lay-out of the siding and its approach.

The relay cabinets and contractor racks holding the gear (see Fig. **3**) for operating the various circuits are placed in the tunnel inverts under the station. It will be convenient here to say something further about their operation.

When the route lever is pulled to the point-operating position, current is supplied to the point contactor coils. This causes the point contactor to operate and to close the 150 volt circuit of the point motor. On completion of the point movement the circuit through the point detector contacts is closed, together with the corresponding coil of the point detector relay, thus closing all the contacts in circuit, which require proof of the reversal of the points.

The operation of the track circuiting system, by means of which current is supplied to the conductor rails in the tunnel sections, may be explained briefly as follows:—When the train enters section A, that is, the first automatically operated section, it causes the track relay A to be picked up. This open-circuits stick relay AS which drops. The train passes on to section B, stick relay BS being dropped in a similar manner. Track relay A drops as soon as the train leaves section A. With track relay A down, track relay B up, and stick relay BS down, the AS stick relay is reset, provided that the power contactor supplying section A is open. The power contactor for Section A will not be closed until stick relay BS has been reset by the train running on to section C. If a train runs on to a particular track without operating it for any cause, the stick relay of the section behind will not reset, thus providing protection for the train ahead.

As the train approaches a station it runs off the last automatic section on to a braking section. This is on a rising gradient, so that the brakes are assisted by gravity in bringing the train to rest. The length of this section is sufficient to ensure that this happens under all conditions. It has been found that at any particular station the time which it takes for a train to come to rest does not vary very much. It is therefore possible by experiment to select a time which gives a little margin during which it is quite certain that the train will stop in the braking section. This time may be called the braking time. When it has come to rest in the braking section, the control of the train is assumed by camshaft control gear of a pattern very similar to the equipment used on the English Electric Company's electric locomotives. (See Fig. 4).

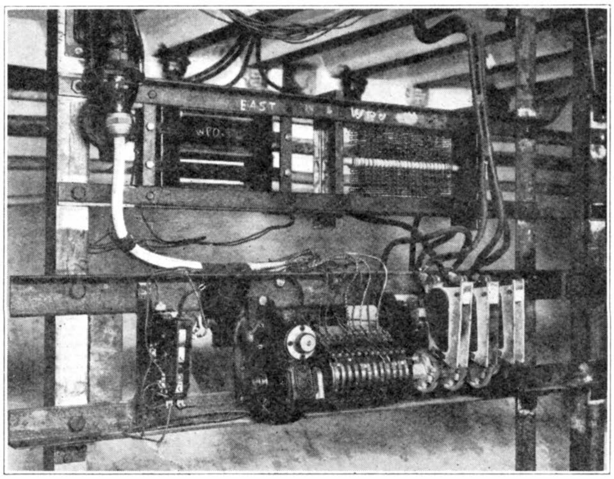


FIG. 4.—CAMSHAFT GEAR.

Fig. 5 shows a three-wagon train, such as will form the normal traffic unit, being loaded at a station. The bodies of these wagons were manufactured by the Kilmarnock Engineering Company, Limited, and the electrical equipment by the English Electric Company, Limited.

As regards design, great care has been taken to ensure easy access to all parts, and to admit of the rapid inspection and replacement of such important portions as the motors, wheels and axles, journal boxes, brake gear and collector shoes. The general dimensions of the wagons are: Total length of body, 12ft. 6in., total length over buffers, 13ft. 5in., total width over axle boxes, 3ft. 6in., and total height above rail level, 4ft. 11½in. The wheel base is 7ft. 3in., the diameter of the wheels, 2ft., while the gauge is also 2ft. The under frame of each wagon is of channel steel, the body being built up of steel angles securely braced and riveted together and secured to the underframe by bolts. The flooring sides and ends are constructed of mild open-hearth steel plates. The wheels have cast-steel centres and steel tyres. The diameter of the wheel over the tyre is 2ft. and the breadth of the tyre on the tread is 2½in. The axles on to which the wheels are pressed hydraulically are of acid open-hearth steel and are fitted with roller bearings. After assembly the wheels and axles were carefully balanced and tested to ensure that they run smoothly and without vibration at a speed of 500 r.p.m. The axle boxes are of the roller bearing type, and are self-lubricating and dustproof. The end thrust is taken by ball thrusts. The wagons are coupled by links which are fitted to spring buffers.

The collector shoes are carried on frames which are suspended from the axle boxes. The horn plates are of steel plate, their sliding surfaces, and the corresponding sliding surfaces of the axle boxes, being machined and arranged so that they can be lubricated. Two vertical helical springs are fitted over each journal to take the weight of the wagon body under all conditions of service. These springs are of acid open-hearth steel, and have been specially designed to render the running of the wagon as smooth as possible, both when empty and loaded, and to prevent undue pitching and rolling.

The two series motors receive their supply through two shoes, one at each end of the wagon. Reversal is effected by a hand switch which changes the direction of the fields. The negative brushes of each motor are connected to a common bar, which in turn is connected through the brake solenoid to earth. The

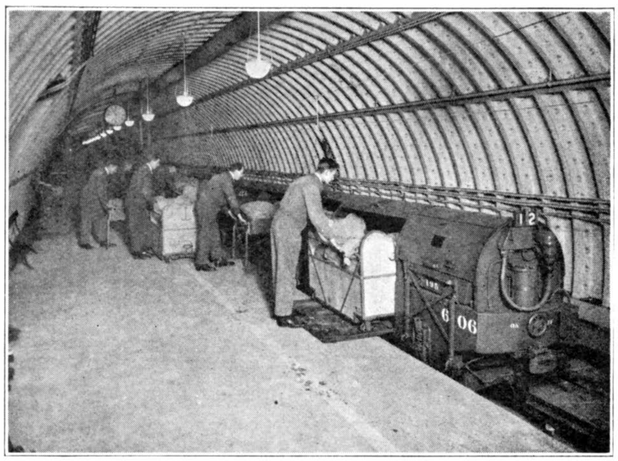


FIG. 5.—LOADING WAGONS.

equipment of the wagons forming one train are paralleled by means of a bus line and electrical couplers on the negative side of the permanent resistance.

When a wagon is standing on a de-energised track, no current passes through the brake solenoid and the springs therefore hold the blocks against the wheels. As soon as current is supplied to the conductor rail, the solenoid is energised, the brakes are released, and the motors start up, the current rush being damped by the resistances. On entering a dead section, current ceases to pass through the solenoid, and the brakes are immediately applied.

This arrangement enables the direct-current series motors to be operated on what is virtually an alternating current characteristic when giving the specified output of 22 h.p. The arrangement has the great advantage, from the operating point of view, that as little as possible control equipment is carried on the wagons themselves.

Each motor is slung from the wagon axle in bearings, and from the wagon frame by springs. The motor is totally enclosed, and generally complies with the English Electric Co. standard design for traction work. The armature shaft bearings are carried outside the frame, and are of the roller pattern. Driving is effected through spur gearing of the single-reduction type, the ratio of reduction being 3.33 to 1. Like the motor the gearing is totally enclosed.

As already stated, it is proposed that the wagons shall be connected together in trains of three. For this purpose a twin-core train cable with a twin coupling at each end is used. Each core of this cable has a sectional area of 0.66 sq. in. The train couplings are interchangeable at both ends, and are fitted with a locking device so as to prevent them from working loose.

The loads on these wagons are carried in special containers, which have been designed so that they can be wheeled across the platforms. These containers are of two different types, depending on whether they are to be carried in the centre or side compartments of the wagon.

The mail bags are passed from the ground level to the railway platform with a minimum of human intervention, an extensive system of conveyors, elevators, spiral chutes and lifts; either individually or in combination. In general, it may be said that the lifts and elevators, combined with the conveyor, are used for the upward traffic and conveyors and spiral chutes for the downward. More particularly, conveyors are used for all the up traffic at Paddington and for the parcels at Mount Pleasant, and bag elevators combined with conveyors for the up traffic of letters at King Edward Building and Mount Pleasant.

When lifts are used, the bags are loaded into containers in the Sorting Offices, and are wheeled to the lifts by hand for the downward journey. At the railway platform level they are wheeled from the lifts by hand to the wagons where they are placed into position. (See Fig. **5**). The elevators, which are of the bucket type, are loaded by conveyors which are fed through hatches on the Post Office railway platforms. The bags are discharged from the elevators in the Post Office where the contents are deposited either on to a short conveyor or on to the floor level.

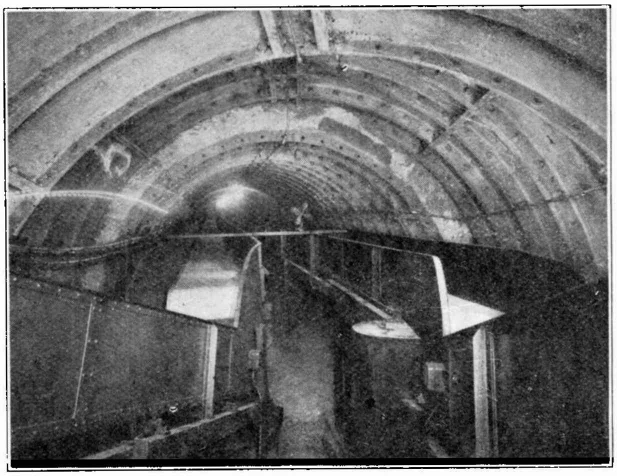


Fig. **6**.—Band Conveyors, Liverpool Street Station.

There are in all 21 band conveyors, five at Mount Pleasant, four at King Edward Building, seven at Paddington, and two at Liverpool Street, and one each at the Western, West-Central, and Eastern Post Offices. This excludes a number of short conveyors at various delivery points. Generally the construction of these conveyors is the same, and is shown in Fig. **6**.

At King Edward Building there is one 20 cwt. bag elevator, which also receives its load from the two under-platform conveyors, and delivers it on the ground floor of the building at a point in the lobby near the east loading platform. All the elevators consist of a number of sheet-steel buckets, which are connected to two parallel endless chains moving in steel guides, the shape of which determines the path of the bucket. The space between the buckets is filled in with stout rubber and cotton belting. At the top and bottom of the elevator the main chains pass round sprocket wheels, the bottom pair of which is driven by a motor through worm and spur gearing. This motor and the rest of the equipment is designed for continuous operation. The path of each elevator is at first horizontal, and then gradually changes to the vertical, the bags being loaded on when the elevator is in the former position.

Lifts are provided at all stations and are used for parcel traffic in both directions and letter traffic in an upward direction, except at King Edward Building and Mount Pleasant where band conveyors, elevators and spiral chutes are employed, the lifts being available in case of emergency. The total number of lifts in use at the various stations is 17.

As it is important that the air from the Post Office railway station should not escape into the post offices, a ventilating system has been provided, whereby a continuous down draught is exerted. The air is drawn over the plant, which is, as already noted, installed in the tube inverts, and thus exercises a cooling effect, finally it is exhausted into the open air.

At most stations there are either one or two inlet fans with a capacity of 1,100 cub. ft. per minute, but at the Western Parcel Post Office and at Liverpool Street there are two fans with a capacity of 4,500 cub. ft. per minute. The outlet fans are 4,500 cub. ft., 6,000 cub. ft., or 9,000 cub. ft. per minute in the capacity.

The ducts are constructed of 16 S.W.G. galvanised steel plate. Their area is such that the air velocity does not exceed 2,500 ft. per minute, and they are laid out so that sharp bends are avoided. Messrs. Davidson & Co. were the sub-contractors for this work.

JOINTING A.S.P.C. CABLE CONDUCTORS OF SMALL GAUGE.

A. Morris, M.I.E.E., and F. Stevens.

SYNOPSIS.—An interesting account* was recently given of some of the difficulties which arise in connection with the splicing of overhead conductors. The present article deals with unsoldered twist splices in underground telephone cables containing light gauge conductors.

General.—This type of splice is used almost exclusively at the joints of local cables and trouble is occasionally experienced with it when the usual care has not been exercised during the constructional work. Although abnormally large values of conductor resistance, loop or unbalance, point unmistakably to defective splices in this class of jointing, yet imperfect joints are not always disclosed by the results of such tests. The passage of a current causes variations in the resistance of an imperfect joint. This is particularly noticeable in the case of very defective joints. If the current is increased the resistance will in general decrease; thus in the case of the joint referred to in Table No. 1 the resistance of one of the splices changed from 15 ohms to 3 ohms. In this manner faults arising from imperfect splicing may be temporarily removed. Ringing currents and relatively large direct currents in such circumstances usually produce these effects and it is for this reason that signalling over such faulty circuits is seldom interfered with. To weak alternating currents, however, such joints may offer a high impedance—*i.e.*, the resistance of the joint in such cases may be several times the value as measured with say a direct current of one milliampere—and for this reason speech transmission may be adversely affected.

It is not certain whether such changes of resistance are entirely of electrical origin or whether they are due wholly or in part to mechanical changes at the splice.

* *"The Telephone Plant Job of to-day," P. L. Johnson, "Telephony," Vol. 93, No. 7, August 13th, 1927.*

Visual inspection of a joint, when directed towards certain salient features which are described later, will often enable imperfect or defective splicing to be detected; supervision during construction should specially include this item of cable jointing work.

FIG. 1

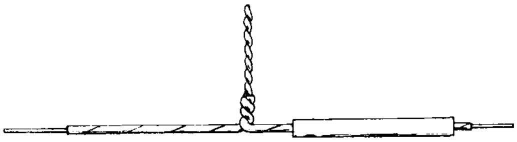
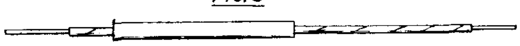


FIG. 2

FIG. 3



FIGS. 1, 2 & 3 - STANDARD METHOD OF TWIST SPLICING.

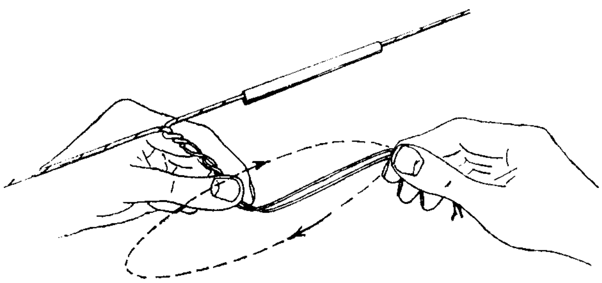


FIG. 4 - CRANK HANDLE SPLICE DURING TWISTING

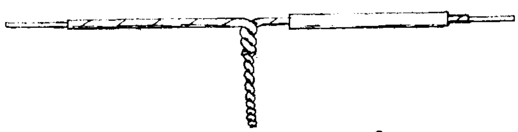


FIG. 5 CRANK HANDLE SPLICE
TWIST COMPLETED AND CUT TO LENGTH

Standard method of twist jointing.

The procedure described in British Post Office Technical Instructions XIV., Part 11, Section V (*b*), page 52, for the twist jointing of 6½ lb., 10 lb., 12½ lb., 20 lb. and 40 lb. cable conductors is as follows:—

(*a*) The two wires to be jointed, on which the paper covering and thread have been allowed to remain, will be twisted together for a few turns, a paper sleeve having first been slipped over one wire. The remainder of the paper and thread will then be removed.

(*b*) The bare conductors will be cleaned with glass paper and twisted together so that the copper joint is 1 inch in length. The joint will not be soldered, except in the case of 20 lb. conductors in Balanced Cables and all 40 lb. conductors, or unless it is to be covered with compound.

(*c*) The twisted conductors will be bent down and the paper sleeve drawn over the joint.

Figs. **1**, **2** and **3** illustrate a twist splice constructed as described above. It will be seen that this splice is characterised by tight, fairly close twisting, which is uniform from the tip to the twisted wrapped portion of the splice.

Crank-handle method of twist jointing.

This method of twist splicing is applied as follows:—

(*a*) The two wires to be spliced, on which the paper covering and thread have been allowed to remain are twisted together for one complete turn, a paper sleeve having first been slipped over one wire. The remainder of the paper and thread is then removed.

(*b*) The bare conductors are then cleaned with glass paper and twisted together thus:—With the left hand hold the two bare wires tightly between the thumb and forefinger at a distance of about one inch from the point at which the paper and string have been cut away. With the right hand, hold the two bare wires between the thumb and forefinger; turn the wires back between the two hands so as to form a crank-handle and rotate the right hand, at the same time permitting the twists to run through the left thumb and forefinger down to the insulated wires as in Fig. **4**. The wires are then cut so as to leave one inch of copper splice as in Fig. **5**.

(*c*) The twisted conductors are then laid back along the length of the joint and the paper sleeve drawn into position. It will be seen that a joint constructed according to this method is characterised by very close, tight twists at the tip, becoming less tight towards the twisted wrapped portion, in the immediate neighbourhood of which the twists are fairly open.

Each of the methods described, when correctly followed, produces twist splices of satisfactory electrical features.

General remarks on unsoldered twist-splices.

The magnitude of the resistance of a splice will depend upon the condition and area of the contact surfaces of the wires. With clean surfaces this resistance will be inconsiderable, even if the contact pressure and area are each small. If, however, the wires are coated or discoloured by an oxide film or are unclean in any other respect, the splice will be of high resistance unless the contact pressure and area are considerable.

In general the area of contact for tightly twisted wires will be proportional to the length of the copper splice. Owing to the thickness of the paper and thread coverings, there is a general tendency for the first two or three twists of the copper splice (beyond the twisted wrapped portion of the splice) to be imperfectly bedded upon each other. This in itself is not a serious objection since it lessens the strain and consequent chance of fracture of the wires during bending down for sleeving purposes. It results, however, in a diminution in the effective length of the splice, and if for any reason the standard length (one inch) of copper splice is reduced, *e.g.*, by maintaining the standard overall length, but increasing the length of the covered portion, or by inadvertently cutting the copper splice too short, or by opening the final twists through the use of blunted cutting pliers, a serious decrease in the contact surface will arise.

If the wires are twisted lightly together, multiple-point or line contact only will result, whereas with tight twisting, surface contact will be secured, owing to the resulting bedding action of the wires upon one another. Light twisting of the wires will generally give rise to a loose splice. The turning back of a joint for sleeving purposes whereby the wires become displaced relatively to each other is another cause of loose splices. This effect appears to be more pronounced in 20 lb. conductors than in 10 lb. conductors, probably because of their greater rigidity. The seasonal variations of temperature of telephone cables in this country is 14 to 15 degrees Centigrade: initial looseness in a splice is probably accentuated by subsequent movements due to such temperature changes, as well as by vibration.

Referring to the angle between two wires prior to twisting as the "Angle of twist," then the area of contact will increase as the angle of twist increases from a small angle up to about 80 degrees. Too small an angle of twist will be apparent on inspection by reason of the splice having too few turns. Such a splice will generally be loose. If the angle of twist is much greater than 80 degrees there will be a tendency for one wire only to rotate. Inspection in this case will reveal a splice of many turns which will generally be of irregular twist. Unless the twisting in this case is extremely tight, there is little bedding action and consequently inadequate area of contact surface whilst, in addition, the joint tends to become loose. Furthermore, such a splice will usually be bent, and broken line or surface contact will result from the accompanying imperfect bedding.

In making the crank-handle twist, if the wires are held too loosely between the fingers of the left hand, the twists become crowded together and are tightest immediately beneath the twisted wrapped portion—" organ-grinder " or " barrel-organ " twist. In such cases the wires when turned down for sleeving become strained and are liable to fracture.

Results of the examination of a defective cable-joint.

The following results were obtained by inspection on site and subsequent electrical test in the laboratory of 80 splices cut out of a 800/10 Twin A.S.P.C. cable joint.

Tests of the 80 splices with one milliampere in the line, showed that the resistance of each of 64 was less than 0.1 ohm, whilst the resistance of the remaining 16 ranged from 0.1 ohm to 7.7 (variable) ohms. Table No. (1) gives the resistance of each of these latter splices, allowance having been made for the resistance of the conductor on either side of the splice. The resistance of 2 yards of conductor is approximately 0.1 ohm. The Table also indicates the type of each splice as revealed by visual examination and classified in general accordance with the next paragraph.

TABLE I.

RESISTANCE (TESTING CURRENT 1 MILLIAMPERE) AND CLASSIFICATION OF DEFECTIVE TWIST SPLICES IN A 800/10 TWIN A.S.P.C. CABLE JOINT.

Splice No.	Resistance (ohms).	Type.	Splice No.	Resistance (ohms).	Type.
62	0.16	A B C F G	70	0.57	A B C . G
13	0.17	A B C F G	66	0.70	A B C . G
37	0.18	A B C . G	19	0.74	A B C F .
26	0.20	A B C . G	28	1.24	A B C F G
43	0.22	A B . . G	27	2.19	A B C F .
38	0.25	A B . G	17	3.0*	A B C F .
24	0.50	A B C . G	79	7.4*	A B C . G
67	0.53	A B . . G	48	7.7*	A B C . G

* Variable.

The more frequent causes of defective twist splices in practice.

From the foregoing, and apart from broken splices, these may be summarised as follows:—

(A) Non cleaning of the wires before twisting, whereby oxide films giving rise to discolouration of the wires, varying in shade from light straw to purple, constitute the actual surfaces of contact.

(B) Shortness of the copper splice. This will occur if the splice is cut too short, but is usually due to the paper wrapping being continued too far in the splice. The length of bare wire actually twisted together is thereby reduced and there is a consequent diminution in the area of contact. Figs. **6** and **7**.

(C) Looseness of the splice. This will be caused by one or other of the defects D, E, F, G, namely:—

(D) Light twisting. Fig. **8**.

(E) The effects of turning back for sleeving purposes. Fig. **9**.

(F) Too few twists, *i.e.*, too small an angle of twist. Fig. **10**.

(G) Bent splice. Fig. **11**.

Conclusions.

In order to avoid faulty twist splices the instruction relating to the method of making such splices should be exactly followed, particularly in respect of the cleaning of the wires and the length of the copper splice.

The loosening which may occur in a splice (which does not conform in all respects to the standard splice), when turned back for sleeving purposes, can be prevented as follows:—

Twist the paper-covered portion in the normal manner; twist the A wire one complete turn around the B wire; and then the B wire one complete turn around the A wire; finally, proceed with the normal twisting operation. This method will prevent the slack of one wire, arising from the turning back, from being transmitted through the splice. A splice of three diameters

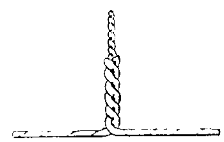


FIG. 6 SHORT COPPER SPLICE - PAPER CONTINUED TOO FAR.

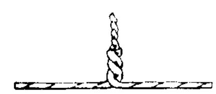


FIG. 7 SHORT COPPER SPLICE - WIRES CUT TOO SHORT.

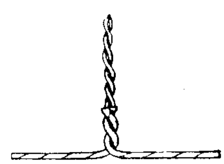


FIG. 8 LOOSELY TWISTED SPLICE.

FIG. 9 TWIST LOOSENED AND DISPLACED IN BENDING.

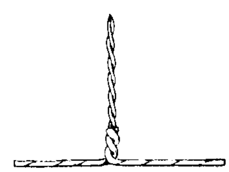


FIG. 10 TOO FEW TWISTS - ANGLE OF TWIST TOO SMALL.

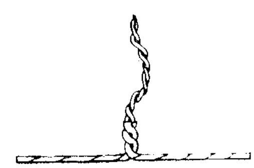


FIG. 11 BENT SPLICE

EXAMPLES OF DEFFECTIVE TWIST SPLICES.

instead of one of two diameters results for part of the length of the splice and a slightly larger paper sleeve may be required. The special turns in question virtually replace non-effective twists of the standard method; no effective contact area is therefore lost and greater rigidity of the wires is secured.

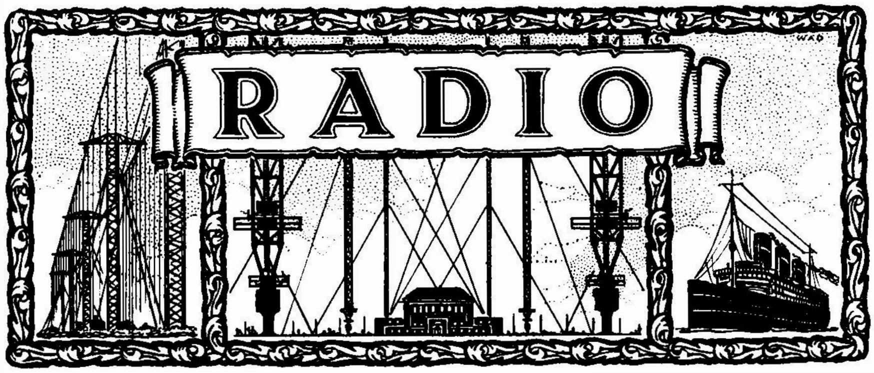
A loose splice seldom occurs when the crank-handle method has been adopted; incorrect procedure in this case, however, may give rise to too few effective twists at the tip, or to strained wires —with liability to fracture—in the neighbourhood of the wrapped portion of the splice.

20 lb. conductors should be more tightly twisted than 10 lb. conductors, not only for the purpose of obviating the above mentioned loosening effect but also to increase the area of contact surface by reason of the bedding action previously referred to.

In order to secure a satisfactory twist the angle between the wires should be about 80 degrees. During the operation of cutting the splice to the required length, the wires should be pulled with a slight rotating action and then cut, so as to obviate opening the final twists of the splice.

Imperfectly made twist joints give rise to considerable maintenance difficulties, since for the reasons already given a circuit which appears from the results of an ordinary conductor resistance test to be quite good, or which gives good results immediately on switching, may be subject to serious deterioration as conversation over the circuit proceeds. Furthermore, if spurious resistances of various magnitudes are present at many cable joints on a circuit, attempts at localisation of the splices giving rise to the major faults are generally very unsatisfactory, whilst even if such attempts are successful the disturbance of any particular joint for the removal of a faulty splice on a particular circuit may precipitate faults in the splices of other circuits at that joint.

The authors are indebted to Mr. J. F. Doust for the illustrations.



HUMBER RADIO STATION.

L. J. Jones, A.M.I.E.E., and W. M. Osborn, A.M.I.E.E.

THE new "Humber" Radio Station equipped with up-to-date transmitting and receiving plant has been erected at Mablethorpe, Lincolnshire, and brought into commission for ship-and-shore communication in replacement of the old Station at Grimsby, which was closed down on December 6th last.

The old Station was erected by the Admiralty during the War and was transferred to the Post Office, together with Wick and Portpatrick Radio Stations, in 1920; it was housed in three passenger railway coach bodies placed end to end on West Pier, Grimsby, and was equipped with a 2 KW Spark Transmitter of naval type. Fig. 1 is a photograph of the old Station at West Pier, Grimsby.

The primary reason for closing down the old Station was the lack of accommodation required for the provision of the necessary plant to enable the station to function as a Direction Finding Station for ships in the Humber district. Pending the erection of the new Station the Direction Finding service for the Humber district was carried out for the Post Office by the Admiralty Station at Flamborough Head. A site near Mablethorpe was selected as the most suitable locality for Direction Finding operations and the new Station has been equipped with valve transmitting apparatus and Direction Finding plant, employing the Bellini-Tosi System, as adopted by the Department at other Coast Radio Stations.

The new Humber Radio Station has also been fitted with a Radio Telephony installation for communication with trawlers and is the first British P.O. Coast Station to be so equipped.

The following is a brief general description of the new Station.

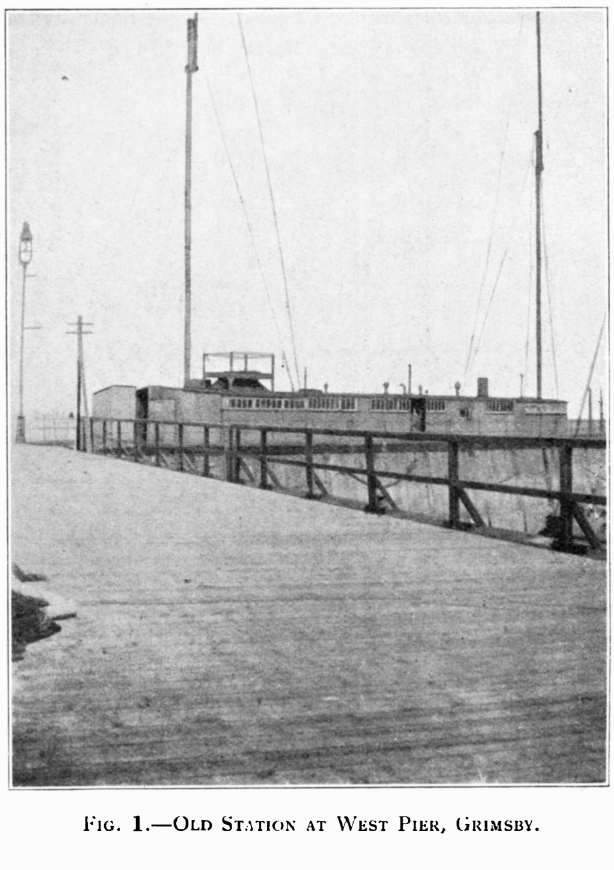


Fig. 1.—Old Station at West Pier, Grimsby.

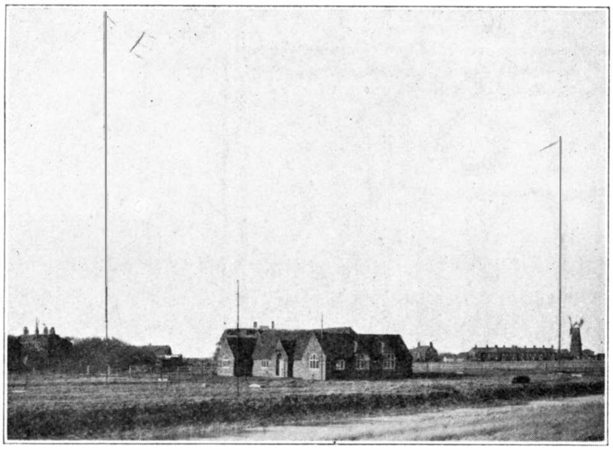


Fig. 2.—General view of Buildings and Site.

Site and Buildings. The site, which is about 2 acres in extent, is situated at Trusthorpe, about a mile from Mablethorpe Railway Station, on land adjoining the sea shore. The buildings are of one story type and are erected approximately at the centre of the site. Fig. **2** is a general view of the site and buildings: Fig. **3** shows in plan the lay-out of the building and engineering plant.

Aerial and Earth Systems. The main transmitting aerial is of three wire "T" type, supported by two tubular masts, 120 feet high, consisting of 20 feet lengths of 4in. diameter steam tubing screwed together and stayed with six sets of stays at 20 feet intervals. The masts are erected 246 feet apart on a line running approximately North-South. A separate aerial of 6-wire cage type, approximately 70 feet long, and suspended from the top of the north mast is provided for short wave telegraphy and telephony.

The Direction Finding and main receiving aerial system, consisting of two triangular frames of approximately 95 feet sides and a base 160 feet long, is rigged beneath the main transmitting aerial and is symetrically disposed about the south mast. The triangular frames are erected at right angles to each other and are supported on the south mast with their apexes and base centres at points 82 feet and 10 feet above the ground, respectively, and at their lower corners by tubular jury masts 25 feet high. In order to maintain the electrical balance of the two triangular frames, the four lead-in wires from the centres of the bases are twisted as in ordinary telephone practice throughout their length between the south mast and the lead-in panel a distance of 110 feet. The wire used

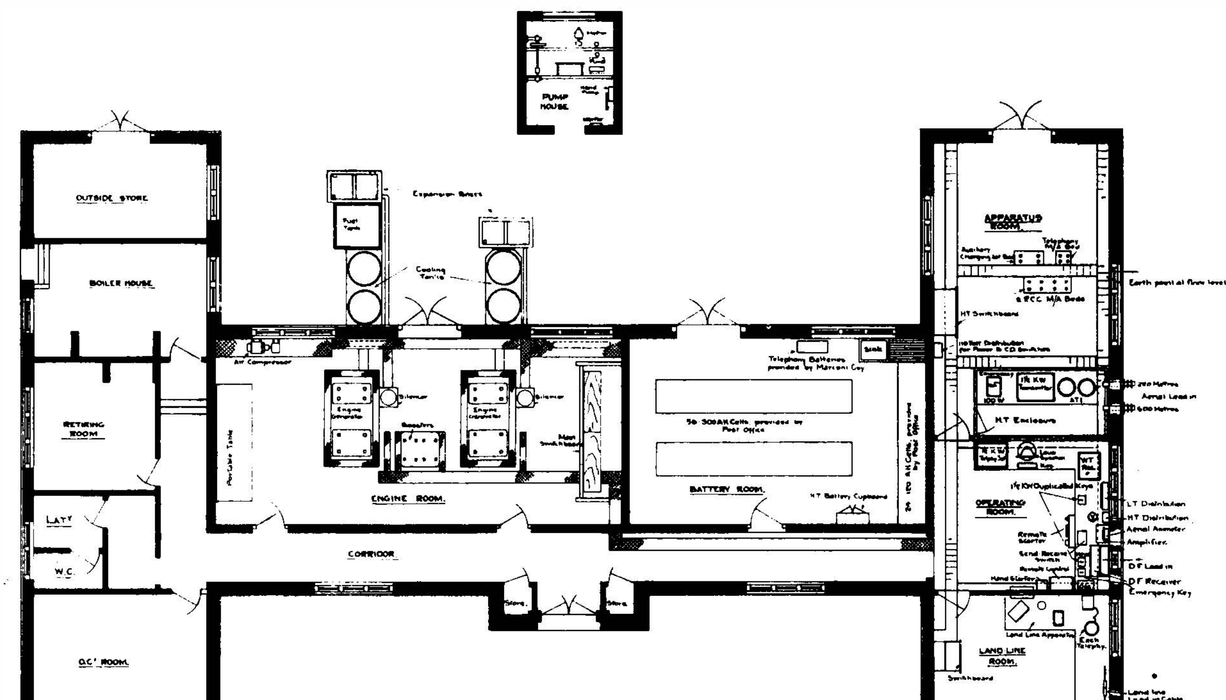


Fig. 3.—Lay-out of Building and Plant.

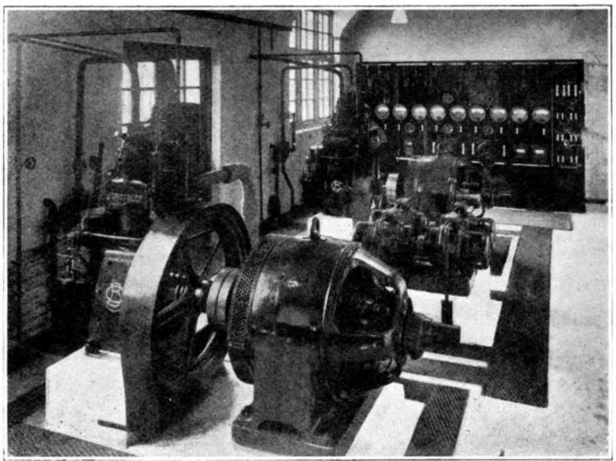


FIG. 4.—ENGINE ROOM.

throughout the construction of the aerial system is of "Wire, Bronze 7/19."

The main earth system is entirely underground and consists of 6ft. by 2ft. corrugated iron sheets, buried vertically with their long edges six inches below surface, and arranged in two semi-circles of 60 feet radius, symetrically disposed relative to the main earth point in the building, the sheets being connected thereto by equal lengths of "Wire Copper Soft 7/18 Strand." A separate earth system of similar type to the main system, but consisting of one semi-circle of 10 feet radius is provided for use in conjunction with the Direction Finding Receiver.

Power Plant. The electrical energy required for the operating and lighting services is generated at the Station as no public supply service is available.

The power plant was installed by the Austin Lighting Co., Ltd., and comprises two 14/16 H.P. Crossley Crude Oil Engines, direct-coupled to two 8 K.W. 110 Volt B.T.H. Generators for charging a Secondary Cell Battery of 56 cells of 300 ampere hour capacity, together with two 2 K.W. B.T.H. Motor Driven Boosters arranged for operation in association with the Generators so as to maintain the main bus-bars at a constant voltage of 110 volts under any condition of charge or discharge of the battery. Facilities have been provided for milking individual cells of the battery by means of either Motor Booster.

The Main Switchboard for controlling the above plant is of the enclosed type and comprises Generator and Booster Panels in duplicate, Battery and Feeder Panels.

Fig. 4 is a view of the Engine Room showing the Engine Generators and the Main Switchboard.

An Auxiliary Battery Charging Set and Switchboard is provided for use in connection with a battery of twenty-four Secondary Cells of 120 Ampere-hour capacity arranged and connected to the Switchboard in eight groups of three cells each; these Cells are used for heating the filaments of the Receiver valves and for power supply to the Emergency Transmitter. The Charging Set comprises a B.T.H. motor-generator, the motor of which is supplied with current at 110 volts from the main bus-bars; the generator provides for an out-put of 12 amperes throughout a range of 5 to 40 volts. The Switchboard is equipped with accessories for the control of the motor-generator and for the change-over of the groups of cells for charging or discharging.

Fig. 5 is a view of the Battery Room showing the main battery in the foreground, the auxiliary battery in the background and on the right of the figure, a cupboard containing a battery of 50 Leclanché cells used for providing the general high tension supply for the receiving plant.

Transmitters. The Transmitters were installed by the Radio Communication Co., Ltd., and comprise 1½ K.W. Main and 100-watt Emergency Valve Transmitters equipped for Continuous Wave and Interrupted Continuous

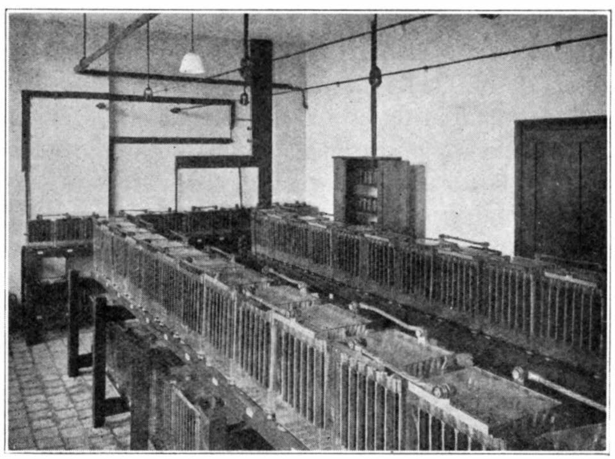


FIG. 5.—BATTERY ROOM.

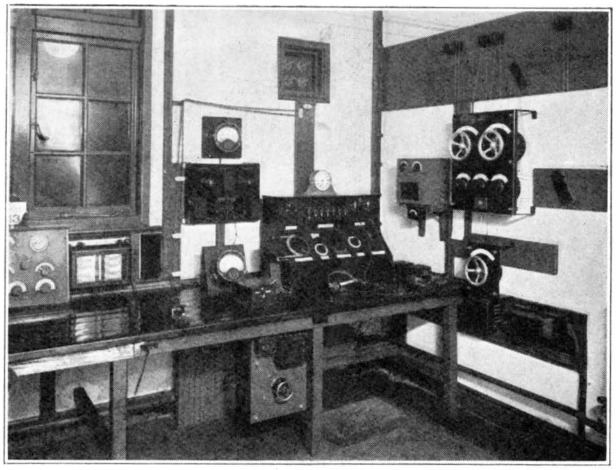


FIG. 6.—OPERATING BENCH.

Wave telegraphy. The Transmitting plant is similar to that installed at Seaforth Radio Station and is described in an article published in Volume 21, Part 1 of this Journal.

The transmitting apparatus is assembled on a bench in a high tension enclosure in the Apparatus Room as shown in Fig. **3**. The operation and all control of the transmitters are effected from the operator's position in the Operating Room, whence the Transmitters are under the observation of the Operator through the glazed partition which divides the Operating Room from the Apparatus Room.

Fig. **6** is a view of the operating bench in the Operating Room, showing on the right the Bowden wire control panels mounted on the wall and the Bowden wires running overhead to the H.T. enclosure. Fig. **7** is a view of the Apparatus Room, showing the rear of the transmitters with the protecting screen removed and on the right the power control panel.

Telephony Installation. A view of the telephony installation which is fitted in the Operating Room is shown in Fig. **8**. This comprises a self-contained transmitting and receiving set arranged for operation on the waves 200 and 220 metres. The apparatus is the Marconi Wireless Telegraph Company's standard "Type XMC 1 Telephone Set" slightly modified to suit Post Office service requirements; the normal rating of the Set is 500 watts.

Power for the Set is supplied by a motor-generator which is housed in the Apparatus Room and is seen in the foreground of **Fig. 7**. It comprises a motor wound to suit the 110-volt D.C. supply of the station and a combined low tension and high tension D.C. generator delivering 14 amperes at 16 volts for charging a floating 12-volt battery which supplies current for the filaments of the transmitting and receiving valves, and 150 milliamperes at 2,500 volts for H.T. supply to the anodes of the transmitting valves.

The well-known choke control method of speech modulation is employed in the Set. The transmitting valves comprise one oscillator valve type T250 and one modulating valve type T400 m/a. The aerial is inductively coupled to the closed oscillatory circuit.

The set is designed for simplex working, the change from speech to listening being effected by the operation of a "Send-Receive" switch mounted on the face of the cabinet, which transfers the aerial from the transmitting to the receiving circuits. The receiver is a 4-valve set, comprising one stage H.F. amplification, one detector stage and two stages low frequency amplification. The valve filaments are all in series across the 12 volt filament battery; the first three valves are of D.E.R. type, the last is of D.E.6 type. Reaction is employed between the anode of the detector valve and the aerial. The telephone receiver is in the anode of the first L.F. valve and a Loud Speaker is joined in the output of the fourth valve.

Provision is made for Interrupted Continuous Wave telegraphy by means of a key controlled

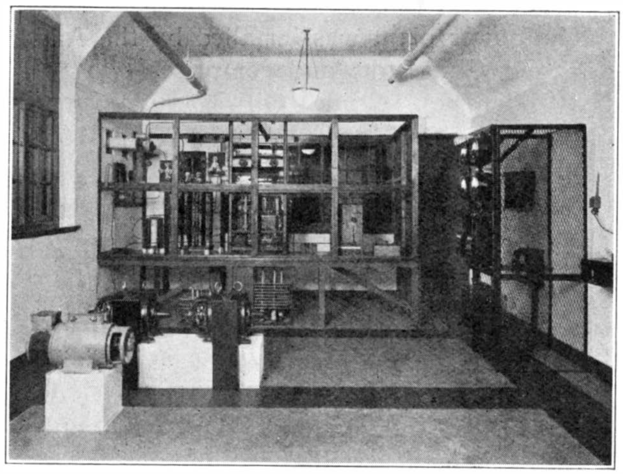


FIG. 7.—APPARATUS ROOM.

buzzer employed as a modulator in place of the microphone. The keying unit is visible in Fig. **8** immediately in front of the Loud Speaker.

Receiving Apparatus. Two complete receivers for the main 600 metre reception are employed and are both visible in Fig. **6**. The main receiver of the Station is the Marconi "Type 12A Direction Finding Receiver" seen on the right of the bench in the figure; the receiver seen on the left is of Post Office pattern, is non-directional in type and is only brought into use in the event of interruption to the D.F. Receiver. The 2-valve low frequency amplifier associated with the Post Office receiver can be seen mounted on the wall to the left of the D.F. receiver. An heterodyne oscillator is also associated with the D.F. receiver to enable the reception of C.W. signals.

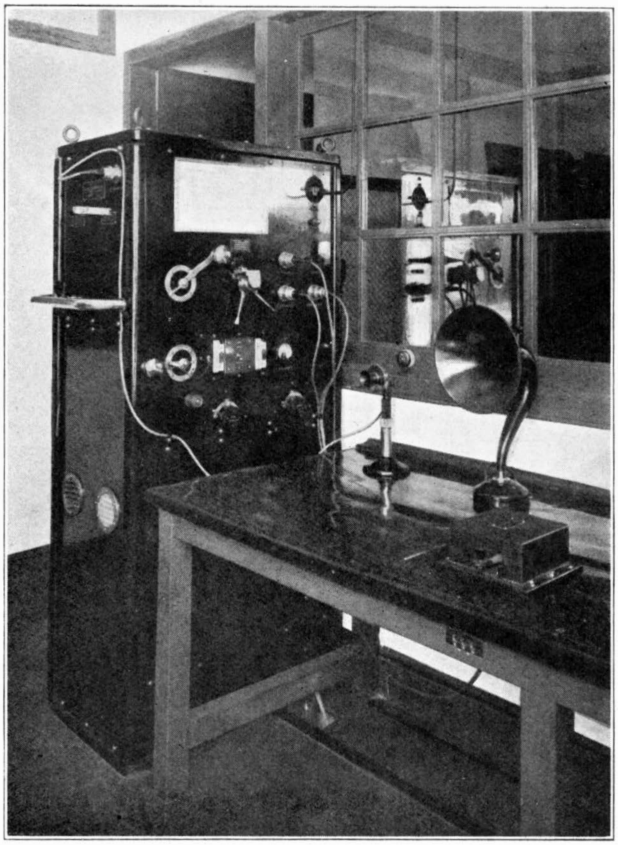


FIG. 8.—RADIO TELEPHONY INSTALLATION.

Special care has been taken in the lay-out of the cables between the filament lighting batteries and the sets with a view to avoiding inductive disturbance from the power plant, landlines, etc. Two groups of 6-volt batteries are reserved exclusively for the D.F. receiver. These are connected to the Battery Charging Switchboard *via* two D.P.D.T. switches located in the Operating Room, and with the object of reducing the wire to earth capacity of the D.F. receiver filament leads to the lowest possible limit the cables between the D.P.D.T. switches and the set are not lead covered and are carried on a route as remote as possible from other current carrying circuits. For a similar purpose the H.T. battery for the D.F. set consists of a box of 50 "Cells, Dry X" placed on a shelf immediately underneath the D.F. receiver. The filament current for purposes other than D.F. in the Operating Room is effected from a "Board, Distributing, No. 10" to which the main supply from the Auxiliary Charging Switchboard is brought, and the General H.T. supply obtained from the Leclanché Cells in the Battery Room already referred to is distributed from a "Cut Out No. 1 $\frac{10}{10}$" fitted with dummy fuses.

A general diagram of the external connections of the receiving plant and its association with the various switches, the Telephony Transmitter and batteries etc., is given in Fig. **9**; from this figure the general interconnection of the various items of apparatus can be traced.

The "Directional—D.F. Switch" has segmental attachment to the Switch lever and is so placed relative to the D.F. Receiver that one half of the Radiogonimeter scale of the set is covered when the switch is at the "Directional" position. It is thus impossible for the operator to take a bearing unless this switch is at the "D.F." position, in which position it operates the Marconi Solenoid Switch thus disconnecting all other aerials to give the conditions necessary for the determination of true bearings.

The action of switching the "Normal-Telephony" switch to "Telephony" is to cause the operation of the Radio Communication Company's type Solenoid Switch, which transfers the short aerial from the main to the telephony set. It also breaks the main key circuit thus making it impossible to transmit

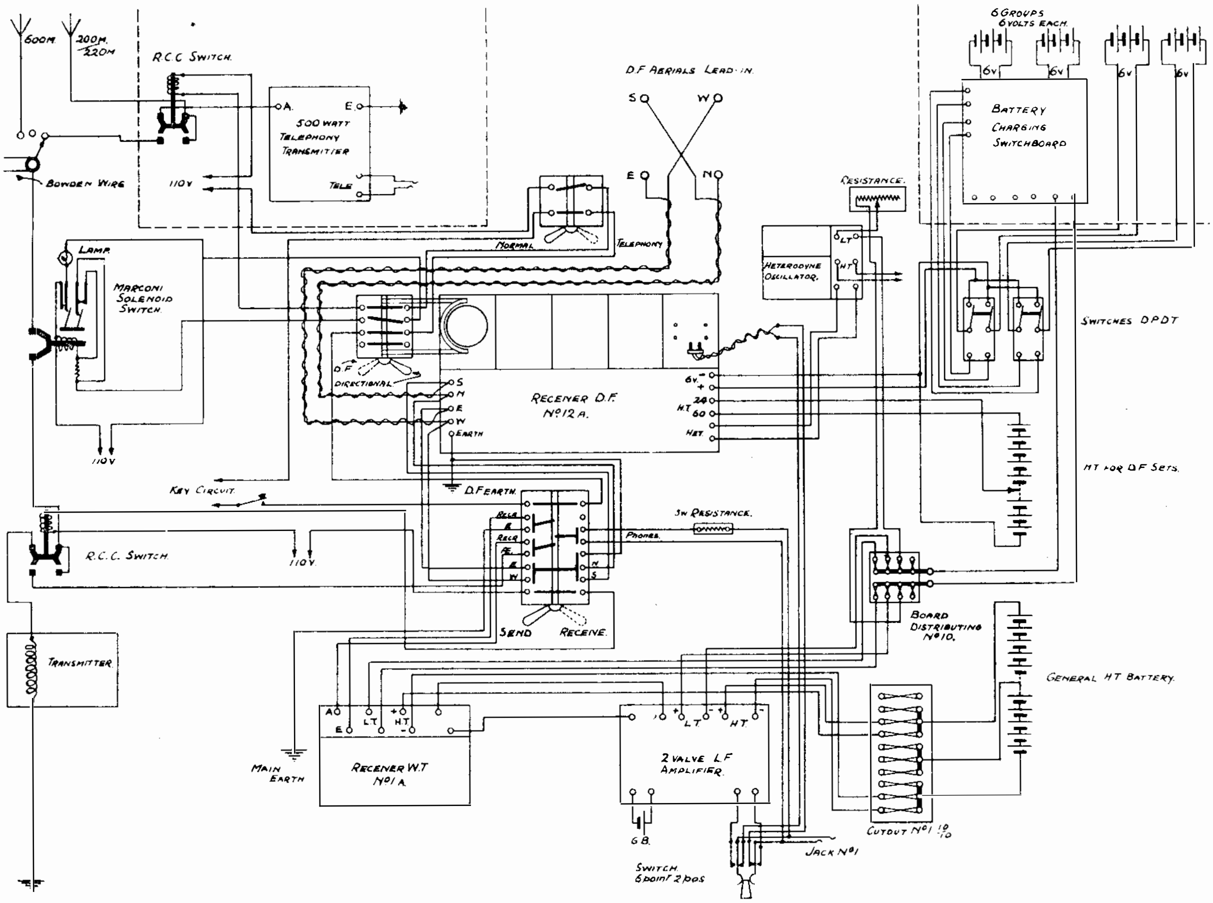


FIG. 9.—DIAGRAM OF CONNECTIONS.

on the main set whilst the telephony set is in operation.

It will be noted that the circuit controlling the R.C.C. switch referred to above is also interlocked with the " Directional—D.F. " Switch so that the action of this latter switch on turning to " D.F." automatically throws the short aerial back to the main set, where it is disconnected by the Marconi Solenoid Switch as already described.

The " Send-Receive " switch when at "Send" performs the usual functions necessary at a D.F. station, in earthing the Bellini-Tosi aerials, disconnecting the Post Office receiver, short-circuiting the telephones and joining up the key circuit, as well as operating a Solenoid switch which transfers the aerial from the receiving to the transmitting apparatus.

Satisfactory tests on C.W. and I.C.W. were carried out with Coast and Ship Stations on completion of the installing work and showed a considerable improvement over the ranges obtained by the old Grimsby Station. Speech ranges of over 200 miles over sea have been satisfactorily effected with the telephony installation.

The Direction Finding plant has been calibrated and was brought into operation on the 19th February last, taking over the D.F. service formerly carried out by the Admiralty Station at Famborough Head, which has now ceased to function.

THE BEHAVIOUR OF A TRANSMISSION LINE AT RADIO FREQUENCIES.

F. E. NANCARROW, A.R.C.Sc., Wh.Ex.,A.M.I.E.E., Member I.R.E.

ALTHOUGH the general case of transmission is well known it does not seem that the solutions have been anywhere developed to portray the behaviour of a transmission line at ultra-radio frequencies where the transmission line is many wave-lengths long. With the development of short wave radio communication such transmission lines are becoming more common and hence the particular development of the general case given below is perhaps not without interest.

The general equations of propagation along transmission lines give rise to the following solutions:—

$$V = Ae^{Px} + Be^{-Px}$$
$$I = Ce^{Px} + De^{-Px}$$

which can be further written (see Appendix I.)

$$V = I_r (Z_o \sinh P_x + Z_a \cosh P_x) \quad \text{...........(1)}$$

$$I = \frac{I_r}{Z_o} (Z_a \sinh P_x + Z_o \cosh P_x) \quad \text{...........(2)}$$

where V = potential difference at a distance x from the load.
I = current at a distance x from the load.
Z_a = impedance of the load.
Z_o = iterative or surge impedance of the transmission line.
P = transmission constant of the line.
I_r = current at the load.

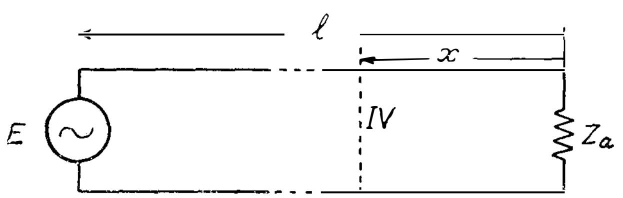


FIG. 1.

By inserting the sending end conditions as shown in Fig. 1, in equation (1), we get

$$E = I_r (Z_o \sinh Pl + Z_a \cosh Pl) \quad \text{...........(3)}$$

and substituting the value of I_r so obtained in equations (1) and (2) we have

$$V = \frac{E}{Z_T} (Z_o \sinh Px + Z_a \cosh Px) \quad \text{.........(4)}$$

$$I = \frac{E}{Z_T Z_o} (Z_a \sinh Px + Z_o \cosh Px) \quad \text{......(5)}$$

where $Z_T = (Z_o \sinh Pl + Z_a \cosh Pl)$; *i.e.*, a constant for a line with fixed terminal conditions.

For frequencies within the telephonic range Z_o is generally a complex quantity and is given by the relation

$$Z_o = \sqrt{\frac{R + j\omega L}{S + j\omega C}} \quad \text{................................(6)}$$

where R, L, S and C are the resistance, inductance, leakance and capacity respectively, per unit length of line, and $\omega = 2\pi n$, where n equals the frequency of oscillation of the transmitted current.

At radio frequencies, however, R and S are, in general, negligible as compared with ωL and ωC respectively, and hence (6) reduces to

$$Z_o = \sqrt{\frac{L}{C}} \quad \text{.......................................(7)}$$

where Z_o is seen to be a pure resistance.

P, the transmission constant, is given by the relation

$$P = \sqrt{(R + j\omega L)(S + j\omega C)} \quad \text{....................(8)}$$

and this can be further written

$$P = \alpha + j\beta \quad \text{..(9)}$$

where α is the attenuation constant of the line and β the so called velocity constant. At radio frequencies it is, in general, impossible to evaluate α except by direct measurement, but β is simply obtained from the relation

$$\beta = \frac{2\pi n}{v} \quad \text{..(10)}$$

where v, the velocity of propagation along the transmission line, is, for ultra-radio frequencies, equal to the velocity of propagation of light.

β can then be alternatively written

$$\beta = \frac{2\pi}{\lambda} \quad \text{...(11)}$$

where λ is the wave-length of the propagated disturbance.

The impedance at any point of the transmission line can be written

$$Z = \frac{V}{I} = Z_o \frac{Z_o \sinh Px + Z_a \cosh Px}{Z_a \sinh Px + Z_o \cosh Px} \quad \text{.....(12)}$$

which is independent of sending end conditions.

Converting the sinh and cosh terms into exponentials we get

$$Z = Z_o \frac{(Z_o + Z_a)e^{Px} + (Z_a - Z_o)e^{-Px}}{(Z_o + Z_a)e^{Px} - (Z_a - Z_o)e^{-Px}}$$

$$= Z_o \frac{(Z_o + Z_a)e^{\alpha x}e^{j\beta x} + (Z_a - Z_o)e^{-\alpha x}e^{-j\beta x}}{(Z_o + Z_a)e^{\alpha x}e^{j\beta x} - (Z_a - Z_o)e^{-\alpha x}e^{-j\beta x}}$$

In what follows, α, for the sake of simplicity, will be taken as being negligibly small. If α is not negligible, however, the argument remains unaffected and absolute values are obtained by multiplying the vectors $(Z_o + Z_a)$ by $e^{\alpha x}$ and the vectors $(Z_a - Z_o)$ by $e^{-\alpha x}$.

Assuming $\alpha = 0$, (12) can be written

$$Z = Z_o \frac{(Z_o + Z_a)e^{j\frac{2\pi x}{\lambda}} + (Z_a - Z_o)e^{-j\frac{2\pi x}{\lambda}}}{(Z_o + Z_a)e^{j\frac{2\pi x}{\lambda}} - (Z_a - Z_o)e^{-j\frac{2\pi x}{\lambda}}} \quad \text{......(13)}$$

This equation enables the effective impedance of the line at any point to be readily calculated, and, since the numerater is representative of the voltage and the denominater of the current, these quantities are also readily calculable, due regard being paid to equations (4) and (5).

The numerator of equation 13 is composed of the sum of two unequal vectors rotating in opposite directions with the same velocity whilst the denominater is composed of their difference. Thus four times in every revolution the vectors in both numerater and denominater come into phase, or 180° out of phase with one another, giving a resultant quotient without angle. Hence, whatever the nature of the load Z_a, the transmission line will behave as a pure resistance at points along the line separated by intervals equal to $\frac{\lambda}{4}$, and the value of Z at these points will alternate from the maximum to the minimum values which Z can assume. The first of these points where $Z = Z_R$ (a pure resistance), will be at a distance y from the load where

$$y = \frac{\lambda}{2\pi} \times \frac{\phi}{2} \text{ when } Z_a \text{ is inductive}$$

$$\text{and } y = \frac{\lambda}{2\pi} \times \left(\frac{\pi}{2} - \frac{\phi}{2}\right) \text{ when } Z_a \text{ is capacitative}$$

ϕ being the angle between the vectors $(Z_o + Z_a)$, $(Z_a - Z_o)$ at the load.

Fig. 2, below, illustrates a case where Z_a is inductive and shows the positions of $Z = Z_R$.

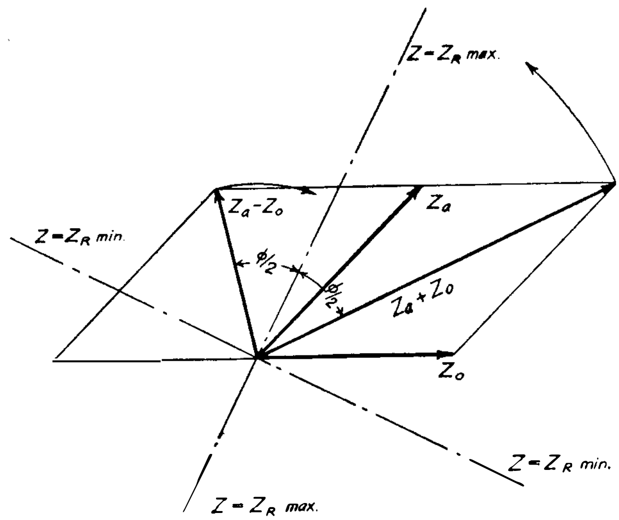


FIG. 2.

Showing the positions where $Z = Z_R$ (a resistance) and the phase displacement ϕ at the load of the vectors $(Z_a + Z_o)$, $(Z_a - Z_o)$ for the case where Z_a is inductive.

If the scalar values of the vectors $(Z_o + Z_a)$ and $(Z_a - Z_o)$ be written aZ_o and bZ_o respectively, the maximum and minimum values which Z can assume can be written as follows:—

(a) *Maximum value of Z.*

This will occur when the vectors $(Z_o + Z_a)$ and $(Z_a - Z_o)$ are in phase giving

$$Z_R = Z_o \cdot \frac{aZ_o + bZ_o}{aZ_o - bZ_o}$$

$$= Z_o \cdot \frac{a+b}{a-b} \quad \text{..................................(14)}$$

(b) *Minimum value of Z.*

This will occur when the vectors $(Z_o + Z_a)$ and $(Z_a - Z_o)$ are 180° out of phase giving

$$Z_R = Z_o \cdot \frac{aZ_o - bZ_o}{aZ_o + bZ_o}$$

$$= Z_o \cdot \frac{a-b}{a+b} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (15)$$

From (14) and (15) it is seen that

$$Z_o = \sqrt{Z_R \text{ (max.) } Z_R \text{ (min.)}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (16)$$

From equation (13) or Fig. **2** it is clear that midway between the positions Z_R max., and Z_R min., the vectors $(Z_o + Z_a)$, $(Z_a - Z_o)$ are at right angles to one another and thus the resultant vectors in numerater and denominater of 13 are equal to one another in amplitude.

The scalar value of Z for these positions is therefore given by

$$|Z| = Z_o \frac{\sqrt{(aZ_o)^2 + (bZ_o)^2}}{\sqrt{(aZ_o)^2 + (bZ_o)^2}} = Z_o \quad \ldots\ldots\ldots\ldots (17)$$

If Z_{R_1}, Z_{R_2}, Z_{R_3} . . . denote the positions along the line from the load at which Z assumes its resistance values, then a little geometry in connection with equation (13) will show that when the load is inductive Z is inductive in the intervals $(Z_{R_2} - Z_{R_3}), (Z_{R_4} - Z_{R_5})$. . . and capacitative in the intervals $(Z_{R_1} - Z_{R_2})$, $(Z_{R_3} - Z_{R_4})$, . . . and *vice versa* for the case of a capacitative load.

The case where $Z_a = Z_o \angle 45°$ is portrayed in Fig. **3** below.

From the general case treated above any particular case of loading can be studied. Thus if Z_a be a resistance $= \delta Z_o$ we have

$$a = 1 + \delta$$
$$b = \delta - 1$$

$$\text{and } Z_{R_1} = Z_o \cdot \frac{(1+\delta)+(\delta-1)}{(1+\delta)-(\delta-1)} = Z_o\delta \cdot \quad \ldots\ldots\ldots (18)$$

$$Z_{R_2} = Z_o \cdot \frac{(1+\delta)-(\delta-1)}{(1+\delta)+(\delta-1)} = Z_o \cdot \frac{1}{\delta} \quad \ldots\ldots\ldots (19)$$

also since $\phi = 0$, $y = 0$.

We have therefore the condition that if the transmission line is terminated in a resistance δZ_o, the line behaves as a resistance at points spaced $\frac{\lambda}{4}$ from the load, the value of the resistance at these points alternating from δZ_o to $\frac{1}{\delta} Z_o$.

If $\delta < 1$ the line impedance will be inductive between $(Z_{R_1} - Z_{R_2})$, $(Z_{R_3} - Z_{R_4})$ . . . and capacitative in the intervals $(Z_{R_2} - Z_{R_3})$, $(Z_{R_4} - Z_{R_5})$, . . . and *vice versa* if $\delta > 1$.

If $\delta = 1$ the turn $Z_a - Z_o$ in equation (13)—which is the turn taking account of reflection—vanishes, and we have $Z = Z_o$ everywhere along the line.

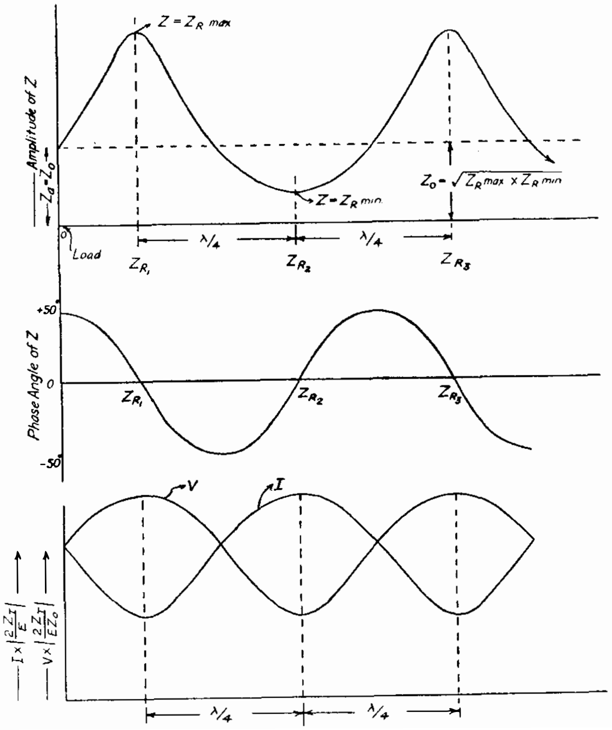


FIG. 3.
Showing how the amplitudes of Z, V and I and the phase of Z varies with increasing distance from the load. Drawn for the particular case of $Z_a = Z_o \angle 45°$.

The current or voltage at any point of the transmission line is dependent upon the total length of line. Thus from equation (5)

$$I = \frac{E}{Z_T Z_o} (Z_a \sinh P_x + Z_o \cosh P_x)$$

$$= \frac{E}{2Z_T Z_o}\left[(Z_o + Z_a)e^{j\frac{2\pi x}{\lambda}} - (Z_a - Z_o)e^{-j\frac{2\pi x}{\lambda}}\right] \quad (20)$$

$$\text{and } V = \frac{E}{2Z_T}\left[(Z_o + Z_a)e^{j\frac{2\pi x}{\lambda}} + (Z_a - Z_o)e^{-j\frac{2\pi x}{\lambda}}\right] \quad (21)$$

where α has been taken as negligibly small.

At points where $Z=Z_R$ (max.) these reduce to

$$I=\frac{E}{2Z_T}(a-b)$$

$$V=\frac{EZ_o}{2Z_T}(a+b)$$

and where $Z=Z_R$ (min.) to

$$I=\frac{E}{2Z_T}(a+b)$$

$$V=\frac{EZ_o}{2Z_T}(a-b)$$

where a, b, and Z_T have the significance previously stated.

$$Z_T=Z_o \sinh Pl+Z_a \cosh Pl$$

which can be written

$$Z_T=\tfrac{1}{2}\left[(Z_a+Z_o)e^{j\frac{2\pi l}{\lambda}}+(Z_a-Z_o)e^{-j\frac{2\pi l}{\lambda}}\right]$$

if α is assumed very small, and is a function amenable to simple graphical evaluation.

APPENDIX I.

$$V=Ae^{Px}+Be^{-Px} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{I.}$$

$$I=Ce^{Px}+De^{-Px} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{II.}$$

And in any transmission line we have

$$\frac{dV}{dx}=RI+j\omega LI=FI$$

and $\frac{dI}{dx}=SV+j\omega CV=GV.$

also $P=\sqrt{FG}$ and $Z_o=\sqrt{\frac{F}{G}}$.

At the load $x=0$ and $V=I_rZ_a$.

Hence putting $x=0$ in equations I. and II. we get

$$\left.\begin{aligned}I_rZ_a&=A+B\\ I_r&=C+D\end{aligned}\right\}$$

differentiating I. and II., substituting for $\frac{dV}{dx}$ and $\frac{dI}{dx}$ putting $x=0$ we get

$$\left.\begin{aligned}\frac{FI_r}{P}&=A-B\\ \frac{GI_rZ_a}{P}&=C-D\end{aligned}\right\}$$

Hence $A=\frac{I_r}{2}\left[Z_a+\frac{F}{P}\right]=\frac{I_r}{2}[Z_a+Z_o]$

$$B=\frac{I_r}{2}\left[Z_a-\frac{F}{P}\right]=\frac{I_r}{2}[Z_a-Z_o]$$

$$C=\frac{I_r}{2}\left[1+\frac{Z_a}{Z_o}\right]=\frac{I_r}{2Z_o}[Z_a+Z_o]$$

$$D=\frac{I_r}{2}\left[1-\frac{Z_a}{Z_o}\right]=\frac{I_r}{2Z_o}[Z_o-Z_a]$$

$$\therefore V=\frac{I_r}{2}[(Z_a+Z_o)e^{Px}+(Z_a-Z_o)e^{-Px}]$$

$$=I_r[Z_o \sinh P_x+Z_a \cosh P_x]$$

and $I=\frac{I_r}{2Z_o}[(Z_a+Z_o)e^{Px}+(Z_o-Z_a)e^{-Px}]$

$$=\frac{I_r}{Z_o}[Z_o \cosh P_x+Z_a \sinh P_x]$$

APPENDIX II.

For a transmission line consisting of two wires raised sufficiently high above the earth, each wire being of diameter d, and the wires being spaced a distance D, it can be shown that

$$L=4\log_e\frac{2D}{d} \text{ per unit length [E.M. units]}$$

$$C=\frac{1}{4\log_e\frac{2D}{d}} \quad ,, \quad ,, \quad ,, \quad \text{[E.S. units].}$$

Hence multiplying L by 10^{-9} to convert to Henrys and C by $\frac{1}{9\times 10^{11}}$ to convert to Farads we get

$$Z_o=\sqrt{\frac{L}{C}}=\sqrt{\frac{4\log_e\frac{2D}{d}\times 10^{-9}}{\frac{1}{4\log_e\frac{2D}{d}}\times\frac{1}{9\times 10^{11}}}}$$

$$=\sqrt{16\log_e^2\frac{2D}{d}\times 900}$$

$$=120\log_e\frac{2D}{d}$$

A curve showing values of Z_o for various ratios of $\frac{2D}{d}$ is given in Fig. **4**.

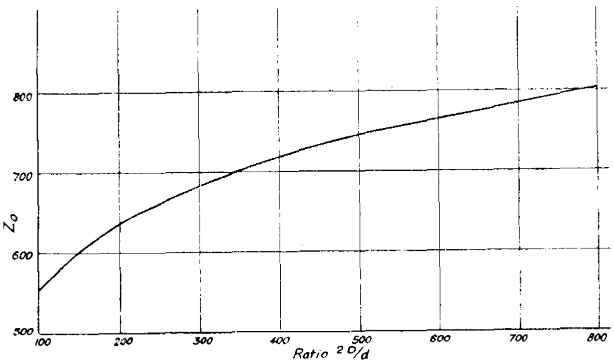


FIG. **4**.

Variation of Z_0 with the ratio $\frac{2\,D}{d}$ for the case of a raised 2-wire transmission line.

Again for the case of a transmission line consisting of concentric tubes, the inner tube having outer radius r and the outer tube having inner radius R. it can be taken as being approximately correct at high frequencies that

$L = 2 \log_e \frac{R}{r}$ and that $C = \frac{1}{2 \log_e \frac{R}{r}}$ the values being again in the appropriate units.

$$Z_o = \sqrt{\frac{L}{C}} = \sqrt{\frac{2 \log_e \frac{R}{r} \times 10^{-9}}{\frac{1}{2 \log_e \frac{R}{r}} \times \frac{1}{9 \times 10^{11}}}}$$

$$= 60 \log_e \frac{R}{r}$$

A curve showing values of Z_o for various values of $\frac{R}{r}$ in the case of this type of Transmission line is given in Fig. **5**.

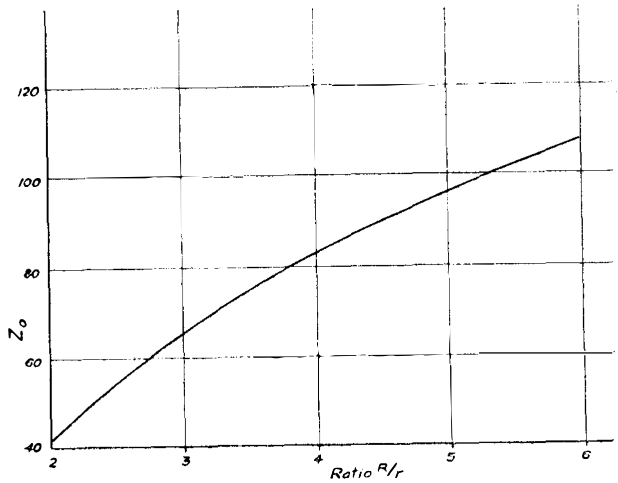


FIG. **5**.

Variation of Z_0 with the ratio $\frac{R}{r}$ for the case of a transmission line made up of concentric tubing.

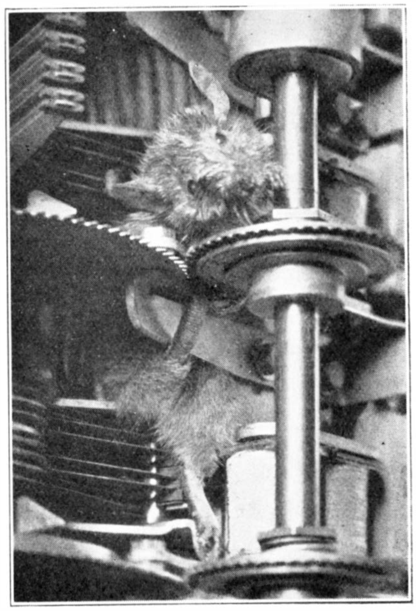
NOTES & COMMENTS

THE Council of Administration of the Association "des Ingénieurs Electriciens sortis de l'Institut Electro-technique Montefiore," Rue Saint Gilles 31, Liége, announces the closing date for their triennial prize competition as the 30th April, 1929. The prize, which amounts to some twenty-nine thousand francs, is awarded to the best work describing a new idea which has had important bearings on developments in the domain of electricity. Further information can be obtained from the General Secretary, M. L. Calmeau, at the above address.

We have received a copy of the Balance Sheet, Revenue Statement and Statistics of the Guernsey States Telephone Department for the year ended 31st December, 1927. The number of exchange lines shows an increase of 176 for the year, the total being now 3,478. The gross revenue is £18758 and the net profit £796, increases of £648 and £34 respectively. It is observed that Trunk service to Alderney opened on the 27th September, a service which, we understand, is superposed on the already existing single core telegraph cable. A similar service to Sark has been in existence since 1915.

We have received the following item and photograph from Mr. A. Jas. Perry, the Shanghai Mutual Telephone Co., Shanghai:—

During a trial run of a Western Electric Rotary System Exchange, recently installed in the Far East, a sudden stoppage caused considerable alarm.



An Automatic rat trap!

A vigorous campaign had been made against deserters of the rat family, who frequent the hotel kitchens next door. Being on the *qui vive*, they were looking for every loophole of escape, and the one shown in the accompanying photograph got into the equipment room through the main cable chute, a casing door having been left off during work. The only damages to the plant were a few gory stains on the shafting and geared drive and a blown fuse.

Going upon this idea, the engineers are now talking about an automatic rat trap!

"*Wired Wireless in Canada.*—The Canadian National Railways Telegraph Department is installing, at a cost of $2,500,000, a new modern high-speed telegraph system between Vancouver and Montreal, which is expected to be in operation within three months. Mr. R. W. Ball, General Manager of the Western region, states that the carrier current system which is being used, and which is practically the application of the wireless audio-frequency system to telegraph service, will make it possible to transmit 84 messages simultaneously. The new system uses two wires, whereas the old sysem used one wire over which eight messages could be sent simultaneously. The new service will therefore result in speeding up communication tenfold. Installation of the new equipment between Montreal and Winnipeg has already been completed.

17, West India Dock Road,
E.14.
3rd May, 1928.

The Editors P.O. *Engineers' Journal.*

Dear Sir,—One misses in our Journal recently correspondence showing that purchasers are reading and weighing the matter in the articles.

I propose to say something about the extract from "Economies in Line Plant Provision."

The teeing system has been tried and found wanting. The fatal objection to it are inherent in the system. If only two D.P.'s are teed, one branch is spare plant when the main cable pair is used; and that spare branch being teed to the working circuit is a menace to it. The teed spare branch adds electrostatic capacity to the circuit and it may—in practice it frequently does—bring low insulation, short-circuits, and earth faults to the working circuit. The more D.P.'s are teed together, the worse the trouble.

The record question is a very serious one. Theoretically possible, it is, in practice, impossible to maintain it as it should be.

When a fault occurs a difficulty arises at once. Imagine the lineman on being handed the fault being told "The circuit is on pair 7 at D.P.243, but it is teed at the junction of Green St. with Romford Rd. with pair 9 on D.P.327." I saw the system in use, saw the trouble and confusion caused, and was glad to see the last of it.

"This will allow one-third of the circuits terminating at a D.P. to be connected direct to the exchange and two-thirds to be teed with other D.P.'s." Taking the above and assuming that the ten year cables reach approximately halfway, then, when the main pairs are all used up, 20% of the total wire mileage, and the most expensive part too, remains spare. But in spite of the teeing it would have been necessary to open joints to put the spares where wanted.

When the main cable pairs are exhausted and a new cable run, then would come the unteeing—and what then?

I think that the auxiliary joint which Mr. Harvey Smith has done so much to popularise is much the best solution yet brought forward. The main pairs are not stumped as stated; they are actually joined up to pairs beyond at the outset, in the best foreseen way; but it is the auxiliary joint only that need be opened when any joint at all must be opened.

The aggregate cost of "wires changed over" is very great. It is a question whether much of the money would not have been better spent in providing new conductors.

Yours faithfully,
E. V. SMART.

HEADQUARTER'S NOTES.

EXCHANGE DEVELOPMENTS.

The following works have been completed :—

Exchange.	Type	No. of Lines.
Armley	New Auto.	590
Tandem (Holborn)	,,	—
Gloucester	,,	1060
Arkwright St.	,,	1000
Churchtown	,,	920
Birkdale	,,	1100
Bishopsgate	,,	7300
Macclesfield	,,	1220
Epsom	Auto Extn.	300
Chapeltown	,,	810
Arkwright st.	,,	500
Sherwood	,,	680
Gosport	,,	270
Portsmouth	,,	—
York	,,	405
Hayling Island	,,	300
Leeds Obsn Desk	,,	—
Ambassador	New Manual	2000
Goole	,,	560
Garston	,,	1400
Northwich	Manual Extns.	180
East (London)	,,	1410
Cambuslang	,,	280
Queens Park	,,	1080
New Cross	,,	900
Weymouth	,,	240
Chiswick	,,	2140
Camberley	,,	260
South Shields	,,	1360
Old Swan (L'pool)	,,	1050
Hecla & Sons	P.A.B.X's	30
Bristol Corporation	,,	50
Blackburn Infirmary	,,	20
Ferranti	,,	Rearrange-ment.
Groves & Whitnall	,,	30
Harrods	,,	720
Halifax Corporation	,,	50
Hughes & Son	,,	30
Carricks	,,	30

Orders have been placed for the following works :—

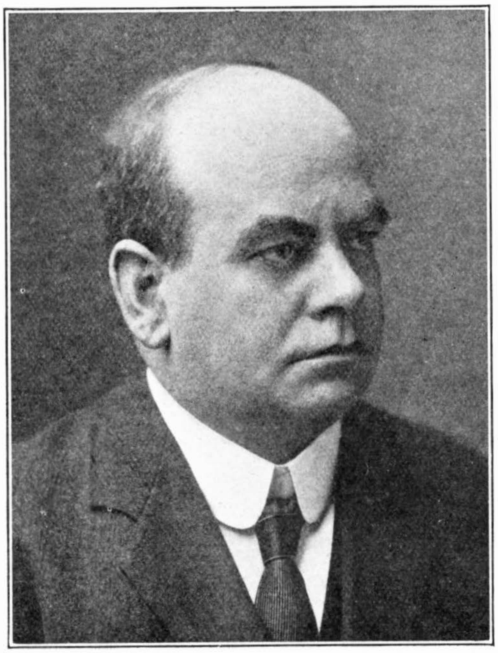
Exchange.	Type.	No. of Lines.
Amherst	New Auto	3600
Fulham	,,	7500
Moss Side	,,	1775
Dudley	,,	1220
Brierly Hill	,,	490
Cradley Heath	,,	540
Stourbridge	,,	1020
Bridlington	,,	1270
Castleton	,,	155
Heywood	,,	365
Littleborough	,,	260
Milnrow	,,	80
Norden	New Auto.	70
Shaw	,,	270
Whitworth	,,	80
Mumbles	,,	570
Fleetwood	Auto Extns.	220
Hayling Island	,,	300
Leeds	,,	Modfns.
Southborne	New Manual	1880
Petersfield	,,	500
Winchester	,,	400
Deal	,,	860
Purley	Manual Extns.	1020
Mansfield	,,	460
Putney	,,	1040
Anfield	,,	1140
Ferranti	P.A.B.X's	Rearrange-ment.
Delta Metal Co.	,,	20
Davenports	,,	20
Manchester Corpn.	,,	300
Ratcliffe & Ratcliffe	,,	20
Carricks, Ltd.	,,	30
Groves & Whitnall	,,	30
Salford Corpn.	,,	30
Hughes & Son	,,	30
Wiggins Teape & Co.	,,	30
May & Co.	,,	20
Nairn & Co.	,,	30
Calico Printers	,,	30
Atkinson & Son	,,	20

STAFF CHANGES.

Several important changes in the personnel of the higher posts have been recently announced. Mr. Sinnott, who retired on age limit, is succeeded by Mr. E. H. Shaughnessy, whose position as Assistant Engineer-in-Chief will be filled by Lt.-Col. Lee. The Metropolitan Power District has been absorbed by the London Engineering District, and a Deputy Superintending Engineer, in the person of Mr. Gomersall, has been appointed to the L.E.D. Mr. J. W. Atkinson succeeds Mr. T. B. Johnston at Leeds, and Major H. Brown takes Mr. Gomersall's place at Nottingham. Mr. Greenham will go to Croydon on the retirement of Mr. F. Tandy, S.E. of the South Eastern District, and Mr. A. B. Hart will take over the charge of the Lines Section at headquarters when Mr. France retires in November. Mr. Hardham has been appointed Principal Officer in charge of the Staff Section in place of Mr. M. F. G. Boddington, retired on age limit.

We have been fortunate in securing life histories of several of the above. Others will follow in next issue.

MR. J. SINNOTT, O.B.E.



Mr. J Sinnott, O.B.E.

Mr. J. Sinnott, O.B.E., Assistant Engineer-in-Chief, retired from the service at the end of April last, having reached his allotted period but hale and hearty as ever. His popularity with the staff was evidenced by the large gathering which assembled in the Chief's room on the afternoon of the 22nd May to bid him an official farewell and to witness the presentation of a silver tea and coffee service with an engraved salver, which had been subscribed for by members of the staff in all Districts as well as at headquarters. The Engineer-in-Chief presided and opened the proceedings in his usual genial manner. The lead set by the chief was followed by the other speakers, among whom were Mr. Sparkes, Controller of Stores, Mr. De Lattre, Mr. McIlroy, Mr. J. E. Taylor, representing the Districts, Mr. Pollock, Mr. R. A. Wells, Mr. J. W. Atkinson, and Mr. Shaughnessy. All the speeches bore testimony to the ability of Mr. Sinnott, to his characteristic good nature and kindliness of heart and to the valuable services rendered by him to the state.

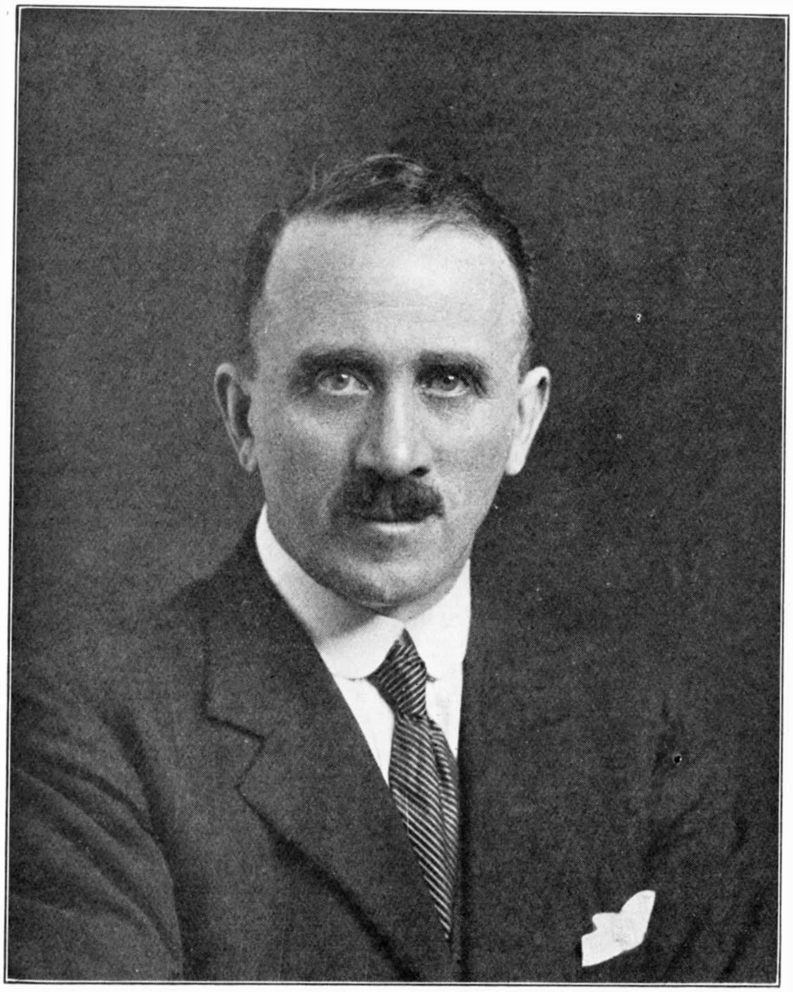
Col. Purves then made the presentation in a eulogistic but humorous speech, in which he paid tribute to his long friendship with the retiring Assistant Engineer-in-Chief, and to the assistance he had received from him throughout their service.

Mr. Sinnott replied in a similar vein, and excelled himself in the adroitness of his remarks. His explanation of how he grew in weight and in substance while occupying the chair formerly used by Col. Purves caused great amusement. He was leaving them only officially; he trusted he would meet most of the members present on the golf links, where he hoped to be able to reach—if not the plus four position, at least equal terms with another Colonel, namely, Bogey of that ilk. He thanked them all for their kindness and for the good words that the speakers had used towards him.

An account of Mr. Sinnott's career appeared in the July, 1922, issue of the Journal when he was promoted to the position of Assistant Engineer-in-Chief.

LIEUT.-COL. A. G. LEE, O.B.E., M.C., B.Sc., ASSISTANT ENGINEER-IN-CHIEF.

Colonel Lee's father was engineer in charge of Bangor section when his son entered the Engineering Department in November, 1901. His first job was with Mr. Tremain, who was then engaged in loading the London-Birmingham cable with experimental air core coils fitted in wooden boxes. The work was extraordinarily interesting and this introduction to the service, plus of course his natural bent in that direction, no doubt led Mr. Lee to devote himself more particularly to the purely scientific side of the work. For several years he was assisting the late Mr. Hartnell in the design and testing of submarine and other types of cables. While engaged in this work he graduated B.Sc. at London University. His articles on



LIEUT.-COL. A. G. LEE, O.B.E., M.C., B.Sc.
[We are indebted to the T. and T. Journal for the loan of this block.]

Telephone Transmission in the early years of this Journal were of the utmost service to the staff and established his reputation as an authority on the subject, which was then beginning to be tackled in a systematic manner by the Administration. In 1908 he was appointed Second Class Engineer at Darlington, and in the following year promoted to be First Class Engineer at Bolton. An open competitive examination for Assistant Staff Engineer in 1912 gave Mr. Lee his opportunity and he came back to headquarters as an Assistant Staff Engineer in the Telephone Section (Transmission and Maintenance Group). He was serving in the Local Lines when war broke out in 1914 and he immediately secured a commission in the R.E. Signal Service. During a large part of the war he was in charge of Telegraph Construction Coy., R.E., and later was O.C., G.H.Q. Signal Area, and at the same time Second in Command, L. Signal Battalion. For his services he received the M.C., and when the war finished he held the rank of Major. He is now Lieut.-Colonel, Royal Corps of Signals (Supplementary Reserve).

On his return to civil life Major Lee was for some time in the Construction Section, but was transferred to the growing Radio Section under the active leadership of Mr. Shaughnessy. In 1921 he acted as British Delegate to the Inter-Allied Radio Conference in Paris and in 1921-2 he visited Egypt and India in connection with the development of wireless services between this country, Egypt and Kurachi. In 1923 he began work on Trans-Atlantic Telephony in conjunction with the A.T. and T. Company. He paid a visit to America in connection with this problem in 1925 and two years later witnessed the culmination of his work in the opening of the telephone service to the States. For his services he was created an Officer of the Order of the British Empire.

Colonel Lee is a Member of the Institution of Radio Engineers and one of the Committee on Admissions to that body. He was chairman of the Wireless Section of the I.E.E. in 1927-8, and was awarded a premium for his opening address to the section. He is a member of several committees of the Radio Research Board and is chairman of the Committee on "Atmospherics."

THOMAS BOYES JOHNSON, M.I.E.E.

Mr. T. B. Johnson, Superintending Engineer of the North Eastern District, retired on the 31st May after completing 43 years' service.

A Yorkshireman by birth, Mr. Johnson joined the Post Office Service at Hull in 1885. Mr. Johnson passed to Newcastle as a Junior Clerk in the P.O. Engineering Department in 1890. His appointment as Engineer in charge of the Newcastle Section came in 1894; subsequently he took charge of the Sunderland Section. At Newcastle the Post Office Telephone system had developed along its own lines under the able guidance of the Superintending Engineer, the late Mr. A. W. Heaviside. It was then competing with the late National Telephone Company. With characteristic energy and resource Mr. Johnson did all that was possible to ensure the satisfactory working of the Trunk and Local (Newcastle) system.

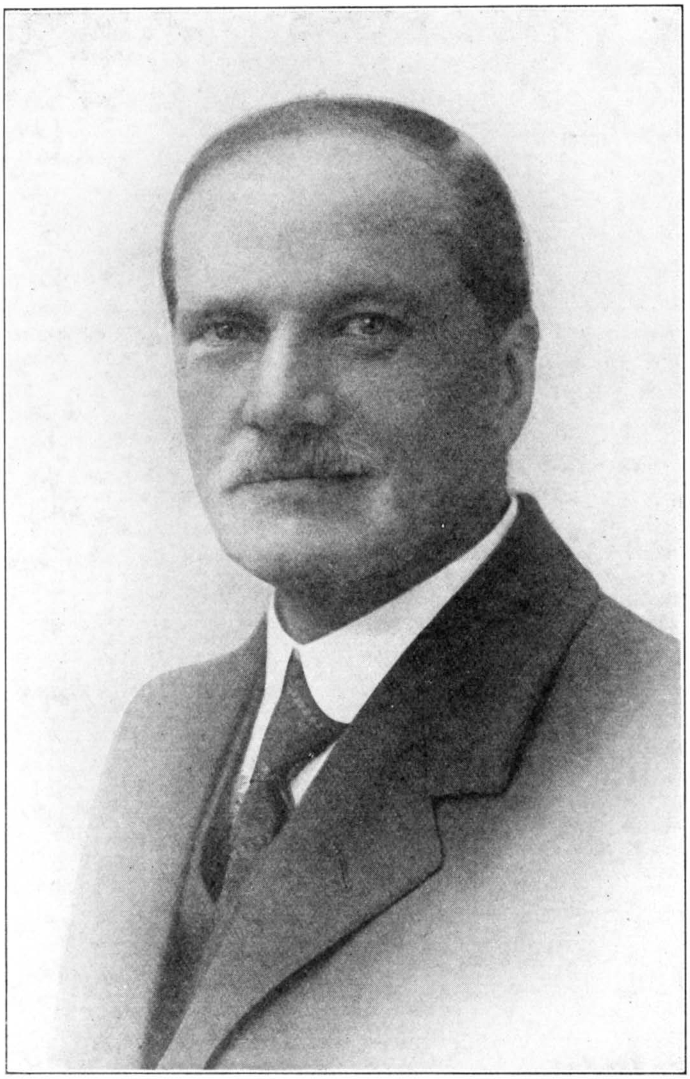
In 1900 the development of the telephone service of London called a number of provincial engineers there on promotion, and Mr. Johnson was promoted to be 1st Class Engineer, and two years later Assistant Staff Engineer. The wide experience gained served in good stead, and he was interested in long distance speech transmission, carrying out experiments between this country and France and Belgium.

In 1907 Mr. Johnson was promoted to be Assistant Superintending Engineer in the Northern District, and for a few years returned to the field of his earlier activities between the Tees and Tweed. It was necessary, however, to make a further break in 1911, on his appointment as Superintending Engineer of the North Eastern District.

The North Eastern District has been fortunate in its association with officers of outstanding personality but never more so than when Mr. Johnson returned to Yorkshire. The first long distance balanced and loaded cable in the country was laid in 1913 between Leeds and Hull. This gave a great impetus to Trunk underground construction generally, and one of the first to grasp its significance was Mr. Johnson, who never ceased his advocacy of the extension of underground; nearly all the towns in the District are now linked up by underground cables. Concurrently, a large extension of local underground was carried out. In 1918 the Leeds Automatic Exchange was brought into service. This is considered to be a turning point in Telephone history in this country, inasmuch as no large industrial city had been worked on the Automatic System. The success at Leeds Exchange assisted the case for the general adoption of Automatic working. Mr. Johnson was not content to support the extension of Automatic working by recommendation only, but gave lectures and demonstrations. Since the Leeds Exchange was opened, Automatic working has been introduced at Grimsby, York, Harrogate, Halifax, Wakefield, Sandal, Keighley, and five Satellite Exchanges in the Leeds Automatic Area.

Outside the Department Mr. Johnson's activities have been varied and heavy. He has been Chairman of the North Midland Centre of the Institution of Electrical Engineers. His address as Chairman was a noteworthy definition of his broad outlook on modern industrial conditions. For many years, too, he has taken an active part in Church work, not only locally, but in the Ripon Diocese.

Mr. Johnson's relations with his staff have been cordial. Even during the war period when



Mr. T. B. Johnson.

so many changes were made and in the reconstruction period after the war, the staff problems were disposed of with surprising smoothness. He was always ready to help in any way possible. Naturally a very kindly chief, he was most anxious to alleviate cases of hardship or misfortune which came to his notice.

The Staff of the North Eastern District presented Mr. Johnson with a five-valve portable wireless set, and Mrs. Johnson with a handbag, on the occasion of a complimentary dinner at Leeds. Mr. A. L. De Lattre, Assistant Engineer-in-Chief, was present, together with old friends and colleagues—Mr. J. D. Taylor, Superintending Engineer, Edinburgh; Messrs. Bailey and Whillis, of the Engineer-in-Chief's Office; Mr. Bell Smith, Postmaster of Bradford, representing the Postmasters, and Mr. T. A. Bates, District Manager. Mr. G. S. Wallace, Assistant Superintending Engineer, occupied the chair, and Mr. W. S. Tinsley, Sectional Engineer, Bradford, proposed the health of the guest. Mr. S. A. Pickering, Staff Officer, made the presentation.

It is a matter of deep regret to Mr. Johnson, and the Staff in the North Eastern District, that Mr. F. E. Gibbins, late Assistant Superintending Engineer, had to retire from active work in April owing to ill-health.

It is difficult to couple Mr. Johnson's name with leisure in view of his present activities. He leaves the Service with the best wishes of the

Staff for his continued happiness. If, at any time, he is persuaded to take some leisure, some say that the hills and moors beyond the Wharfe will still test his powers as a pedestrian. On the other hand, there is undoubtedly a call from the east where walking is not so strenuous, where the country is close to the river and the sea, not far from the City of the Three Crowns—Holderness.

How heavy do I journey on the way
When what I seek, my weary travels end
Doth teach that ease and that repose to say
"Thus far the miles are measured from thy friend."

MR. E. GOMERSALL.

MR. E. GOMERSALL.

MR. E. GOMERSALL, O.B.E., M.I.E.E., who took up duty as Deputy Superintending Engineer in the London District on the 1st June, entered the Engineering Department at Leeds in 1895. He was transferred to the Engineer-in-Chief's Office in London in 1898 and was associated for many years with the Assistant Engineer-in-Chief, the late Mr. M. F. Roberts, who was responsible for the design and method of the underground construction adopted in connection with the scheme for the telephoning of London. On 1/7/00 he was promoted to Engineer 2nd class, and on 1/9/04 after a competitive examination to Technical Officer 2nd class. During the following years he was attached to the Headquarters Staff and was engaged chiefly on external construction matters until 1909, when he was transferred to the South Metropolitan District as Assistant Superintending Engineer. In this District he assisted in dividing the Southern District after the transfer of the Royal Engineers to Ireland, and in the formation of what is now the South Eastern District.

During the greater portion of 1912 he was Acting Superintending Engineer of the South Metropolitan District, during which period the Engineering Staff and plant of the National Telephone Company were merged in that District. It is interesting to note that during the period Mr. Gomersall was in charge of this District the automatic equipment at Epsom was opened—the first automatic exchange in Great Britain. Automatic Exchange transfers have also engaged his attention for the last two years, during which period 23 Automatic Exchanges were brought into use in the North Midland District, including Chesterfield, Sheffield, Coventry, Nottingham and Leicester. The simultaneous transfer at Sheffield from Magneto to Automatic working was the largest operation of the kind undertaken by the Post Office up to date. Eleven Magneto Exchanges were closed and 9 new Automatic Exchanges were opened.

On the formation in 1912 of a new London Engineering District, Mr. Gomersall was transferred to Reading as Assistant Superintending Engineer, where he was associated with Mr. McL. Robb in forming the new South Midland District, incorporating part of three other Districts and combining the National Telephone Company and the Post Office staffs in the territory.

At the outbreak of war, Mr. Gomersall was actively engaged in various defence and other schemes in the military areas in the South Midland District.

On the 23rd April, 1915, he took up duty as Superintending Engineer in Ireland in replacement of the Royal Engineer Officer who had been withdrawn. He had to face many difficult problems in Ireland. The Post Office staff maintained practically all the Railway signalling lines and apparatus, as well as the telephone and telegraph system and a number of important wireless stations, including Valentia and Malin Head.

In Easter, 1916, came the Irish Rebellion, and with it the destruction of the General Post Office in Dublin and the line plant there and in different parts of the country. In the trying times which followed, Mr. Gomersall was in close touch with the Admiral commanding at Queenstown, the Irish Command at Dublin and the United States Air Force Command, and many large and important schemes of communication, open, underground and submarine, were carried out successfully.

In recognition of his work at this time, Mr. Gomersall was awarded the decoration of Officer of the Order of the British Empire.

In July, 1919, Mr. Gomersall was transferred to England as Superintending Engineer of the North Midland District and during the nine years which followed considerable development took place in that District. The number of telephone stations increased by 110%, the mileage of underground wire by 303%, the mileage of duct by 209%, the mileage of open wire by 30% and the number of Exchanges by 38%.

634 miles of main underground cable were laid including the London - Manchester, London - Derby and Derby - Leeds main cables. The Leicester Repeater was opened and subsequently the Derby Repeater Station.

Recently, Mr. Gomersall has devoted much time to the application of machinery to the Department's accounting requirements and to the simplification of the Unit Construction Cost system. He takes with him to his new sphere the good wishes of the staffs of the various Districts in which he has worked.

MR. G. F. GREENHAM.

Mr. G. F. Greenham.

Mr. Greenham was educated at Emmanuel School, Wandsworth Common, at King's College (London University) and for one year at a school in Germany.

At King's College he studied under the late Dr. John Hopkinson and Prof. Ernest Wilson, and gained a scholarship which entitled him to a further period of one year in the Siemens Electrical Laboratory, free on the understanding that he assisted in the conduct of the evening classes.

During this period he was associated with Dr. Hopkinson's research work on the distribution of magnetism in iron, concerning which a paper was read before the Royal Society.

After leaving King's College he spent a year as an improver in the Charing Cross and Strand Electricity Supply Station. This station was at the time equipped with Williams' high speed engines and Mather and Platt dynamos.

In March, 1895, a friend suggested to him that the telephone business offered a good field for young engineers, and Mr. Greenham joined the National Telephone Company's service as switchboard fitter. The change from lighting station switchboards to telephone switchboards was very marked.

His first employment was at the exchange in Queen Victoria Street. A new switchboard of the flat multiple type was being built to replace the single line switchboard then in operation.

The flat board gave good service, being recovered in June, 1926, after 31 years' service. For many years it was known as the Bank Exchange. When the new switchboard was put into service Mr. Greenham became Test Clerk and, later, exchange inspector.

In 1897 he was transferred to the Gerrard Exchange. While there the flat board was replaced by one of the Christiania type. This installation was not a success and the Christiania board was subsequently replaced by a C.B. board. In June, 1899, he was appointed Switchroom Manager. The Switchroom Manager in those days controlled the electrical work, both construction and maintenance as well as the traffic.

In 1901 Mr. Greenham became Assistant Electrician, Western District (London). In this capacity he took part in the provision of the first C.B. exchange in London (Kensington). In 1903 he was appointed Electrician of the Western District, under the then District Manager—Mr. R. A. Dalzell. In 1905 the staff of the Metropolitan Area was re-organised on functional lines under Mr. C. B. Clay, the Superintendent at this stage, and Mr. Greenham became Metropolitan Maintenance Electrician and in 1907 Metropolitan Electrician responsible for all internal construction and maintenance. During his period of service with the Company he was connected with two big events—the London Wall exchange and Bank Test Room fires.

Mr. Greenham was one of three men who started and ran the Company's Correspondence Classes. In 1911 he was transferred to the P.O. Engineering Department as Assistant Superintending Engineer, Met. South District. Shortly afterwards the present London Engineering District was formed under the Superintending Engineership of Mr. A. Moir, when he was transferred to Denman Street.

During the war period he acted as liaison officer between the Department and the London Air Defence Control and was responsible for the equipment, so far as communications were concerned, of the gun and searchlight stations and control stations, including the arrangements at G.H.Q. Horse Guards. For his services he was made M.B.E. In 1922 he was elected to fill the vacancy for an Assistant Staff Engineer caused by the transfer of Mr. H. P. Brown to Australia.

Since his advent in the Engineer-in-Chief's Office the amount and complexity of the duties have grown considerably, thanks to the activities in connection with the introduction of the automatic system, particularly the Director System. As a measure of his responsibilities it may perhaps be pointed out that he was responsible to the Staff Engineer for the work of five groups performing widely different duties.

MAJOR H. BROWN.

Mr. Brown entered the Superintending Engineer's Office at Birmingham in 1896, after serving six years in the Telegraph Instrument room in that city. In 1900 he was appointed Sub-Engineer at Coventry and in 1903 he became Second Class Engineer in charge of the Stafford Section. In spite of a small staff, many big works were carried out in the section and on the reorganisation in 1904 he was transferred to the newly formed District Estimates Section, from which he was transferred by Major O'Meara, then Engineer-in-Chief, to the Survey (now Lines) Section at headquarters. In 1910 Mr. Brown was promoted to be First Class Engineer at Belfast and while there he was sent as one of the Department's representatives to the International Telegraph and Telephone Conference at Paris. Later in the same year he was seconded for duty on the Inventory Staff for the valuation of the N.T. Coy's plant. On completion he returned to headquarters in charge of a valuation group, and during the time the case was before the Courts he and the late Mr. Walter Twells were engaged until well after midnight on many nights preparing for the next day's proceedings. For his services he received a special award of £200 from the Department.

Mr. Brown was in the Local Lines when he was appointed Assistant Director of Army Signals, with the rank of Captain, prior to the war, and on the outbreak he acted as assistant to the late Sir Andrew Ogilvie. He was then given

MAJOR H. BROWN.

command of No. 5 Telegraph Construction Coy. in France. He was twice mentioned in Despatches and awarded the O.B.E.

Since his return he has been engaged in the Construction Section, chiefly on the delicate work of negotiation with Road authorities in respect of costs of re-instatement of pavings and damage to property. In June last year Major Brown was sent on a commission to Sweden to inquire into the methods of construction adopted in that country, and what he saw there he has detailed to many hundreds of his colleagues during the tour he has made throughout the country to effect economies in construction costs.

At the last grand manœuvres in the South West of England, Major Brown was the P.O. representative at the Directing Force camp, and he has acted in other matters for several years past as a liaison officer between the Department and the Defence forces of the country.

LONDON DISTRICT NOTES.

Telephones.—The changes in the number of exchange lines, extensions and stations during the quarter ending, and the totals on, 31st March, 1928, were as follows:—

	Increase.	Total.
Exchange Lines ...	8,570	335,502
Extensions ...	4,365	280,832
Stations	11,8832	561,744

External Plant.—The changes in mileage during the three months ended 31st March, 1928, and the totals on that date were as follows:—

Line Mileage.

	Increase Miles.	Total Miles.
Pole Line	31	5,855
Pipe Line	187	9,625

Single Wire Mileage (decreases in italics).

	Overhead. Miles.	Underground. Miles.	Total. Miles.
Telegraphs ...	*4*	238	25,218
Telephones (Ex.) ...	*537*	42,057	2,235,536
,, (Trunk).	*54*	2,720	71,281
Spare*	—	—	106,950

EXCHANGE WORKS.

The installation of the Automatic Exchanges known as Sloane, Bermondsey and Monument is well advanced and it is expected that they will be opened, in the order named, during the next few months.

Fairfield Exchange—hypothetical on Croydon—was opened on May 2nd.

Ingrebourne Exchange (C.B.S.), situated in the Sunny Town Post Office, has been installed to relieve the Romford Exchange and was opened on May 24th.

Temple Bar (Relief) Exchange was opened on May 25th on the old Holborn manual equipment and forms a nucleus for transfer to Temple Bar (Auto.) Exchange at a later date.

Beckenham (Relief) Exchange—C.B. No. 10, capacity 800 lines, is being installed by the Department's staff, and, it is anticipated, will be opened for traffic on July 14th.

The General Electric Company have started work on the new Sutton Exchange. The equipment (C.B. No. 1) will provide for 4,880 lines.

At Woolwich Exchange an extension of 1,080 lines was commenced by Messrs. Siemens on May 21st.

Willesden Exchange equipment is being increased by 1,060 lines to a total capacity of 7,400 lines. It is anticipated that the work, which is

* *i.e., excluding small gauge local conductors.*

being carried out by the General Electric Company, will be completed by September.

Included in the P.B.X. installations now in hand are two C.B. 10A equipments for Imperial Chemical Industries Limited and Grosvenor House, respectively, each of which has a capacity of over 1,000 circuits. A P.A.B.X. has recently been installed by Messrs. Siemens for Messrs. Harrods, with a capacity for 900 extensions. This was brought into service at the end of May.

The transfer of Lloyds from the Royal Exchange to the new building in Leadenhall Street, which was officially opened by the King on 30/3/28, involved the installation of the following:—

Lloyds Exchange Service—

2 Switchboards $\frac{10 \times 50}{65}$
12 Exchange lines.
81 Internal extensions.
3 Tie lines.

Underwriters' Installations—

3 Switchboards No. 9.
8 Incoming Exchange lines.
18 Outgoing Exchange lines.
5 Bothway Exchange lines.
26 Lines to cabinets.
90 Extension lines to Underwriters' tables in main hall.
90 Private wires to Brokers' Offices.

Main Frame—

1000 Pair cable to Avenue Exchange.
200 Pair cable to Central Exchange.
1400 Pairs to various floors.
1200 Miscellaneous circuits.

Machine Telegraph School.

A small school has been fitted up with Start-Stop apparatus to enable instruction to be given to operators. This school is on similar lines to that provided for the engineering staff.

Telegraphs.

Central Telegraph Office.

New Test Room.—The first stage of the new Test Room has been completed, namely, the erection of the ironwork with accommodation for 10,000 wires. It occupies a large room in the basement of the main building; whereas the existing frame is outhoused in an unsatisfactory position in the area.

Telegraph Typewriters. — These have now become engineering items. At the C.T.O. 134 typewriters have either been newly provided or taken over from the Stationery Office, and are to be maintained by engineering workmen. They have been supplemented by double-slip guides and lecterns; covers have also been fitted over the keyboards of instruction machines, to force students to rely on touch alone.

Slip-Wheels.—The needs of the Beam Services have led to a proposal for slip-wheels with springs at the sides, so that the relative telegram forms may be associated with the perforated slips.

Baudots. — The conversation to automatic working continues, the latest circuit altered being Newcastle.

Pneumatic Tubes.—Building operations at the C.T.O. having revealed unsatisfactory supports of the tubes, the facilities afforded by the Office of Works scaffolding enabled new supports to be provided, and, incidentally, to improve the general appearance of the ceiling above the Centre.

An engineering officer has devised new types of Carriers constructed of rubber. Another officer has devised a new type of teleswitch for use on automatic tubes.

THE INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS.

The Annual General Meeting of the Institution was held at the Institution of Electrical Engineers London, on Tuesday, May 8th, 1928. The Chair was taken by the President, Col. T. F. Purves, M.I.E.E.

The Annual Report of the Council was read by the Secretary (Dr. R. V. Hansford) and the Annual Financial Statement was presented by the Treasurer (Mr. B. O. Anson). Mr. J. W. Atkinson moved the adoption of the Annual Report and Financial Statement and this was seconded by Capt. J. G. Hines. After Mr. Anson had replied to several queries raised by the speakers the resolution was carried unanimously. Mr. S. Upton proposed a hearty vote of thanks to the retiring Members of the Council, Messrs. A. S. Carr, C. W. Messenger, H. J. Millett and E. J. Wilby, for their services on behalf of the Institute. This was seconded by Mr. J. Cowie, and Mr. A. S. Carr replied on behalf of he retiring members.

The President then presented the Institution Medals for the Session 1926-27 as follows:—

Senior Silver Medal to Mr. J. Innes, B.Sc., for Paper No. 114 on "The Edinburgh Automatic Multi-Office Transfer."

Senior Bronze Medal to Mr. W. Cruickshank, M.I.E.E., for Paper No. 113 on "Voice Frequency Telegraphs."

Junior Silver Medal to Mr. B. Miller, for Paper No. 115 on "Wayleaves and Relative Difficulties."

The President also presented Mr. R. W. O. Abbott, Cable Room Workshop, C.T.O., with the Booth-Baudot Award for the year 1927-8 for his suggested improvements in telegraph systems.

The Annual Meeting was followed by a meeting of the London Centre, at which an address was given by Capt. B. S. Cohen, M.I.E.E., on "The International Committee on Long Distance Telephony and some aspects of its Engineering Work," of which the following is a synopsis:—

Introduction and historical.

Note on the growth of International Telephony.

Organisation of the Committee.

The five sub-committees dealing with engineering subjects.

Transmission units.

Overall transmission allowance from subscriber to subscriber on International Circuits, and allocation of the allowances between the instruments and the circuits.

Telephone Transmission Master Reference System, and general notes on its construction, installation, calibration and operation.

Transmitter and receiver, electro-acoustic efficiencies.

Articulation and intelligibility; how defined and measured.

Some articulation efficiencies of transmitters, receivers, lines, etc.

The testing of the transmission efficiency of subscribers' instruments *in situ*.

Notes on telephone acoustics with a brief introduction to the theory of plane and spherical fields of sound radiation and electrical analogies.

COUNCIL FOR THE YEAR 1928-29.

The constitution of the new Council is as follows:—

Chairman—Mr. A. L. DeLattre.

Honorary Treasurer—Mr. C. J. Mercer.

Representing Staff of the Engineer-in-Chief's Office—

Mr. B. O. Anson and Mr. P. J. Ridd.

,, Executive Engineers—
London: Mr. J. Cowie.
Provinces: Mr. S. Upton.

,, Asst. & Second Class Engineers—
London: Mr. P. G. Hay.
Provinces: Mr. A. E. White.

,, Chief Inspectors—
London: Mr. J. D. Boulton.
Provinces: Mr. W. A. Satchwell.

,, Clerical Staff—
London: Mr. E. T. Larner.
Provinces: Mr. H. Longley and Mr. H. Willcock.

,, Inspectors—
London: Mr. N. Layton.
Provinces: Mr. Thos. Davidson.

,, Draughtsmen—
London and Provinces: Mr. R. J. Stewart.

Secretary—Dr. R. V. Hansford.

PRINTED PAPERS.

The following is a list of the printed papers issued to the Membership during the year 1927-28:—

No. 108. "Some Applications of Optical Methods to the Examination of Engineering Material," F. O. Barralet, M.Inst.Metals, A.M.I.E.E.

No. 109. "The Problem of Flexibility in Subscribers' Cable Distribution," Harvey Smith.

No. 111. "Scientific Organisation and the P.O. Engineering Department," F. G. C. Baldwin, M.I.E.E.

No. 112. "Telephone Repeaters and their Maintenance," C. Robinson, B.A., A.M.I.E.E.

No. 113. "Voice Frequency Telegraphs," W. Cruickshank, M.I.E.E.

No. 114. "The Edinburgh Automatic Multi-Office Transfer," J. Innes, B.Sc.

No. 115. "Wayleaves and relative difficulties," B. Miller.

The following paper is in the press:—

No. 110. "Testing of Telephone Circuits and Apparatus with Alternating Currents," E. S. Ritter, D.F.H., A.M.I.E.E., and G. P. Milton.

The Council has decided to print the following papers:—

"The Director. Its Application and the Functions performed," C. W. Brown, A.M.I.E.E.

"Satellite Working in Automatic Areas," F. I. Ray, B.Sc., F.H.D., A.M.I.E.E.

"Sparking and Arcing at Relay Contacts and the use of Spark Quench Circuits," A. H. Jacquest, A.M.I.E.E., and L. H. Harris, M.Sc.(Lond.), A.C.G.I.

LOCAL CENTRE NOTES.

SCOTLAND EAST CENTRE.

The opening meeting of the Session was held in the Royal Scottish Society of Arts Hall, Edinburgh, on November 24th. The Chairman, Mr. J. D. Taylor, intimated the sudden and unexpected death of Mr. J. C. Sim, Draughtsman, and members stood in silence as a mark of respect and esteem. After a few appropriate remarks, the Chairman introduced the lecturer, Mr. F. I. Ray, B.Sc., D.F.H., A.M.I.E.E., of the Engineer-in-Chief's Office, who lectured on "Satellite Working in Automatic Areas." The lecture proved most interesting and instructive, and was illustrated by a splendid series of lantern slides. Full working models showing various arrangements were operated during the course of the lecture, and afforded an exceedingly useful demonstration. Mr. J. Innes and Mr. J. S. Elston raised a number of interesting points which were replied to by Mr. Ray.

At the December meeting Mr. R. T. Robinson, A.M.I.E.E., Engineer-in-Chief's Office, lectured on "Motor Transport in the Engineering Department." After dealing with its historical aspect and describing the various makes of vehicles in use, the Lecturer's headings included Statistical records, Estimated savings and Percentage efficient use, Inspection reports, Overhauls and Repairs, Replacements, Trading account, Future development, and Training of Staff. Lantern slides were used to illustrate the various points as the lecture proceeded. The subject provoked a very long, keen and interesting discussion, which showed how closely this phase of the Department's operations was being studied.

The arrangement under which the Stores Department deals with the Engineering work in connection with postal motor vehicles was severely criticised by several speakers. The work could, without a doubt, be handed over to the Engineering Department with marked advantage to the Service.

At the third meeting of the Session on 17th January, Mr. J. McIntosh read a paper entitled "Forms and Methods in Preparing Estimates." He proceeded to show how, by the use of suitable forms, the work of preparing estimates, including the pricing of the stores in blocks, could be considerably simplified and expedited, and the risk of omissions reduced to a minimum. The system provided the Works Inspector with a detailed plan of the work to be undertaken and a ready means of keeping in touch with the work as it progressed and noting at once any necessary departures and the reasons for them. It also provided for the efficient clerical control of Stores. Other suggestions included an ingenious set square with standard symbols, also an arrangement for determining the available spare space in ducts and pipes; and a simplified method of preparing local line plant records.

A useful item included in the suggestions was a slide rule, which had been made by Mr. McIntosh, together with instructions regarding its use. The slide rule enables the diameter, make-up, etc., of Lead Covered Paper Core Composite Cables to be calculated in a mere fraction of the time ordinarily taken, and also provides a ready means of ascertaining the weights of recovered scrap lead and copper for estimate purposes. The discussion was of a very high order and was ably replied to by the lecturer. Many of the suggestions have been tried out in actual practice, with entirely satisfactory results.

The system is simple and effective as compared with existing procedure, and the bulkiness of the numerous tables, etc., which had been prepared, serves but to emphasise the gigantic tasks which form the day to day routine of the Engineering Department.

The February meeting took the form of a joint session with the Institution of Electrical Engineers, Scottish Centre, and was open to the general public.

An illustrated lecture, entitled " Rugby Radio Station," was delivered by Mr. E. H. Shaughnessy, O.B.E., M.I.E.E., M.I.R.E., Assistant Engineer-in-Chief. As the lecturer proceeded to develop his subject in an easy conversational style, the crowded gathering followed each phase with wrapt attention, and it was readily apparent that the subject matter made a strong appeal to all who were privileged to be present.

Sir J. Alfred Ewing, K.C.B., M.A., D.Sc., L.L.D., F.R.S., Principal of the Edinburgh University, presided at the meeting and also moved a vote of thanks to the lecturer. The choice of chairman was particularly appropriate, as the lecturer was in close association with him on important work during the war. The lecture was given considerable publicity. Display bills were posted throughout the town, the newspapers printed preliminary reports, and a detailed announcement was broadcasted on two occasions. The various Scientific Societies and Educational Bodies were well represented at the meeting, and more than 1,500 requests were received for the 750 available tickets. The freely expressed opinion was that the lecture had been an unqualified success, and it was certainly an excellent advertisement of the Post Office activities.

At the meeting on 20th March, the chairman intimated that the Senior Silver Medal of the Insitution had been awarded by the Council to Mr. J. Innes, B.Sc., for his paper entitled " Edinburgh Automatic Multi-Office Transfer." Mr. Taylor, on behalf of the members, congratulated Mr. Innes and said that the award of the Medal was very gratifying to his fellow members in the Scotland East Centre.

Mr. H. Burgher then read a paper on " Problems and Methods of Subscribers' Distribution." Edinburgh is probably unique as regards the large number of lofty tenements, each house of which is generally owned by a different landlord. The lecturer dealt with the ex-National Telephone Company's system of distribution by means of roof standards, and showed the advantages gained by scrapping that system. Smaller D.P. areas and block-wiring schemes had provided a more economical and reliable service, and reduced to a minimum the dangerous overhead maintenance work.

The organisation for carrying out block-wiring schemes was detailed. It was considered that a lay-out plan of the work should be prepared a few hours in advance of the work being actually put in hand. Particulars were given of a specially made tool for dooking walls, which had given excellent results. The desirability of including in the gang a first-class jointer skilled in all departments of cable jointing was emphasised. A new form of cable clip was suggested, which, it was claimed, would avoid the necessity for " threading " cables, with the consequent liability to damage to the lead sheathing, and would also provide a quicker and more economical arrangement for replacing cables.

The advantages accruing from the fixing of C.D. Plugs upside down, together with an improved method of fixing the plug and tails to the wall, were explained. A suggestion was made that telephone wires should be led in at the top of windows and builders of future houses should fit a suitable pipe between the top of the side frame of the window and the lintel, where it would be in a sheltered and protected position. The paper was followed by a useful discussion.

The Agenda then provided for " Informal Discussions."

The subjects dealt with included " Fault Returns," " The Right Mental Attitude towards Subscribers' Complaints," " A Working week of five days for Gangs in Isolated Localities," " Standard Form used in connection with the Provision of Subscribers' Circuits," " Improvements which could be effected by the Control of Complaints directly in Automatic Exchanges at the Test Desk instead of by the Monitors as at present." The subjects were fully debated.

Hearty votes of thanks to all the Lecturers were carried with acclamation.

SOUTH LANCASHIRE CENTRE.

At the sixth meeting of the Session, held on March 5th, Mr. A. S. Renshaw, of the Engineer-in-Chief's office, gave an informal address on "Some Considerations relating to the Clerical Organisation of the Engineering Department." A very interesting review was given of the improvement which have been made in the clerical organisation during the past 15 or 20 years, followed by an explanation of the basis on which the size of the clerical staff was at present determined. Criticism of these arrangements was sought from the members, and a spirited discussion resulted.

At the final meeting, held on April 2nd, a joint paper was presented by Messrs. F. E. Bentley, A.M.I.E.E., and L. H. Crane, A.M.I.E.E., entitled "Underground Cable Maintenance — Notes on the results of three years special testing." The paper, while referring to the success achieved by Routine and Precision testing, dealt more particularly with the large number of electrolytic corrosion cases experienced in the District. A description was given of the systematic surveys of sheath currents and voltages which had to be undertaken and the manner in which the source of such currents was traced. A useful discussion followed.

NORTHERN CENTRE.

On the 18th January Mr. G. F. Bellwood, M.I.E.E., delivered a paper on "Through Signalling on Trunk and Junction Circuits." The author stated that the object of the paper was to deal in a simple manner with through signalling over circuits worked on a full automatic signalling basis. The facilities provided by such circuits were detailed. The arrangements for through signalling on C.B.S. No. 1 Exchange circuits and on circuits connecting different types of Exchanges were described, together with the apparatus connections involved in setting up such calls by controlling telephonists. The through clearing operations from the distant subscribers to the Controlling Exchange were also described and notes given on the difference between the method of through signalling in C.B.S. No. 1 Exchanges compared with Common Battery and C.B.S. No. 2 Exchanges. The paper was illustrated with diagrams and was commented upon as being instructive and interesting.

On the 15th February Mr. W. Weightman read a paper on "The Laying of Holy Island Cable." The work in question was the laying of a four core light sheathed Submarine Cable across, approximately, three miles of mud flats between Beal and Holy Island T.P's. and followed on a decision to provide a Call Office at Holy Island Post Office and to provide additional communication facilities for the Coast Guard Station. The author described the organisation for carrying out the work and the method of laying the cable which was adopted, together with the reasons for its adoption, and the alternative methods which were available. The difficulties encountered in carrying out the work were dealt with and the varying experiences of the men, who, owing to the lack of housing accommodation on the Island, were provided with a well-organised camp, replete with all conveniences for their comfort, were described.

The paper, which was rather out of the ordinary, was illustrated with twenty-two slides and was very well received.

The Junior Silver Medal has been awarded by the Council to Mr. B. Miller for his paper on "Wayleaves and their Difficulties."

Arrangements are in hand for a summer outing in the second week of July.

NORTH WALES CENTRE.

The final meeting of the 1927-28 Session was held at Shrewsbury on 14th March, 1928, when Mr. E. A. Pearson, A.M.I.E.E., read a paper entitled "Waste," of which the following were the principal headings:—The need for economy; Engineering design in relation to waste; The function of an Engineer; Capital Expenditure; Lost interest and lost revenue; Temporary work; Plant Lay-out; Standardisation; Planning Department; Execution of works; Misdirected Energy; Waste of time, — Prevention and checks; Importance of the individual. The paper was a very thoughtful and comprehensive contribution and provoked a lengthy discussion and many appreciative comments.

BOOK REVEIWS.

Official Minutes of the work of the 4th Plenary Conference of the International Advisory Committee on Long Distance Telephony (C.C.I.) held at Como from 5-12 September, 1927.

1. List of delegates and experts from the private industry.
2. Minutes of the Opening Session.
3. Questions of General Organisation.
4. Questions of transmission, maintenance and supervision on lines and in exchanges.
5. Questions of traffic and operating.
6. Questions concerning the protection of telephone cables against electrolytic action and chemical action.
7. Minutes of the Closing Session.
8. Summary of questions dealt with by the Committee since its inception.

Book in quarto paper cover, containing 169 pages and 37 illustrations. Price, in France, 10 Frs. (post free 11 Frs.); other countries 12 Frs. post free.*

* *Payment should be made by post office order addressed to M. le Secrétaire Général du Comité Consultatiff International des Communications Téléphoniques a Grande Distance, 23 Avenue de Messine, Paris, 8e.*

" Electrical Engineering Economics." By D. J. Bolton, B.Sc., A.M.I.E.E. Chapman & Hall, Ltd. 21/- net.

In view of the importance of economics to engineering—in fact most engineering problems are essentially economic—it is strange that the literature of this aspect of engineering is so sparse. Indeed, as the author points out in his preface, most of the books on this subject have dealt only with production problems—costing, price fixing, and works management economy—and have given no account of the problems of economics arising after the stage of manufacture. The aim of the author of this work is, therefore, to explain the principles of the economics of use, or, as he calls it, " consumption economics."

With the object of making his work self-contained, the author has divided his subject into three parts. The first deals with general economic principles, and, as such, makes no claim to originality. But the information given therein regarding capital, interest, depreciation, and the various types of annuity and sinking fund is sufficient to enable a reader to master the main argument of the work without reference to other literature. ...

The second and third parts are concerned more particularly with the application of the economic principles enunciated in the first part to electrical engineering problems—from the standpoint of the utilisation of electrical energy, rather than from that of the manufacture of electrical apparatus. A rough distinction between the second and third parts assigns " Choice of Plant " to the former, and " Supply Problems " to the latter, but some overlapping between the two is inevitable.

Thus in the second part the economic basis of Kelvin's Law for Cables occupies the first chapter, while later chapters show how economic principles should determine the choice of motors of differing capital cost, efficiency, life and salvage value. This is followed by a similar treatment of transformers, while the peculiar conditions in the case of lamps are the subject of the last chapter of this part.

In the third part, problems of tariffs, load and diversity factor, power factor and so on receive attention, and in view of the great variety of tariffs in existence there is no need to stress the importance of their economic aspect.

A very valuable feature of the work is the number of worked examples, both in the text, and at the end of many of the chapters. Others, unworked, are included in an appendix. Important equations relating to simple and compound interest and tables for sinking fund deposits and for life of plant form other useful appendices.

The book is very readable and is a valuable addition to the literature of electrical engineering.

G. F. O'Dell.

" Automatic Telephony Simplified." By C. W. Brown, A.M.I.E.E. Sir Isaac Pitman & Sons, Ltd. 6/-.

This is an addition to the series of Telephone handbooks published by Sir I. Pitman & Sons, items of which have already been reviewed in these columns. The publication maintains the standard set by previous authors. The book is an excellent introduction to step-by-step automatic telephony and carries the student by easy stages to the elements of the system adopted for Metropolitan areas.

The arrangement of the text and method of treatment are excellent and the illustrations including the diagrams distinctly above the average. The book can be confidently recommended to students who are preparing for examinations that include Automatic Telephony in their syllabuses. Mr. Brown is an experienced teacher, a fact which is evident on reading his book. B.O.A.

Kempe's Engineer's Year-Book for 1928. Thirty-fifth edition, with over 3,000 pages and 2,500 illustrations. Crosby Lockwood & Son. Price 30/- net.

There is no book of reference in the English language so useful to engineers of all classes as Kempe's; it is doubtful whether there is any volume in existence so packed full of reliable data and figures and so well arranged for ready reference. The developments in highway construction, steam power, electrical engineering, traction, internal combustion engines and their application to road and air traffic, have been kept pace with in a remarkable manner, while due regard has been paid to the advances made in marine engineering, gas and gaswork practice, mining and machine tool treament, etc. Many notes on practice become obsolete have been excised, but the book, as might be expected, is bigger than ever. It has for long been an understood thing among engineers when points are raised outside usual everyday practice to "look it up in Kempe," and the latest edition will not be found wanting. Our advice to those who treasure their old edition is to scrap it and buy a new copy, in the same way as they would treat an old machine which had served its time faithfully but which could not be brought up to date economically.

"A Text Book of Telegraphy." A. E. Stone, A.R.C.Sc. Macmillan & Co., Ltd., London. 20/- net.

The author's experience in teaching at the Polytechnic has resulted in his producing a text book on Telegraphy which will be regarded as a classic work on the subject. Intended primarily for the use of students preparing for examinations, the author has compiled a work which not only fully meets its original requirements, but will serve also as a valuable book of reference to engineers engaged in the practice of electrical communications generally.

The first seven chapters dealing with the fundamentals of electrical measurements contain a mass of information useful to the student and lead naturally up to the consideration of the application of the principles to working systems. The following chapters deal systematically with universal battery working, the simpler key systems, double current, duplex, central battery and concentrators, quadruplex, Wheatstone automatic, repeater and type printing systems. In the last-mentioned the subject is brought right up to-date and the descriptions cover all apparatus recently tried out and in operation by the British Post Office Department. Line work, protection from power circuits and lightning and the testing of lines are dealt with in three chapters, while a fourth gives an account of the construction of submarine cables and the methods of operation. It is a pity the author has omitted a description of the system of regenerative repeaters now used so successfully by cable companies, but this, we hope, will be included in a later edition. Mr. Stone should note also that a knot is a velocity and not a length. A very useful chapter on alternating currents and the propagation of signals along telegraph lines follows, and finally a brief summary of the principles involved in radio-telegraphy is included for the purpose of covering the Departmental examinations and City and Guilds syllabus. Two appendices are embodied at the end of the volume, one treating of the new system of voice-frequency telegraphs and the other giving a table of exponential and hyperbolic functions.

We can thoroughly recommend the book to our readers. The illustrations are excellently drawn and reproduced; the theoretical matter is ably dealt with, and the formulæ are evolved from first principles and clearly stated. A first class book on the subject.

STAFF CHANGES.

POST OFFICE ENGINEERING DEPARTMENT.

Promotions.

Name.	Grade.	Promoted to	Date.
Lee, Lt.-Col. A. G., O.B.E., M.C. ...	Staff Engineer E-in-C.O.	Assistant Engineer-in-Chief.	14-5-28
Greenham, G. F., M.B.E.	Assistant Staff Engineer E-in-C.O.	Supty. Engineer S.E. District.	1-8-28
Hart, A. B.	Assistant Staff Engineer E-in-C.O.	Staff Engineer, E.-in-C.O.	1-11-28
Atkinson, J. W.	Assistant Suptg. Engineer, London	Supty. Engineer, N.E. District.	1-6-28
Brown, Major H., O.B.E.	Assistant Staff Engineer, E.-in-C.O.	Supty. Engineer, N. Mid. District.	1-6-28
Vickery, W.	Assistant Engineer S.W. District.	Executive Engineer, S.E. District.	11-4-28
Booth, C. F.	Inspector of Radio Section, E.-in-C.O.	Chief Insp. Radio Section, E.-in-C.O.	17-3-28
Sturgess, H. E.	Inspector Rugby Radio.	Chief Inspector Rubgy Radio.	14-2-27
Luckhurst, J. E.	Inspector Cupar Radio.	Chief Inspector, Cupar Radio.	23-6-27
Hollis, W. A.	S.W.I. N. Wales District.	Inspector, N. Wales District.	24-10-27
Milford, T. S.	S.W.I., N. Wales District.	Inspector, N. Wales District.	24-10-27
Holt, H. L.	S.W.I. S. Lancs. District.	Inspector, S. Lancs. District	9-5-27
Rigg, P. H.	S.W.I. N.E. District.	Inspector, N.E. District.	To be fixed later.

Retirements.

Name.	Districts.	Grade.	Date.
Sinnott, J., O.B.E.	E.-in-C.O.	Assistant Engineer-in-Chief.	30-4-28
Johnson, T. B.	N.E.	Superintending Engineer.	31-5-28
Twells, W. E.	E.-in-C.O.	Assistant Staff Engineer.	8-4-28
Gibbins, F. E.	N.E.	Assistant Suptg. Engineer.	6-4-28
McIntosh, D.		Assistant Engineer.	11-5-28
Gardner, A. W.	E.	Assistant Engineer.	25-3-28
Morris, A. C.	N. Mid.	Assistant Engineer.	1-6-28
Hill, G. A. D.	E.-in-C.O.	Assistant Engineer.	30-4-28
Lade, J. A.	S. Wa.	Chief Inspector.	30-4-28
Fowlds, W.	N. Wa.	Inspector.	3-3-28
Bucklitsch, J. H. C.	N.W.	Inspector.	23-2-28
Hosgood, J. S.	S. Wa.	Inspector.	30-3-28
Moon, F.	N.W.	Inspector.	16-3-28
Wallis, R. C.	N.E.	Inspector.	11-3-28
Marchant, J. A., ...	London.	Inspector.	29-2-28

Deaths.

Name.	District.	Grade.	Date.
Jackson, R. W.	N.	Assistant Engineer.	14-5-28
Yeadon, N.	E.-in-C.O.	Assistant Engineer.	8-4-28

Transfer.

Name.	From.	To	Date.
Payne, C. F.	Inspector S. Lancs. District.	N.W. District.	8-3-28
Angus, J.	Inspector S. Lancs. District.	N.W. District.	

APPOINTMENTS.

Name.		Appointed to	
Gomersall, E., O.B.E.		Deputy Suptg. Engineer, London.	1-6-28
Hunt, R. H.	Probationary Inspector N. Mid.	Inspector, N. Mid.	29-2-28
Bourdeaux, N.	,, ,, E.-in-C.O.	Inspector, E.-in-C.O.	1-5-28
Arman, L. T.	,, ,, ,,	Inspector, E.-in-C.O.	,,
Stacey, P. A.	,, ,, ,,	,, E.-in-C.O.	,,
Simpson, C.	,, N. Ireland	,, N. Ireland	,,
Young, J. E.	,, ,, London.	,, London	,,
Dore, L. J.	,, ,, N. Waels	,, N. Wales.	,,
Devereaux, R. C.	,, ,, London.	,, London	,,
Shrubsall, F. W.	,, ,, London.	,, London	,,
Henderson, V. R.	,, ,, E.-in-C.O.	,, E.-in-C.O.	,,
Barrett, H.	,, ,, London.	,, London	,,
Barry, C.	,, ,, N.W.	,, N.W.	,,
Blackburn, E.	,, ,, N.E.	,, N.E.	,,
Reed, T. F.	,, ,, S.W.	,, S.W.	,,
Waters, H. S.	,, ,, S.E.	,, S.E.	,,
Howarth, H.	,, ,, N.W.	,, N.W.	,,

CLERICAL ESTABLISHMENT.

PROMOTIONS.

Name.	Rank.	Promoted to.	Date.
Whitehead, J. H.	Higher Clerical Officer. N. Wales District.	Staff Officer, N. W. District.	15-4-28
French, J. J.	Acting Higher Clerical Officer, London.	Higher Clerical Officer, London.	13-4-28
Coster, F. J.	Clerical Officer, London.	Acting Higher Clerical Officer, London.	18-4-28
Coster, F. J.	Acting Higher Clerical Officer, London.	Higher Clerical Officer, London.	1-6-28
Emmett, H. H.	Clerical Officer.	Acting Higher Clerical Officer, London.	1-6-28
Lay, J. W.	Clerical Officer, E. District.	Higher Clerical Officer, E. District.	22-4-28
Smith, W. B.	Clerical Officer, S. Lancs.	Higher Clerical Officer, Ireland N.	1-5-28

Retirements.

Name.	Grade.		Date.
Terrill, F. G. A.	Executive Officer, London.		12-4-28
Mullens, H. W.	Higher Clerical Officer, London.		31-5-28
Cousins, E. W.	Higher Clerical Officer, London.		30-6-28

TRANSFERS

Name.	Rank.	From	To	Date.
Adams, H. G.	Higher Clerical Officer	E. District.	N. Wa. District.	22-4-28

COMMUNICATIONS.

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Colombo,
Ceylon.

CENTRAL LIBRARY.

The following books have been added to the Central Library. Applications for the loan of same should be addressed to the Librarian, Institution of P.O. Electrical Engineers, Alder House, E.C.1.

List IV.

No.	*Title.*	*Author.*
867	Practical Television	E. T. Larner.
868	Modern Road Construction ...	F. Wood.
869	Electrical Engineering Economies	D. J. Bolton.
870	Radio Communication	J. H. Morecroft.
871	Industrial Telephony	J. Lee.
872	Automatic Telephony	C. W. Brown.